8458-EN-02
DTIC



PROTECTION AND RESTORATION OF THE ENVIRONMENT IV

Proceedings of an International Conference

Halkidiki, Macedonia

Greece

Volume II

EDITORS: K. L. Katsifarakis
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SANI, July 1998



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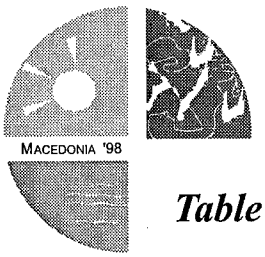


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Wastewater treatment

A COMPUTER PROGRAM TO DESIGN AIR STRIPPERS FOR THE REMOVAL OF VOLATILE ORGANIC COMPOUNDS (VOCs)

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ABSTRACT

A Visual Basic™ program to assist in the design of a stripping column for the removal of VOCs was developed and presented. Basic input features of the program include: 1) a built-in database with physico-chemical properties of common VOCs, 2) a built-in database with information about different packing materials and their respective characteristics, 3) selection of the appropriate operational parameters (water flow rate, column pressure, temperature, and air to water ratios). The program performs an optimization and develops a tower of minimum column size and energy requirements, and maximum contaminant removal. Design methodologies used, the development of the program, and a discussion on its capabilities are presented along with a case study from a contaminated groundwater site where air stripping was the technology of choice.

ΠΡΟΓΡΑΜΜΑ ΣΧΕΔΙΑΣΜΟΥ ΠΥΡΓΩΝ ΕΚΡΟΦΗΣΗΣ ΠΤΗΤΙΚΩΝ ΡΥΠΑΝΤΩΝ

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ΠΕΡΙΛΗΨΗ

Η εργασία αυτή παρουσιάζει ένα πρόγραμμα για το σχεδιασμό πύργων εκρόφησης πτητικών ρυπαντών γραμμένο σε Visual Basic™. Βασικά χαρακτηστικά του προγράμματος περιλαμβάνουν: 1) ενσωματωμένη βάση δεδομένων με φυσικο-χημικές ιδιότητες συνήθων πτητικών ρυπαντών, 2) ενσωματωμένη βάση δεδομένων με χαρακτηριστικά διαφόρων πληρωτικών υλικών, και 3) δυνατότητα επιλογης καταλλήλων λειτουργικών παραμέτρων (ογκομετρική ροή υγρού, πίεση, θερμοκρασία, αναλογία αέρα-υγρού). Το πρόγραμμα βελτιστοποιεί και αποδίδει σχεδιασμό πύργου ελαχίστου μεγέθους και ενεργειακών απαιτήσεων, και μέγιστης απομάκρυνσης ρυπαντών. Παρουσιάζεται η μεθοδολογία σχεδιασμού του προγράμματος, οι δυνατότητές του και συγκεκριμένη εφαρμογή απορύπανσης υπογείων υδάτων όπου πύργοι εκκρόφησης ήταν η τεχνολογία επιλογής.

1. INTRODUCTION

Although the short-comings of pump-and-treat systems are well documented in the literature [1], these technologies still represent the most common means for cleanup of contaminated groundwater sites. In a typical pump-and-treat system, contaminated water is initially extracted using any one of a number of recovery methods including wells, wells points, and drain tile collection systems. Subsequently, the pumped water could be treated using a wide range of water treatment techniques such as air stripping, carbon adsorption, or biofiltration. The choice of the treatment technology employed depends on the nature of the contaminant(s) as well as the treatment objectives. In VOC contaminated groundwater sites, a commonly applied on-site, *ex-situ* treatment is air stripping. Air striping is a mass transfer process that forces the contaminant from the liquid phase (water) to the gas phase (air). Although, packed towers are generally used, the process can be performed using tray towers, or spray systems.

The design of packed towers is not trivial, and is based on the following operational and design parameters: 1) type of contaminant, 2) air flow rate, 3) liquid flow rate, 4) ground water temperature, 5) tower pressure drop, 6) mass transfer coefficients, 7) tower diameter, 8) tower height, and 9) packing material [2]. Data to determine some of these parameters are obtained in pilot plant studies. Pilot plant studies are usually very effective, and provide a lot of insight about the final design, however, they tend to be expensive. The cost of these studies usually hinders the number of experiments that can be set up, thus compromising the final design.

With the advent of personal computing, and the popularity, speed and versatility it has gained in recent years; programming has become an important design tool for unit operations and processes. The aforementioned limitations of pilot plant studies can be significantly lessened by programs employing user friendly interfaces. A computer program used as a tool for the design of packed towers was developed. This program offers notable benefits when used as a tool for preliminary design and selection of appropriate pilot plant studies. For instance, it allows the user to study a variety of operating conditions and design configurations, and optimize the number of pilot plant experiments required. Furthermore, the program unlike the pilot plant studies provides a means to evaluate each of the design and operational parameters independently of one another. For example, the ability of the program to study the effect of each VOC present in groundwater independently from the others, allows one to determine which contaminant controls the design process. Also, in case that one wishes to establish the applicability of air stripping over other treatment technologies (*i.e.* carbon adsorption), the computer program could provide important information about a "go/no-go" decision early in a feasibility assessment.

2. THEORETICAL BACKGROUND

2.1 Mass Transfer Between Phases

Mass transfer is a process by which a chemical compound is transferred between phases by means of turbulent and molecular diffusion. In air striping the mass transfer process is mainly governed by turbulent diffusion, and is better described by the two-film theory. Accordingly, the overall resistance to mass transfer is equal to two independent mass transfer resistances: 1) mass transfer resistance in the gas phase, and 2) mass transfer resistance in the liquid phase. For dilute contaminant concentrations such as those encountered in groundwater sites, the chemical equilibrium relationship in the liquid-gas interface is considered linear and follows Henry's partitioning law. The liquid and gas phase resistances are described by local liquid and gas mass transfer coefficients. The overall mass transfer coefficient is represented by the following equation:

$$\frac{1}{K_L a} = \frac{1}{k_L a} + \frac{1}{H \cdot k_G a} \qquad [1]$$

Often, packing manufactures supply mass transfer data as a function of temperature and flowrates. Since $K_L a$ is system dependent, it is preferable to be determined in pilot plant studies. However, in absence of experimental data, for preliminary design purposes, empirical correlations can be used. The computer program estimates the mass transfer coefficient using correlation's developed by Onda *et al.* [3]. The striping program uses these correlations to determine the mass transfer coefficient, and they are presented below:

$$k_l\left[\frac{\rho_L}{\mu_L g}\right]^{1/3} = 0.0051\left(\frac{L}{a_w u_L}\right)^{2/3}\left(\frac{\mu_L}{\rho_L D_L}\right)^{-0.5}\left(a_t d_p\right)^{0.4} \qquad [2]$$

$$\frac{a_w}{a_t} = 1 - exp\left[-1.45\left(\frac{\sigma_c}{\sigma}\right)^{0.75}\left(\frac{L}{a_t \mu_L}\right)^{0.1}\left(\frac{L^2 a_t}{\rho_L^2 g}\right)^{-0.05}\left(\frac{L^2}{\rho_L \sigma a_t}\right)^{0.2}\right] \qquad [3]$$

$$\frac{k_G}{a_t D_G} = 5.23\left(\frac{G}{a_t \mu_G}\right)^{0.7}\left(\frac{\mu_G}{\rho_G D_G}\right)^{1/3}\left(a_t d_p\right)^{-2} \qquad [4]$$

2.2 Packed Towers

Packed towers are cylindrical columns where the contaminated water is fed through the top and is allowed to flow down by gravity. The water, usually countercurrent to the rising air, is distributed evenly by a liquid distributor. The tower is filled with packing material that provides a large area of contact between the liquid and gas streams, and promotes intimate contact between phases.

There are two conditions which drastically impair the efficiency of packed towers, one of them is known as channeling. This condition is brought about when the water, instead of flowing evenly across the column, follows along a preferential path (*i.e.* along the walls of the column). Thus, the appropriate degree of contact between the gas and the liquid is minimized. The other condition, known as flooding, is achieved when the gas phase flows so fast as to hinder the flow of the liquid phase. One way to prevent flooding is designing the packed towers on the basis of definite pressure drops per unit height of packing. To prevent flooding, it is recommended to design packed towers gas pressure drops of 200-400 N/m^2/m of tower height [2]. The pressure drop across a column represents the frictional and kinetic energy losses through the packing. Correlations for estimating gas velocities and pressure drops in packed towers are abundant in the literature [2, 4-6]. For the purposes of the computer program, generalized flooding and pressure drop correlations given by Treybal [6] were used. Regression analysis to correlate Eckert's coordinates produced the following relationship.

$$Y = exp(A + BX^{1/2}) \qquad [5]$$

$$Y = \frac{G^2 F \mu_L^{0.1}}{\rho_G\left(\rho_L - \rho_G\right) g} \qquad [6]$$

$$X = \frac{L}{G}\left(\frac{\rho_G}{\rho_L - \rho_G}\right)^{0.5} \qquad [7]$$

The regression produced a very high correlation coefficient (0.995) and the values of the regression coefficients for different pressure drops are shown in Table 1.

TABLE 1: Values of the Pressure Drop Regression Coefficients

Pressure, N/m^2	A	B
50	-4.21	-1.38
75	-3.66	-1.52
100	-3.31	-1.58
125	-3.13	-1.61
150	-2.97	-1.62
200	-2.72	-1.65
250	-2.53	-1.74
300	-2.39	-1.78
350	-2.26	-1.83
400	-2.15	-1.88

2.3 Column Design

The height of the column packing, Z, required to achieve the desired removal of solute is the product of two quantities, the height of a transfer unit (HTU) and the number of transfer units (NTU). Thus,

$$Z = HTU \cdot NTU \quad [8]$$

The height of the transfer unit (HTU) characterizes the efficiency of the column, and it is defined as shown below:

$$HTU = \frac{L}{M_w \cdot K_L a} \quad [9]$$

The number of transfer units characterizes the difficulty of removing the contaminant from the liquid phase, and it is defined as shown below:

$$NTU = \int_{C_{out}}^{C_{in}} \frac{dC}{\left[C - C_{eq}\right]} \quad [10]$$

for dilute solutions and solutes obeying Henry's law, this integral expression can be solved analytically as shown below:

$$NTU = \left(\frac{R}{R-1}\right) ln\left[\frac{(C_{in}/C_{out})(R-1)+1}{R}\right] \quad [11]$$

$$R = H'\left(\frac{Q_A}{Q_L}\right) \quad [12]$$

3. RESULTS AND DISCUSSION

3.1 Computer Program Rationale

The program was written using Visual Basic™. This powerful programming language allows for the creation of easy to use graphical user interfaces (GUI) that take full advantage of the Windows operating system. In addition, this programming language supports the concept of open data base connectivity (OBDC). Thus, information from external databases can be accessed and manipulated inside Visual Basic's programming environment.

The air strip program takes advantage of this feature, incorporating two databases inside the program. One of the databases allows the user to select the contaminant(s) of choice from a wide range of possible VOCs. Physico-chemical properties for each contaminant such as gas and liquid diffusivities, Henry's constants are stored in this database. Another database allows the user to

select the type of packing material. Hence, packing material information such as the type of packing, size of packing, packing coefficients are stored in this database. The program makes use of an important feature of Visual Basic, its ability to manipulate and use other Windows applications in a concept known as Object Linking and Embedding (OLE). This way, an external spreadsheet such as Excel can be embedded inside a Visual Basic application; to feel and act as being part of the application itself. The air strip program takes advantage of this tool by outputting the final results into an Excel spreadsheet. The final results can be further manipulated and graphed using the powerful Excel features. Third party tools, is another important feature of Visual Basic. These are external packages which act as extensions to the Visual Basic programming environment. They provide additional functionality and capabilities to the application. These third party tools can range from text boxes to complete graphics packages, word processors, or spreadsheets. By using these tools the effort needed to write an application is greatly reduced. The air strip program uses a graphics package to perform the packed tower optimizations.

3.2 Input/Output Interfaces

The first input form of the air strip program, presented in Figure 1, allows the user to select the contaminants present in ground water and their respective concentrations in ppm. The existing database can be enriched with additional contaminants and their properties by the user, if so desired.

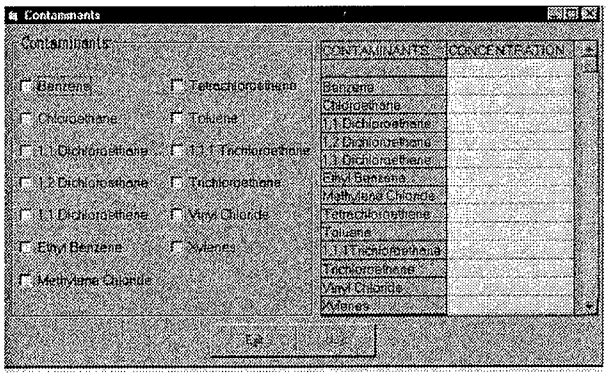


Figure 1. Contaminants Selection Input Form.

In the second step, presented in Figure 2, the user selects the operational parameters such as pressure drop through the column, temperature, water flow rate, liquid to gas ratio. A third form, shown in Figure 3, invokes a database allowing the user to select the appropriate packing for the column. The database possesses information about the packing material including type, nominal size, surface area, and porosity. The last form summarizes the design output for the user. The following information is presented in both tabular and graphical form as a function of contaminant type and liquid to gas ratios: 1) column height, 2) column volume, 3) mass transfer coefficient, and 4) diameter. This form also contains a menu allowing the user to perform two types of optimizations: a) energy optimization: the objective is to minimize the operating costs of the column; by selecting the air to water ratio which renders the lowest total power brake on the column, and b) size optimization: the objective is to minimize the initial capital cost.; by selecting the air to water ratio which renders the smallest column (packing volume). Both optimizations are performed on the contaminant offering the highest resistance to mass transfer. This form is presented in Figure 4.

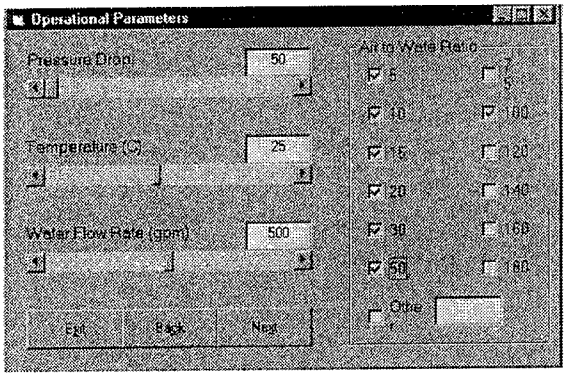


Figure 2. Operational Parameter Input Form.

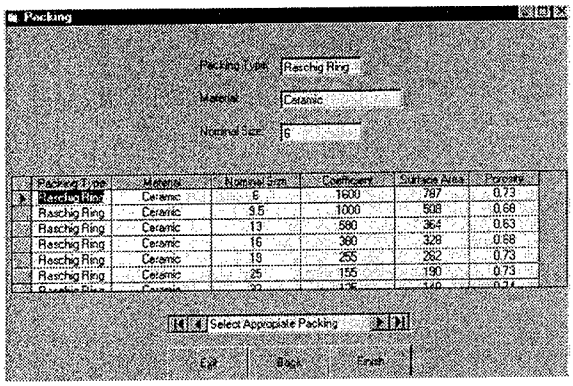


Figure 3. Packing Material Input Form.

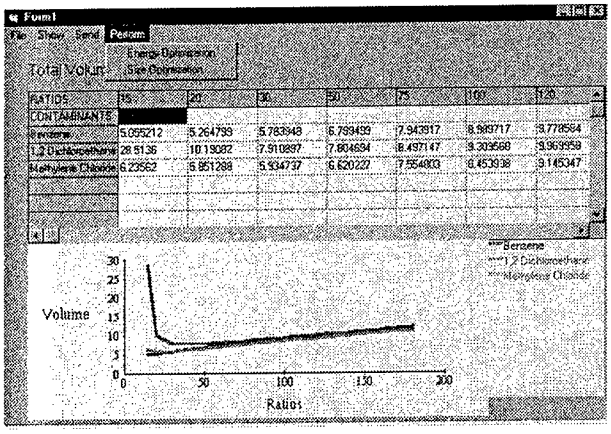


Figure 4. Design Summary Output Form.

3.3 Program Application: Case Study

The basic features of the program and its capabilities are will be demonstrated using a well known case of a ground water site contaminated with VOCs. Several other case studies using the program have been performed and are presented elsewhere [7]. In 1983, EPA placed the Bay/South Tacoma Channel on the National Priorities List of hazardous waste sites. Preliminary studies demonstrated that the site was contaminated with volatile organic compounds VOCs [8]. The most important contaminants and their concentrations are outlined Table 2. Air stripping was selected as the preferred technique for the treatment of these contaminants. The program was used as an aid for the design of an air stripping unit. Tower specifications and conditions are outlined on Table 3.

TABLE 2. Selected Groundwater Contaminant Concentrations

Component	Liquid Influent Concentration (ppm)	Liquid Effluent Concentration (ppm)
1,1-Dichloroethane	30.0	5.0
Methylene Chloride	67.0	5.0
Trichloroethene	14.0	5.0
Vinyl Chloride	24.0	2.0

TABLE 3. Specifications and Operating Conditions of the Air Stripping Unit.

Tower Packing	Specifications
Packing Material	Raschig Ring
Specific Surface Area, m^{-1}	92
Nominal Diameter, m	0.050
Packing Factor	65
Column Conditions	**Specifications**
Air-to-Water Ratio	15,20,30,50,75,100,120
Liquid Loading gpm	760
Pressure Drop N/m	100
Water Temperature,°C	20

Packing volumes (height×cross-sectional area) for the different contaminants and conditions specified in Table 3 are summarized on Table 4. From Table 4, one can see that methylene chloride is the contaminant offering the largest resistance to mass transfer, and thus, it is the contaminant which is controlling the design process. Therefore, the computer program will base the optimization on this contaminant. For the first optimization, the computer will determine which liquid to gas ratio will give the smallest tower size as shown in Figure 5. The striping program estimates the minimum point in Figure 5, by taking the first derivative of the curve. For this case, the minimum tower volume which represents the minimum capital cost was determined to be an air to liquid ratio of approximately 40. For the second optimization the program will determine which air to water ratio requires the lowest total brake power to achieve the removal objective as shown in Figure 6. As with Figure 3, the program calculates the fist derivative of this curve and determine the minimum (optimum) air to water ratio, which in this case is approximately 25. From the two minimum points obtained previously, one can conclude that column can be operated at air to water ratio of 30.

TABLE 4. Program Results, Packing Volume of the Air Stripping Unit (m^3)

	Ratios						
Contaminants	**15**	**20**	**30**	**50**	**75**	**100**	**120**
1,1 Dichloroethane	4.82	4.86	5.14	5.85	6.73	7.55	8.18
Methylene Chloride	11.24	9.32	8.61	8.99	9.93	10.95	11.76
Trichloroethane	2.54	2.64	2.87	3.33	3.86	4.35	4.73
Vinyl Chloride	4.63	4.97	5.60	6.67	7.85	8.92	9.73

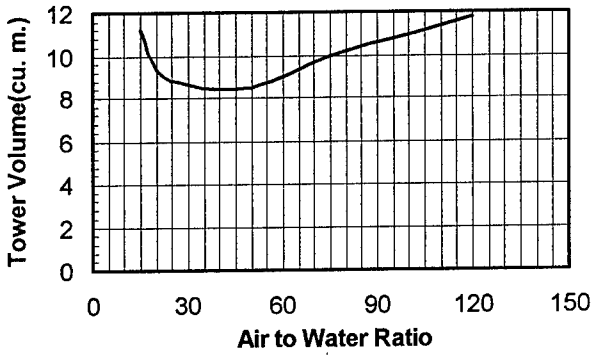


Figure 5. Relationship between Packing Volume and A/W Ratio for Methylene Chloride

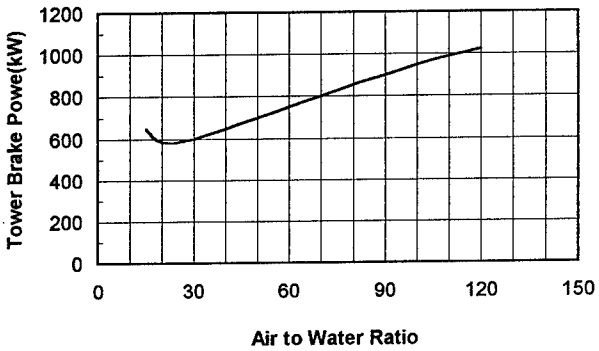


Figure 6. Relationship between Total Brake Power and A/W Ratio for Methylene Chloride

4. CONCLUSIONS

The development of a Visual Basic computer program that designs air stripping towers for removal of VOCs was presented. The program, through graphical user interfaces (GUI), open database connectivity (ODBC) and object linking and embedding (OLE), takes a full advantage of the Windows operating environment, is user friendly, versatile, and simple to use. The well documented two-phase resistance models serve as the basis for the calculation of the overall mass transfer coefficients (K_La) for BTEX and other VOCs. The number of transfer units (NTU) approach is then utilized for designing air stripping columns for a variety of compounds, operational conditions, and packing materials. Optimization with respect to striper volume (capital expenses) and energy requirements (operational expenses) can also be performed. The basic features of the program are demonstrated in a case study of VOC contaminated ground water. The program offers flexibility and allows the user to probe a wide range of operational scenarios and packing materials. Consequently, the program can be a very useful tool used for preliminary design purposes or for selecting and implementing pilot scale experiments to derive scale-up data.

5. SYMBOLS AND TERMINOLOGY

$a_{t/w}$ = total/ wetted specific packing area, m^{-1}
d_p = nominal packing diameter, m
g = gravitational constant, 9.81 m/s^2
$k_L a$ = liquid-phase mass transfer coefficient, m/s
$k_G a$ = gas-phase mass transfer coefficient, m/s
$C_{in/out}$ = influent/effluent liquid stream contaminant concentration, $kmol/m^3$
F = packing factor, dimensionless
$D_{G/L}$ = gas/liquid diffusivity, m^2/s
G = gas mass or molar loading rate, $kg/m^2 \cdot s$ or $kmol/m^2 \cdot s$
H = Henry's constant, dimensionless
HTU = height of a transfer unit, m
$K_L a$ = overall volumetric mass transfer coefficient, s^{-1}
L = liquid mass or molar loading rate, $kg/m^2 \cdot s$ or $kmol/m^2 \cdot s$
M_w = molar density of liquid stream, $kmol/m^3$
NTU = number of transfer units, dimensionless
R = air stripping factor, dimensionless
Q_G = gas stream volumetric flowrate, m^3/s
Q_L = liquid stream volumetric flowrate, m^3/s
Z = total column height, m
$\mu_{G/L}$ = gas/liquid stream viscosity, $kg/m \cdot s$
$\rho_{G/L}$ = gas/liquid stream density, kg/m^3
σ = liquid surface tension, N/m
σ_c = packing medium critical surface tension, N/m

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DISINFECTION OF WASTEWATER BY UV RADIATION

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ABSTRACT

Ultraviolet (UV) light is more frequently being considered as a promising alternative to chlorine for the disinfection of wastewater. In this work, a critical literature review is attempted for the up to now knowledge and experience of the UV disinfection as it is usually applied in wastewater treatment. The general principles of UV radiation are referred and special emphasis is given to the modeling of the process, to the economic elements of UV disinfection resulting from various investigations, to the advantages and disadvantages of UV disinfection, and it is compared with other known disinfection processes.

ΑΠΟΛΥΜΑΝΣΗ ΥΓΡΩΝ ΑΠΟΒΛΗΤΩΝ ΜΕ ΥΠΕΡΙΩΔΗ ΑΚΤΙΝΟΒΟΛΙΑ

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ΠΕΡΙΛΗΨΗ

Η απολύμανση με υπεριώδη ακτινοβολία (ΥΑ) κερδίζει τελευταία συνεχώς έδαφος έναντι των εναλλακτικών μεθόδων απολύμανσης. Στην εργασία αυτή επιχειρείται μια κριτική βιβλιογραφική ανασκόπηση της μέχρι τώρα γνώσης και εμπειρίας της διαδικασίας απολύμανσης με ΥΑ όπως εφαρμόζεται κυρίως στην επεξεργασία αποβλήτων. Αναφέρονται οι γενικές αρχές λειτουργίας και δίνεται ιδιαίτερη έμφαση στη μοντελοποίηση της διεργασίας, στα οικονομικά στοιχεία της απολύμανσης με ΥΑ όπως προκύπτουν από διάφορες έρευνες, στα πλεονεκτήματα και μειονεκτήματά της, και συγκρίνεται με τις γνωστές εναλλακτικές μεθόδους απολύμανσης.

1. INTRODUCTION

Until recently chlorine, free and in compounds, was widely accepted as the main disinfectant in most wastewater treatment plants. However, the disinfection by-products (DBP) caused by the chlorine use, the potential toxicity of the residual chlorine to the marine organisms and the probable risks from the transfer and use of the chlorine, have prompted engineers to evaluate alternative wastewater disinfection processes. Ultraviolet (UV) radiation has emerged as an important alternative to conventional chlorination of municipal wastewater and its popularity has grown significantly over the last ten years. Over 600 UV disinfection systems operate today in the USA and the vast majority of these facilities have been installed since 1986, [1]. Approximately 2,000 treatment plants in Europe currently use UV as well, [2]. A proper dosage of UV radiation has shown to be an effective bacteriocide and virucide while not contributing to the formation of toxic compounds.

The UV light is emitted by lamps containing mercury vapor, which is striked by an electric arc. Operationally, the lamps are either suspended outside of the liquid to be treated or submerged in the liquid and in this case the lamps are encased in quartz tubes to prevent cooling effects on the lamps.

By now, the low-pressure mercury vapor arc lamp is the principal means of generating UV energy. This mercury vapor lamp is favored because about 85% of the light output is monochromatic at a wavelength of 253.7 nm, which is within the optimum range (250 to 270 nm) for germicidal effects. There are also medium and high-pressure mercury vapor lamps with a broader band of UV light and a higher energy output. This results in greater treatment capacity (approximately 25 times) but they are more expensive than the low-pressure lamps, [2, 3]. The high-pressure UV lamps are used in special applications whereas the medium-pressure lamps are being used increasingly because fewer lamps and smaller reactors are needed than for low-pressure lamp systems. This means lower capital cost, and savings in operation and maintenance, [4].

2. THEORY OF UV RADIATION

The inactivation of bacteria by UV radiation results primarily from the absorption of radiation by the deoxyribonucleic acid (DNA) of microorganisms and subsequent dimerization of thymine bases in DNA. These thymine dimers distort the double helix conformation of DNA and may block replication, which effectively inactivates the bacteria, [5]. The inactivation of microorganisms by UV is proportional to the intensity (W/cm^2) multiplied by the time of exposure (s), which is termed the UV dose ($W \cdot s/cm^2$).

Most bacteria and viruses require relatively low UV dosage for inactivation, usually in the range of 2,000 to 6,000 $\mu W \cdot s/cm^2$ for 90% kill. The order of sensitivity for the different groups of microorganisms is bacteria, viruses, and fungi. Bacteria are the most sensitive and fungi are most resistant to UV radiation, [6]. However protozoan cysts appear to be considerably more resistant to UV inactivation than other microorganisms. Although the maximum designed dose of many commercially available UV units is 25,000 to 35,000 $\mu W \cdot s/cm^2$, it has been found that less than 80% of *G. lamblia* cysts were inactivated at UV dosages up to 63,000 $\mu W \cdot s/cm^2$ and 90% of *G. muris* cysts were inactivated when the dosage was increased to 82,000 $\mu W \cdot s/cm^2$, [2].

The dose of germicidal UV light reaching a targeted organism is a difficult quantity to measure, particularly under field conditions. Currently there are three approaches used to estimate UV dose: chemical actinometry, biological assays, and mathematical models, [7]. Chemical actinometry and biological assays provide a direct measure of UV dose, whereas mathematical methods provide an

estimate of UV intensity, which when coupled with an estimate of average exposure time can be used to calculate UV dose. Biological assays and mathematical methods are used most frequently, [8, 9]. The most common mathematical method used to determine average UV intensity in a disinfection system is the point source summation method, [8, 9, 10].

Total and fecal coliform bacteria have been and continue to be used as the principal indicators of disinfection performance. However, use of coliform organisms does have limitations, both in ensuring that adequate disinfection has occurred and in serving as research tool, [7]. Other organisms are increasingly being investigated as indicators of disinfection performance such as the MS2 coliphage, an F-specific single-stranded RNA virus. This is usually present in low concentrations (<100/ml) in wastewater, is nonpathogenic to humans, is more resistant than coliform bacteria to UV disinfection and is easy to enumerate relative to pathogens. Therefore MS2 coliphage is an appropriate indicator organism for testing the performance of UV disinfection systems, [7].

A potential problem with UV disinfection is that bacterial regrowth may occur. Exposure of UV damaged cells to higher wavelength light, primarily in the visible range, may often repair much of the damage to the DNA. This repair of pyrimidine monomerization process is termed photoreactivation and occurs primarily at wavelengths between 300 and 500 nm with the most effective wavelength dependent on the particular microorganism, [5, 11]. Reactivation of UV inactivated bacteria can also occur in the dark. This dark repair mechanism is believed to be an excision-repair mechanism whereby dimers are excised by a multienzymatic mechanism. The subsequent synthesis of a new component of the DNA then occurs from information on the complementary strand, [5].

3. PARAMETERS AFFECTING THE EFFICIENCY OF UV DISINFECTION

The parameters which affect the efficiency of UV disinfection are: a) those parameters which determine the dose of the UV energy reaching to the microorganisms (either by acting on the intensity of the UV energy or by changing the exposure time), and b) the nature of the microorganisms, [12].

The parameters, which affect the intensity of the UV energy reaching to the microorganisms, are the following physicochemical characteristics of the water:

1. Turbidity and suspended solids (SS): High levels of turbidity and SS reduce the efficiency of UV disinfection. The turbidity and the color are related with the presence of compounds and elements in the water, dissolved or not, which screen out the transmittance of the radiation. The absorption is due primarily to the dissolved matter. From the dissolved substances, humic acids absorb a great amount of the UV radiation, [8, 12]. Normally the high microbiological pollution is related with high turbidity. However, the turbidity and the color are not reliable indicators for the transmittance of the UV radiation in the water. Two types of water may have the same degrees of turbidity but different transmittances, [12].
   In the same way, the efficiency of UV disinfection reduces with the increase of the SS. The solids reduce the dose of UV radiation reaching to targeted organisms by a) absorbing UV light, b) scattering UV light and c) protecting organisms either by particle shading or by attaching them in their body. Particulate material in wastewater is one of the primary causes of tailing, [14]. Increasing the dose of UV radiation the reduce in the efficiency of the disinfection can be counter-balanced to an extent, but for an effective disinfection the SS must be normally under 20 mg/l, [6,13]. In different cases the filtration of the wastewater is strongly recommended. Filtered effluent are more effectively disinfected than secondary effluent, [8, 9, 10, 15]. Recent

experiments have shown that the transmittance of the wastewater is correlated with the particulate matter for high concentrations of SS (TSS>15 mg/l) whereas for low concentrations it seems that the transmittance is mainly determined by the colloidal solids, [15, 16].

2. Size of the particulate material: For similar concentrations of SS, the higher the average size of the solids the smaller the effectiveness of the UV disinfection is, [15]. This is due to the fact that the largest solids can protect the microorganisms better than the smallest ones.
3. Total dissolved solids (TDS), hardness, pH, temperature: The TDS, hardness, pH and temperature do not seem to affect the transmittance of the wastewater by UV light and as a result the effectiveness of the radiation, [2, 6, 15]. However these parameters affect the rate of the fouling creation on the case of the UV lamps which reduces the intensity of the UV light emitted by the lamps. Further, the energy emitted by the lamps depends on its temperature which follows the temperature of the water, [15].
4. Iron: The iron absorbs UV radiation and increases the rate of the fouling creation on the UV lamps. It was found that the iron does not affect the transmittance of the UV light in concentrations less than 3 mg/l, but over 4.8 mg/l the transmittance is significantly affected. The UV lamps manufacturers suggest the concentration of the iron in the wastewater to be under 0.5 mg/l to avoid fouling, [15].
5. Initial bacterial density: The effectiveness of a UV disinfection system depends on the ratio of the final over the initial bacterial density [15, 17], although some manufactures claim that it is not valid for the range of doses usually applied in UV systems.

The factors, which affect the exposure time of the microorganisms to UV radiation, are mainly of hydraulic type and include the flow regime, the short-circuiting and the dead spaces. These phenomena can be faced by the turbulent plug flow, the proper ratio, length to width, of the flow channel, the proper effective exposure depth, and the uniform flow upstream and downstream of the radiation chamber, [6, 8, 13].

Finally, the characteristics of the microorganisms, which affect the effectiveness of UV disinfection, are their sensitivity to the UV radiation, their initial concentration, the mechanisms of reactivation and the ability of the microorganisms to flocculate.

4. MODELING OF THE UV DISINFECTION EFFICIENCY

UV inactivation of bacteria in the ideal case of uniform UV intensity and plug flow, can be approximated by the following expression based on first-order kinetics, [8, 14, 17]:

$$N = N_o \exp(-kIt) \quad (1)$$

where: N = bacterial density after exposure to UV (MPN/100ml), N_o = initial bacterial density (MPN/100ml), k = inactivation rate constant ($cm^2/W \cdot s^{-1}$), I = intensity of UV light energy (W/cm^2), and t = exposure time (s). However, in practice, the performance of UV disinfection systems has been observed to deviate from first-order kinetics. The real systems operate in the tailing region of the log survival versus UV dose curve. Particulate material in the water is one of the main reasons for tailing. Explanations for the deviations from first-order kinetics include a lag in the initial response to UV radiation due to bacterial resistance and possible clumping, reduced disinfection performance due to uneven dispersion within UV reactors, and reduced disinfection performance due to the aggregation of the microorganisms or the occlusion of bacteria in particulate material, [14].

Scheible [17] proposed a modification of the Eq. 1 in order to account for the above effects:

$$N = (N_o' + N_p) \exp(-kIt) + N_p \quad (2)$$

where: N_o' is the initial, non-aggregated density, and N_p is the density associated with the particulates that are unaffected by UV radiation. In most wastewater disinfection applications N_o' is much larger than N_p, such that the total initial density, N_o, can be considered equal to N_o'. Then the expression can be written:

$$N = N_o \exp(-kIt) + N_p \quad (3)$$

However, under actual conditions, ideal plug flow with no axial dispersion does not exist. Scheible [17], in order to account for the axial dispersion and velocity gradients suggests the following modification of the Eq. 3 which describes the residence time distribution of the reactor under steady-state conditions:

$$N = N_o \exp\left[\frac{ux}{2E}\left\{1-\left(1+\frac{4KE}{u^2}\right)^{\frac{1}{2}}\right\}\right] + N_p \quad (4)$$

where: x = characteristic length of the reactor (cm), u = velocity of the wastewater which is equal to $X/(V_v/Q)$, V_v = effective liquid volume in the reactor, Q = total flow (l/s), E = dispersion coefficient (cm^2/s), and K = rate constant for the bacterial inactivation (s^{-1}). Furthermore K and N_p are estimated by the following equations, [14]:

$$K = aI^b \quad (5)$$

$$N_p = c(SS)^m \quad (6)$$

where: I = average UV intensity in the reactor (W/cm^2), SS = concentration of suspended solids (mg/l), and a, b, c, m = empirical coefficients.

From Loge *et al* [14] the following empirical model is suggested, integrating both UV dose and multiple water quality parameters, to describe coliform densities in the tailing region after exposure to UV light:

$$N = f(D)^n \quad (7)$$

where: f = empirical water quality factor, D = UV dose ($W \cdot s/cm^2$), and n = empirical coefficient related to UV dose. The water quality factor has the following general functional form:

$$f = A(SS)^a (UFT)^b (N_o)^c \quad (8)$$

where: UFT = unfiltered UV transmittance at 253.7 nm (%), and A, a, b, c = empirical coefficients. The specific functional form of the water quality factor and the corresponding values of the model coefficients are determined through a multiple linear regression of water quality data collected at the particular wastewater treatment plant.

The relative significance of the characteristics of the wastewater (type and concentration of particulate and dissolved material, nature and degree of particle association of target organisms), the nature of the discharge permit itself and the confidence in meeting that permit, has not been quantified and varies to different plants. Since a purely deterministic approach is unlikely to be successful in describing this variability, Loge *et al* [18] suggested two probabilistic approaches for designing a disinfection facility. These approaches require different amounts of pilot testing but quantify the probabilistic nature of wastewater variability and permit requirements.

5. COMPARISON WITH ALTERNATIVE DISINFECTION TECHNIQUES

UV radiation is a promising future disinfection technique with increasing popularity. UV disinfection systems are already being used to meet relatively stringent effluent coliform permit criteria (for example 240, 23 and 2.2 MPN/100 ml), [14].

The available literature indicates that UV disinfection does not contribute to undesirable DBPs. Recent investigations showed that UV radiation did not produce increased mutagenic activity in the

water and UV treatment of carbon-filtered drinking water did not produce assimilable organic carbon (AOC), [2]. Also other researchers have shown that UV does not produce any tastes and odors. The potential for UV reactions to produce organic by-products is minor because the intensities required for UV disinfection are less than those needed to cause photochemical effects, [19].

A comparison of disinfection processes performance and economics is site specific because of the unique set of water quality characteristics and cost factors that apply to any given facility. However most of the cost analyses have shown that costs of UV disinfection are comparable to or slightly higher than the cost of chlorination, and lower than those of ozonation and chlorine dioxide disinfection, [2]. Also, it seems that if the dechlorination process is included, then UV disinfection is less expensive than the system of chlorination-dechlorination, [1]. In the Table 1 the relative costs of four disinfection systems for three plant capacities can be seen from a review conducted in 1984 by Gumeran, Burris and Hansen (cited in [2]).

TABLE 1. Total annual costs for disinfection based on 1989 construction cost indexes (from [2])

		Annual costs			
Disinfectant	Plant capacity, MGD	Capital[a], $	O&M[b], $	Total, $	Total, c/1000gal
Chorine	0.05	2,260	2,480	4,740	26.0
Chorine	0.5	2,260	3,260	5,520	3.0
Chorine	1.0	2,260	3,850	6,110	1.7
UV	0.05	2,000	2,000	4,000	21.9
UV	0.5	5,500	7,700	13,200	7.2
UV	1.0	7,030	12,430	19,460	5.3
Ozone	0.05	2,240	11,000	13,240	72.5
Ozone	0.5	3,160	14,300	14,460	9.6
Ozone	1.0	4,180	19,800	23,980	6.6
Chorine dioxide	0.05	4,070	5,500	9,570	52.5
Chorine dioxide	0.5	4,070	16,200	20,970	11.1
Chorine dioxide	1.0	4,070	27,200	31,270	8.6

[a]Calculated at 8% interest rate over a 20-year period.
[b]O&M = operation and maintenance.
Note: to convert c/1000 gal to $/acre-feet, multiply by 3.26

In Table 2 a similar comparative analysis can be seen between a chlorination-dechlorination and a UV disinfection plant where the second is more cost effective in both capital and operation costs, [1].

TABLE 2. Projected system cost associated with a) chlorination-dechlorination and b) UV radiation plants (from [1])

Chlorination-dechlorination	Cost, 10^3	UV radiation	Cost, 10^3
Capital and construction costs		Capital and construction costs	
Demolition and removal	45	Demolition and removal	10
Earthwork	109	Contact chamber and utilities	210
Concrete and reinforcing steel	289	Other concrete and reinforcing steel	5
Grating, plates, misc. metal	13	Architectural	8
Piping and valves	10	HVAC	24
Architectural	18	Process equipment	294
Plumbing, HVAC, electrical	115	Two cleaning tanks	40
Parshall flume	13	Total	591
Process equipment	310	Operation and maintenance costs (annual)	
Total	922	Lamp replacement	8.4
Operation and maintenance costs (annual)		Miscellaneous replacement	2.0
Chemicals		Electrical power	9.0
NaOCl	15.4	Labor	
NaHSO	16.6	Jacket cleaning	3.0
Routine cleaning and maintenance	1.4	Relamping	0.4
Total	33.4	Total	22.8

Table 3 summarizes important aspects and technical advantages and disadvantages of the major disinfection technologies, [19].

TABLE 3. Applicability of alternative disinfection techniques (from [19])

Consideration	Cl_2 †	Cl_2/deCl_2	O_3	ClO_2	UV
Size of plant	All sizes	All sizes	Medium to large	Small to medium	Small to medium
Equipment reliability	Good	Fair to good	Fair to good	Good	Fair to good
Relative complexity of technology	Simple to Moderate	Moderate	Complex	Moderate	Simple to moderate
Safety concerns	Yes	Yes	Moderate	Yes	Minimal
Bactericidal	Good	Good	Good	Good	Good
Virucidal	1✣	1✣	Good	Good	Good
By-products of possible health concern	2✣	2✣	3✣	Yes	No
Persistent residual	Long	None	None	Moderate	None
Contact time	Moderate	Moderate	Short	Moderate	Short
Reacts with ammonia	Yes	Yes	No	No	No
pH dependent	Yes	Yes	Slight	Slight	No
Process control	Well developed	Well developed	Developing	Developing	Developing

†Includes Chloramination
✣1 = moderate for free residual chlorination; poor for combined residual chlorination; 2 = fewer by-products with combined residual chlorination, 3 = health significance of by-products is unresolved at present

More extensively the advantages and disadvantages of UV disinfection are as follows, [2, 12]:
Advantages

- Excellent disinfection performance with bacteria and viruses. Normal doses (20-40 mW•s/cm^2) kill all the common pathogenic microorganisms (6-10 mW•s/cm^2 required). Higher doses are required for killing of protozoan cysts.
- Short contact times (of the order of seconds) required to inactivate viruses and bacteria which means smaller facilities and greater safety factors.
- Very few (if any) undesirable by-products, no AOC, little or no mutagenic activity, no obvious tastes and odors, no halogenated by-products.
- Ability to combine with hydrogen peroxide or ozone to stimulate production of hydroxyl radicals for enhanced breakdown of selected organic contaminants, and taste and odor compounds.
- Lower cost than most alternative methods of disinfection.
- No special safety factors, regarding chemicals management, toxic transport and storage, personnel training etc.
- No effect to the atmosphere and no noise production.
- No need for special civil works, housing etc.

Disadvantages

- Limited information on factors influencing effectiveness in the field.
- Limited experience with UV technology.
- No residual provided for disinfection in the distribution system. Post-disinfectant need for potable waters.
- Uncertainties regarding accuracy and reliability in measuring UV dose. Current systems rely on sensors and theoretical measurements.
- Technological limitations on practical size (up to approximately 20 MGD) of treatment plants that can be cost-effectively disinfected by UV.

CONCLUSIONS

UV light is being used increasingly as alternative technique for wastewater disinfection. Factors influencing the UV energy for disinfection include the wastewater characteristics, the variability in these characteristics and the permit requirements.

Disinfection of wastewater by other disinfectants produces residuals which are toxic to aquatic organisms and may cause the formation of carcinogenic compounds. Currently UV disinfection of secondary wastewater is recognized as a viable alternative because there is little evidence that it produces potentially hazardous by-products. Continuously improving technology has made UV disinfection increasingly reliable. Finally UV disinfection eliminates the need to transport, store and treat with highly toxic chemicals such as chlorine gas.

The main disadvantages of UV disinfection are the limited experience with UV technology, and the uncertainty associated with the determination of the dose and the performance capability of UV radiation.

It is believed that in the next few years most of the technological problems will be solved, more experience will be acquired, the UV systems will be more cost effective, so that the UV radiation will be one of the main methods of disinfection.

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PHOTOCATALYTIC TREATMENT OF WASTE WATER: DEGRADATION OF p-COUMARIC ACID OVER SEMICONDUCTOR SUSPENSIONS

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ABSTRACT

The photocatalytic degradation of p-Coumaric acid, a biorecalcitrant polyphenolic compound typically found in olive processing and wine distillery waste waters, has been investigated in aqueous heterogeneous solutions containing semiconductor powders as photocatalysts. The disappearance of the organic molecule follows approximately a pseudo-first kinetic order according to the Langmuir-Hinselwood model. Various commercial photocatalysts were compared with respect to their overall efficiency, as well as the production of CO_2. The effect of H_2O_2 on the reaction rate was ascertained. Biodegradation tests had showed that the photocatalytic pre-treatment leads to more biodegradable products.

ΦΩΤΟΚΑΤΑΛΥΤΙΚΗ ΕΠΕΞΕΡΓΑΣΙΑ ΑΠΟΒΛΗΤΩΝ: ΔΙΑΣΠΑΣΗ ΤΟΥ p-COUMARIC ACID ΠΑΡΟΥΣΙΑ ΗΜΙΑΓΩΓΙΜΩΝ ΚΟΝΕΩΝ

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ΠΕΡΙΛΗΨΗ

Στην παρούσα εργασία μελετάται η φωτοδιάσπαση του οξέος p-coumaric acid, ενός μη βιοαποικοδομήσιμου συστατικού των αποβλήτων ελαιουργείων, σε υδατικά διαλύματα παρουσία ημιαγώγιμων κόνεων(TiO_2, ZnO). Ο συνδυασμός του ημιαγωγού με οξειδωτικά όπως H_2O_2 επιφέρει όχι μόνο μείωση του χρόνου φωτοδιάσπασης αλλά μετατρέπει όλα τα ενδιάμεσα προϊόντα σε CO_2 και ανόργανα ιόντα. Η φωτοδιάσπαση ακολουθεί κινητική ψευδο-πρώτης τάξεως και βρίσκεται σε συμφωνία με το μοντέλο των Langmuir-Hinselwood. Από τα κινητικά δεδομένα υπολογίσθηκε η φαινόμενη σταθερά ταχύτητας της φωτοδιάσπασης του οξέος, καθώς και ο χρόνος υποδιπλασιασμού της αρχικής συγκέντρωσης. Οι μετρήσεις του BOD_5 έδειξαν ότι η φωτοκατάλυση, ως μέθοδος προεπεξεργασίας, επιτρέπει την βιοαποικοδόμηση ουσιών με βιοστατικές ιδιότητες.

1. INTRODUCTION

The elimination of toxic chemicals from waste water is presently of great concern, since their complete biodegradation is usually very slow and requires several days or weeks. These pollutants may originate from industrial applications or from household and personal care areas. The search of effective means of removing these compounds is of interest to regulating authorities everywhere. Recently it has been demonstrated that semiconducting materials mediating photocatalytic oxidation of organic compounds can be an alternative to conventional methods for the removal of organic pollutants in water [1, 2]. A variety of semiconductor powders (oxides, sulfides and others) acting as photocatalysts has been used. Most attention was given to TiO_2 because of its high photocatalytic activity, its resistance to photocorrosion, its biological immunity and low cost. The appropriate illumination (hv>Eg) of these particles produces excited-state high energy electron and hole pairs (e^- /h^+), that can migrate to their surface. These pairs are able to initiate a wide range of chemical reactions, that may lead to complete mineralization of the pollutants. Additionally, advantages of the photocatalytic process are its mild operation conditions and the fact that it can be powered by sunlight, reducing significantly the electric power required and therefore the operating costs [3, 4].

Olive oil is a typical Mediterranean product and its nutritional and economic importance are well known. The waste water from the olive oil milling (extraction) process (OMW) is highly pollutant due to the high organic carbon content, substantial portion of which is present as aromatic compounds (phenols, polyphenols, tannins, et.al)[5]. The pollution potential of OMW, expressed as Chemical Oxygen Demand (COD) concentration varies from 100-250 Kg/m^{-3}. OMW is a serious environmental problem, not only due to its high organic load and the presence of recalcitrant compounds with bio-static action, but also because they are produced in very high quantities during a short period of time.

Several chemical and biological procedures are increasingly used in order to transform them into more biodegradable residues, some with success, but they are not widely implemented due to their high cost of installation and operation [6, 7].

In relation to this problem, a research program on the photocatalytic pre-oxidation of the waste waters coming from the olive oil process was designed.Its main objective was to eliminate the more resistant pollutants in a previous chemical stage before the anaerobic digestion.

The first step of this program is focused on the study of the photocatalytic degradation of p-Coumaric acid, a key polyphenolic pollutant, which is abundantly present in the OMW and so is taken as a model. It belongs to a range of compounds compising gallic, gentistic, caffeic and protocatechuic acids which are known to inhibit biological treatment of waste waters from agricultural origin [8].

2. EXPERIMENTAL

p-Coumaric acid [3(4-hydroxyphenyl)-2-propenoic acid] of purum quality was a Fluka product and was used as received. TiO_2 P-25 Degussa (anatase/rutile = 3.6/1, surface area 56 m^2/g, nonporous) was used for most of the experiments, with a few exceptions, mentioned in the following text..

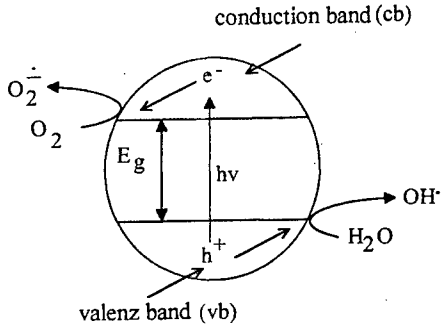
Experiments were performed in an open thermostated Pyrex cell of 250 ml capacity (9 cm diameter, 3.5 cm height). The reaction mixture in the cell was maintained as a suspension by magnetic stirring. The irradiation was carried out using four parallel 15 W blacklight blue fluorescent tubes, mounted in standard 15W fluorescent tube holders (Philips TLD 15W/08, 45 cm length, 2.6 cm diameter). According to the producer each tube has a total radiative output of 2.2 W between 340-400 nm with maximum emission at 370 nm.

In all cases, during the experiments, 200 ml of the p-Coumaric acid solution containing the appropriate quantity of the semiconductor powder, was magnetically stirred before and during the illumination. At specific time intervals, samples of 5 ml were withdrawn. To remove the TiO_2 particles, the solution was filtered through a 0.45 μm filter (Schleicher and Schuell). Changes in the concentration of p-Coumaric acid were observed from its characteristic absorption at 280 nm, using a UV-visible spectrophotometer (Shimadzu UV-160 A).

In order to determine the CO_2 release, a second apparatus was used. It consisted of a borosilicate glass vessel of 6 cm diameter and of 13.5 cm height, hermetically sealed with a silicone rubber. The reaction vessel was fitted with a central 11 W lamp (Osram Dulux S 11W/78) and had inlet and outlet ports for bubbling the desired gas, under which the reaction was taking place. CO_2 formed during the photooxidation in the reaction vessel, was followed by measuring the conductivity increase of ultra pure water, with a conductivity meter according to Matthews [9].

3. RESULTS AND DISCUSSION

It is well established that by irradiation of an aqueous TiO_2 suspension with light energy greater than its band gap energy (Eg> 3.2 eV) conduction band electrons (e^-) and valence band holes (h^+) are generated. After this primary event part of the photogenerated carriers recombine in the bulk of the semiconductor with heat emmision, while the rest reach the surface, where the holes as well as the electrons act as powerful oxidants and reductants respectively. The photogenerated electrons react with the adsorbed molecular O_2 on the Ti(III)-sites, reducing it to superoxide radical anion $O_2^{\cdot-}$, while the photogenerated holes can oxidize either the organic molecules directly or the OH^- ions and the H_2O molecules adsorbed at the TiO_2 surface to $OH\cdot$ radicals and together with other highly oxidant species (peroxide radicals) are reported to be responsible for the primary oxidizing step in photocatalysis(Fig. 1) [10]. According to this, the relevant steps of the photodegradation process at the semiconductor surface can be expressed as follows:



$$TiO_2 + hv \longrightarrow e^- + h^+$$

$$(O_2)_{ads} + e^- \longrightarrow (O_2^{\cdot-})_{ad}$$

$$Ti(IV)\text{-}OH + h^+ \longrightarrow Ti(IV)\text{-}OH\cdot$$

$$Ti(IV)\text{-}H_2O + h^+ \longrightarrow Ti(IV)\text{-}OH\cdot + H^+$$

$$R + h^+ \longrightarrow R(oxidized)$$

FIGURE 1: The TiO_2/electrolyte system under UV-illumination.

The $OH\cdot$ radicals formed on the illuminated semiconductor surface are very strong oxidizing agents, with an oxidation potential of 2.8 V. These can easily attack the adsorbed organic molecules or those located close to the surface of the catalyst, thus leading finally to their complete mineralization.

At first, experiments concerning the photocatalytic decomposition of 20 ppm p-Coumaric acid were performed, in the presence of a variety of semiconductor catalysts such as TiO_2 P-25, ZnO, TiO_2 from Merck, et.al. Among these, ZnO and TiO_2 P-25 were the ones with the best results.

Results of the photolysis of a 20 ppm p-Coumaric acid solution containing 2 g/l TiO_2 P-25, 2 g/l ZnO or 2 g/l TiO_2-Merck are shown in Fig. 2. The amount of the p-Coumaric acid present in the supernatant is plotted as a function of irradiation time. From Fig. 2 it is clear that the photolysis of an air equilibrated p-Coumaric acid solution in the presence of ZnO or TiO_2 leads to the disappearance of the compound. Under these experimental conditions, in the presence of 2 g/l TiO_2 P-25 ~ 85% of the initial concentration of the acid was removed after 2 h of light exposure, while in the same time and in the presence of ZnO the degradation was almost complete. Due to the photocorrosion presented by ZnO, especially in low pH on the one and due to photostability and constant crystalline composition of anatase-based TiO_2 P-25 powders on the other hand, this catalyst was used throughout the work. On the contrary, a very small decrease in the concentration of p-Coumaric acid was observed by illumination in the absence of TiO_2. After 3 h of irradiation, direct photolysis contributed less than 5 % to the degradation of p-Coumaric acid.

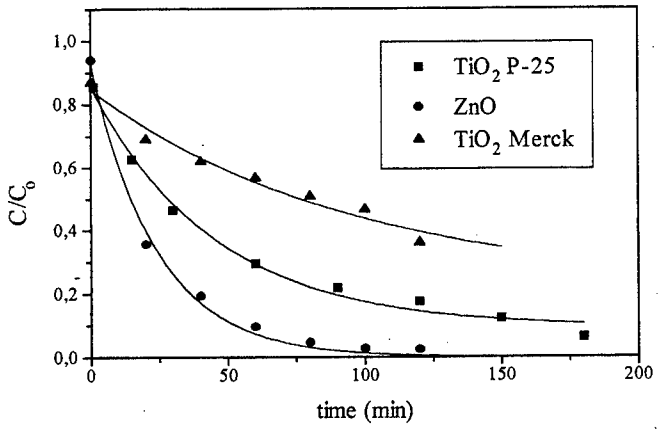


FIGURE 2: Photodegradation of 20 ppm p-Coumaric acid as a function of irradation time in the presence of 2 g/l TiO_2 P-25, 2 g/l ZnO and 2 g/l TiO_2 Merck.

The influence of the initial concentration of the solute on the photocatalytic degradation rate of most of the organic compounds is described by a pseudo-first kinetic order, which is rationalized in terms of the Langmuir-Hinselwood model, modified to accommodate reactions occurring at a solid-liquid interface [11],

$$R = -\frac{dC}{dt} = \frac{k_r KC}{1+KC}$$

where R is the initial rate of disappearance of the organic substrate and C is its initial concentration. K represents the equilibrium constant for adsorption of the organic substrate onto TiO_2 and k_r reflects the limiting rate of reaction at maximum coverage for the experimental conditions. At low initial concentrations of the organic solute the final form of this equation becomes

$\ln(C_o/C)=k_rKt=k_{app}\cdot t$ (2)
where, k_{app}= the apparent rate constant of the photodegradation [min^{-1}].

In Table 1 the kinetic data (k_{app} and $t_{1/2}$) are presented according to equ. (2), from the photodecomposition of the above compound vs. irradiation time, under various experimental conditions. The k_{app} values were obtained by the method of least squares from the slopes of the plots according to equ. (2) and $t_{1/2}$ from equ. (2) for C/C_o= 0.5.

TABLE 1: k_{app} and $t_{1/2}$ values from the photodecomposition of 20 ppm p-Coumaric acid under various experimental conditions.

Experimental Conditions		k_{app} (min^{-1})	$t_{1/2}$ (min)
TiO_2 P-25	(2 g/l)	0.0153	45.3
ZnO	(2 g/l)	0.0360	19.25
TiO_2 Merck	(2 g/l)	0.0059	117.5
H_2O_2 (ppm)*	25	0.0196	35.4
	50	0.0278	24.9
	100	0.039	17.8
	150	0.036	19.25
2 g/l ZnO + 100 ppm H_2O_2		0.030	23.1
2 g/l TiO_2 (Merck) + 100 ppm H_2O_2		0.0264	26.25

*in the presence of 2 g/l TiO_2 P-25

The addition of other powerfull oxidizing species such as H_2O_2 or $K_2S_2O_8$ to TiO_2 suspensions, is a well known procedure and in many cases leads to an increase of the rate of photooxidation [12]. H_2O_2 is considered to have two functions in the process of photocatalytic degradation. It accepts a photogenerated electron from conduction band and thus promotes the charge separation (equ. 8). It also forms OH· radicals according to equ. (9).

$H_2O_2 + e^- \longrightarrow OH^- + OH\cdot$ (3)
$H_2O_2 + O_2^- \longrightarrow OH\cdot + OH^- + O_2$ (4)

In the presence of excess H_2O_2, it may act as a hole or OH· scanvenger or react with TiO_2 and form peroxo compounds, which are detrimental to the photocatalytic action. This explains the need for an optimal concentration of H_2O_2 for the maximun effect.

In our case the photocatalytic degradation of 20 ppm p-Coumaric acid has been studied at diferrent H_2O_2 concentrations. The effect of the concentration of H_2O_2 on the k_{app} of p-Coumaric acid degradation is shown in Fig. 3 and in Table 1. The photocatalytic efficiency increases as the concentration of H_2O_2 is increased and it reaches the optimum at 100 ppm. Consequently it decreases as the concentration of the H_2O_2 is increased beyond the optimum. Under these conditions the addition of H_2O_2 accelerates the degradation only by a factor of 2.5. This positive effect is too small compared to the one observed during photooxidation in other cases.

As mentioned above, the complete decomposition to CO_2 via photocatalytic reactions is of great significance in water treatment, because it is the unequivocal evidence for the total destruction of

organic compounds in water. For this reason the complete oxidation of p-coumaric acid was studied in a separate apparatus described in the experimental section.

The overall equation, valid after long irradiation time in the presence of excess oxygen, which describes the photocatalytic mineralization of p-Coumaric acid is presented below:

$$C_7H_8O_3 + 15/2O_2 \longrightarrow \text{intermediates} \longrightarrow 7CO_2 + 4H_2O$$

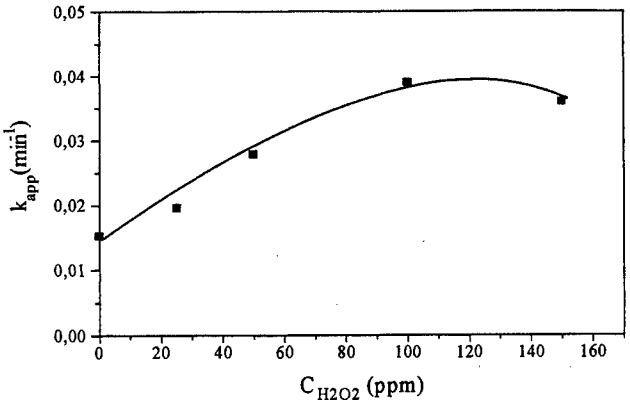


FIGURE 3: Effect of H_2O_2 concentration on the photodegradation of 20 ppm p- Coumaric acid in the presence of 2 g/l TiO_2 P-25.

Fig. 4 shows the formation of CO_2 vs. illumination time of a solution containing 20 ppm p-Coumaric acid in the presence of various catalysts and 100 ppm H_2O_2. The concentration of 100 ppm H_2O_2 according to Fig. 3, is the one with the greater influence on the acceleration of the photodegradation of p-Coumaric acid. In the presence of TiO_2 P-25, only 53% of p-Coumaric acid was converted to CO_2 in the first 1 h of illumination, while 70% (Fig.2) was decomposed at the same time, showing the presence of intermediates. Full oxidation requires longer irradiaton time. The addition of 100 mg/l H_2O_2 in a suspension of TiO_2/p-Coumaric acid, as shown in Fig. 4, alters significantly the photomineralization process, and this is also in agreement with the results of the degradation experiments in the presence of various concentrations of H_2O_2 (Fig. 3). In the presence of ZnO, as is shown in Fig. 4, only 30 % of p-Coumaric acid was mineralized within the first 60 min. The addition of H_2O_2 had no effect on the degradation rate of this compound. In the case of TiO_2 Merck the rate of photomineralization is too low. Only 7 % of the parent compound was converted to CO_2 in the first 1 hour.This is due to the fact, that TiO_2 Merck is of the rutile type, a less active photocatalyst, in contrast to TiO2 P-25 which is mainly of the anatase type.The addition of H_2O_2 increases the photomineralization rate, but the efficiency remains lower compared to the one when TiO_2 P-25 has been used.

The superiority of TiO_2 P-25 may be attributed to the morphology of crystallites, which was proposed to be one of the most critical properties for the photocatalytic efficiency of P-25 among various grades of TiO_2. Crystallographic study shows that it consists of multiphases of amorphous, anatase and rutile forms. The close proximity of these phases and in some cases the overlapping of forms, makes it difficult to differentiate and has been cited as the reason for long lasting excitation of

electrons from the valence band to the conductive bands, allowing for efficient and effective degradation of organic compounds [13].

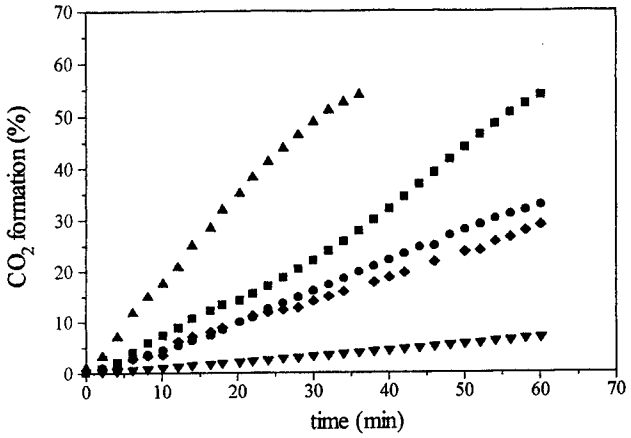


FIGURE 4: CO_2 formation as a function of irradiation time during the photocatalytic degradation of 20 ppm p-Coumaric acid in the presence of 2 g/l TiO_2-P25 (■), 2 g/l TiO_2 P-25 + 100 mg/l H_2O_2(▲), 2g/l ZnO (●), 2 g/l TiO_2 Merck (▼) and 2 g/l TiO_2 Merck + 100 ppm H_2O_2(◆).

The photocatalytic degradation of p-Coumaric acid is a complicated process, with a mechanism involving several chemical and photocatalytic stages and a great number of intermediates. On the basis of our preliminary experimental results and some pertinent suggestions of other researchers concerning the photodecomposition of various carboxylic acids [14-17], we attempted to propose qualitatively for the p-Coumaric acid photooxidation the dual hole-radical mechanism, in which direct h^+ oxidation of the carboxylic group takes place, under liberation of CO_2 , in competition with the OH· attack of the aromatic ring.

Finally some preliminary experiments concerning the biodegradability of this compound were carried out. The Biochemical Oxygen Demand in 5 days (BOD_5) of a 20 ppm p-Coumaric acid solution was measured before and after 2 and 4 h photocatalytic oxidation.From the results (Table 2) it is clear that, after the photocatalytic pretreatment, p- Coumaric acid, a non biodegradeble compound, can be attacked by the microorganisms. The aromatic ring cleavage and the appearance of aliphatic products, which are more biodegradeble, is responsible for this behaviour.

TABLE 2: BOD_5 of 20 ppm p-Coumaric acid before and after photocatalytic treatment

Photocatalytic pre-treatment (h)	BOD_5 (mg/l)
0	0
2	5.3 ± 0.9
4	15.6 ± 2.6

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USE OF SOLAR LIGHT FOR THE PHOTOCATALYTIC DEGRADATION OF AZO-DYES OVER TiO_2 CATALYSTS

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ABSTRACT

In the present study, the photocatalytic degradation of azo-dyes over semiconductive TiO_2 catalysts irradiated with a solar spectrum simulating source, has been investigated. The effect of dopant type and concentration as well as the effect of operational parameters like dye concentration, pH of the solution, and light energy and intensity on the degradation rate of aqueous dye solutions has been examined. It is shown that incorporation of cations of valence higher that the parent cation (W^{6+}) into the crystal matrix of TiO_2 results in enhanced degradation rates while the opposite is observed upon doping with cations of lower valence (Ca^{2+}). It is concluded that the employment of efficient photocatalysts and the selection of optimal experimental condition may lead to complete decolorization and to substantial decrease of the COD of the dye solutions.

ΧΡΗΣΗ ΗΛΙΑΚΗΣ ΑΚΤΙΝΟΒΟΛΙΑΣ ΓΙΑ ΤΗ ΦΩΤΟΚΑΤΑΛΥΤΙΚΗ ΔΙΑΣΠΑΣΗ ΑΖΩΧΡΩΜΑΤΩΝ ΣΕ ΚΑΤΑΛΥΤΕΣ TiO_2

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ΠΕΡΙΛΗΨΗ

Στην παρούσα εργασία μελετήθηκε η φωτοκαταλυτική διάσπαση αζωχρωμάτων με χρήση φωτεινής πηγής που προσομοιάζει το φάσμα της ηλιακής ακτινοβολίας (Xe-arc lamp) και ημιαγώγιμων φωτοκαταλυτών με βάση το διοξείδιο του τιτανίου. Εξετάστηκε η επίδραση της ενίσχυσης (doping) του φωτοκαταλύτη με ιόντα διαφορετικού σθένους από αυτό του Ti^{4+}, και των λειτουργικών παραμέτρων όπως συγκέντρωση χρώματος, pH του διαλύματος, ενέργεια και ένταση προσπίπτουσας ακτινοβολίας στην ταχύτητα φωτοδιάσπασης. Τα αποτελέσματα δείχνουν ότι με την κατάλληλη επιλογή των πειραματικών συνθηκών και του φωτοκαταλύτη μπορεί να επιτευχθεί πλήρης αποχρωματισμός και σημαντική μείωση του COD του υδατικού διαλύματος.

1. INTRODUCTION

The problem associated with discharge of color from dyehouses has concerned the scientific community for many decades in most industrialized countries. Wastewaters produced from textile and other dyestuff industrial processes contain large quantities of organic dyes which are difficult to degrade with standard biological methods. Within the overall category of dyestuffs, azo-dyes constitute a significant portion and probably have the least desirable consequences in terms of surrounding ecosystem.

For the removal of recalcitrant organics, traditional methods like ultrafiltration, extraction, air stripping, carbon adsorption, incineration and oxidation via ozonation or hydrogen peroxide have been applied. A weakness of some of these processes is that they are non-destructive; they simply transfer the pollutant from one phase to another [1]. Over the past few years, several Advanced Oxidation Processes (AOPs) have been proposed as alternative routes to water purification. Among them, heterogeneous photocatalysis seems to be the most attractive method for water decontamination. The main reason for this is that the process can be carried out under ambient conditions and leads, in the best case, to the total mineralization of organic carbon to CO_2. Another advantage of this method is that the photocatalyst (usually TiO_2) is inexpensive and can be supported on suitable materials.

Heterogeneous photocatalysis is based on the irradiation of photocatalyst, usually a semiconductor such as TiO_2, whose irradiation with light energy equal to or greater than the bandgap causes a valence-band electron to be promoted to the conduction band, causing charge separation. The conduction band electrons and valence band holes can then migrate to the surface and participate in interfacial oxidation-reduction reactions. The oxidative degradation of an organic pollutant is attributed to indirect reaction at the positive hole where adsorbed water or a hydroxyl group is oxidized to hydroxyl radicals ($^{\bullet}OH$), which then reacts with the pollutant [2].

In cases where colored organic compounds exist, the color may, after adsorption onto the semiconducting surfaces, be promoted to an excited state following interaction with visible radiation and thus act as a photosensitizer. The degradation of the colored substance may then take place through electron injection into the conduction band of the semiconductor and subsequent oxidation of the cation radical. This process is called sensitized photocatalysis. The sensitized photocatalytic process is advantageous because it extends the range of excitation energies into the visible range, making fuller use of solar energy. Similar products are created at direct and sensitized photocatalysis, and these appear to involve primarily oxidative steps when oxygen is present in the system [3].

The aim of the present study is to investigate the photocatalytic degradation of azo-dyes over semiconductive, TiO_2-based, photocatalysts irradiated with a solar spectrum simulating source (Xe-arc lamp). The effect of the TiO_2 structure, dopant type and concentration as well as the effect of operational parameters like dye concentration, pH of the solution, light energy and intensity on the degradation rate of aqueous dye solutions is examined. It is shown that incorporation of cations of valence higher that the parent cation (W^{6+}) into the crystal matrix of TiO_2 results in enhanced degradation rates while the opposite is observed upon doping with cations of lower valence (Ca^{2+}). It is concluded that the employment of efficient photocatalysts and the selection of optimal experimental condition may lead to complete decolorization and to substantial decrease of the COD of the dye solutions.

2. EXPERIMENTAL SECTION

2.1. Materials

The photocatalyst employed in most experiments presented here was titanium dioxide (TiO_2, P25, Degussa) in powder form (primary particle size: 40 μm), with a specific surface area of 50 ± 15 m^2/g. According to the manufacturer, the crystalline mode of P25 is 80% rutile and 20% anatase. Anatase TiO_2 used in certain experiments was either commercial (Thann Et Mulhouse) or self prepared by hydrolysis of titanium isopropoxide (Alfa Products) in the presence of isopropyl alcohol at a temperature of 25^{0}C. Rutile TiO_2 was prepared by calcination of P25 in air at 700^{0}C for 5 hours.

Acid Orange 7 (95%, Aldrich, $C_{16}H_{11}N_2O_4SNa$) has been chosen as a representative model compound. Acid Orange 7 (AO7) is a non-biodegradable synthetic azo-dye widely used in the textile industry.

2.2. Preparation and characterization of doped photocatalysts

The influence of altervalent cation doping of TiO_2 on its performance as a photocatalyst for the degradation of AO7 was investigated employing cations of lower (Ca^{2+}) and higher (W^{6+}) valence than the host cation (Ti^{4+}). To investigate the effect of the dopant concentration on the degradation rate of AO7, a series of experiments in which the dopant content of the TiO_2 photocatalyst was varied were carried out. TiO_2 catalysts doped with 2, 4 and 6 wt.% WO_3 and 2 and 4 wt% CaO were examined.

Doped TiO_2 was prepared by the method of high-temperature diffusion of the doping cations into the crystal matrix of the parent oxide. Dopant precursors used in this study were $(NH_4)_{12}W_{12}O_{41}*5H_2O$ and CaO. An appropriate amount of the dopant precusor, so as to obtain the desired dopant concentration in the parent metal oxide, was mixed with an appropriate amount of TiO_2 (Degussa, P-25) and distilled water. The resulting slurry was heated gently to 80^{0}C under continuous stirring to provide uniform mixing and was maintained at that temperature until nearly all the water evaporated. The residue was subsequently calcined in the presence of air at 700^{0}C for 5 h. Calcination temperature was approached with a heating time of 3^{0}C/min, while cooling of the material was done slowly, with a rate of approximately 10^{0}C/min.

Catalysts were characterized in terms of total surface area using the BET method with nitrogen adsorption at -196^{0}C. The anatase/rutile content of the samples was determined by quantitative X-ray diffraction analysis using a Siemens 1300 instrument with Cu kα radiation.

2.3 Experimental apparatus

The experimental set-up consists of a quartz photoreactor with optical flat light entry and exit windows with a top that allows the entrance and exit of air and sample-taking from the gas-and liquid phase, an Osram XBO 450 W lamp equipped with a water filter to remove infrared radiation, a lens system for collection and focusing of the light beam, and the analysis apparatus. For the present study the lamp power was kept constant at 400 W except for the experiments where the influence of lamp power was investigated. A double-bundled UV/vis spectrophotometer (Hitachi, Model U 2001) with 10 mm sample cuvettes made of quartz was used for the calculation of the dye concentrations in the solution.

2.4 Experimental procedure

In a typical experiment, a known amount of AO7 is dissolved in 70 ml of distilled water in the photoreactor and the photocatalyst is added during continuous stirring. Air with a constant flow of 60 cc/min is then permitted to the photoreactor and after 10 minutes in dark light is allowed to irradiate the suspension. During the experiment (about 8 hours) 1 ml-samples are taken from the suspension for analysis at fixed time intervals. Immediately after the sample-taking, centrifugation

and filtration with syringe filter 0.2 μm (Gelman Sciences, 4192) is taking place for the removal of TiO_2. Part of the sample is used for the measurements on the spectrophotometer (UV/vis) and in certain cases the rest is used for measuring COD (Chemical Oxygen Demand). The concentration of AO7 in each sample is calculated using calibration curves at 485 nm. The COD is measured with standard methods.

For determining adsorption isotherms of AO7, equal amount of TiO_2 (20 mg) was placed in a series of test tubes into which 10 ml of AO7 solutions with different concentrations (C_i) was added (maximum AO7 concentration was 80 mg/l). The samples were then left overnight in the dark, in order to let the color adsorb onto the catalyst surface, and then filtered. The extent of the equilibrium adsorption was determined from the decreases in the dye concentrations (ΔC_i) detected after filtration. The pH of the solution was adjusted using either HNO_3 (pH 2) or with NH_3 (pH 12).

3. RESULTS AND DISCUSSION

3.1. Effect of Operational Parameters on the Degradation rate of AO7

3.1.1. Effect of pH of the solution

Preliminary experiments showed that the dye adsorbs with different strength onto the TiO_2 surface from aqueous solutions in a way which strongly depends on the pH of the solution. To examine this, adsorption isotherms were obtained at pH values of 2, 6 and 12. Results are shown in Fig.1 where the amount of dye adsorbed per gram of TiO_2 is plotted against the initial dye concentration, for each pH. It is observed that the amount adsorbed at pH 12 is negligible while a large amount of AO7 is adsorbed at pH 2. At pH 6 the adsorption takes intermediate values. This can be explained by taking into account the fact that adsorption depends on the electric charge of the dye and the photocatalyst surface. AO7 has a negatively charged sulfonic group and it is expected that, at low pH, attractive forces between the positively charged TiO_2 surface and the sulfonic group will favor adsorption. The opposite is true for high pH values.

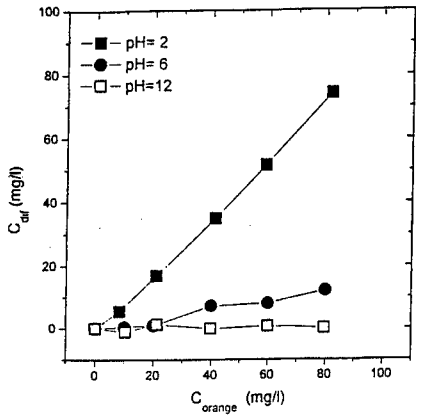


Figure 1. Adsorption isotherms of AO7 on TiO_2 at pH 2, 6 and 12.

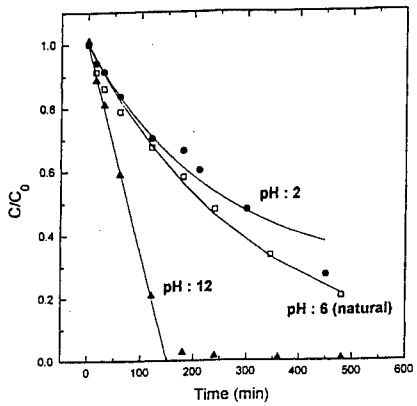


Figure 2. Effect of the pH on the degradation rate of AO7.

The photodegradation of AO7 at pH values of 2, 6 and 12 as a function of time of irradiation is shown in Fig. 2. It is observed that photodegradation is strongly favored at basic solutions, where complete decolorization occurs in less that 2 hours, while the opposite is true at pH 2 where decolorization is very slow. At natural pH, the rate of decolorization takes intermediate values. It is very interesting to notice that the apparent reaction order of AO7 degradation follows first order kinetics at pH 6 and zero order kinetics at pH 12.

The dependence of the degradation rate of AO7 on the pH of the solution could be associated with the differences in the adsorption capacity of TiO_2 discussed above: It is possible that, at low pH values of the solution, adsorption of the dye on the TiO_2 surface occurs with the formation of several monolayers. It is then expected that most of the adsorbed dye molecules are not in direct contact with the photocatalyst surface resulting in the decreased degradation rates observed (Fig. 2). It is also possible that the observed effect of the pH is due to different photoreaction mechanism occuring at different pH: Assuming that degradation proceeds via hydroxyl radical attack, it is expected that it would be favored at high pH values over the hydroxylated TiO_2 surface.

3.1.2.Effect of the initial AO7 concentration

The photodegradation of AO7 as a function of the initial dye concentration at pH 6 is shown in Fig. 3, where the normalized dye concentration is plotted as a function of time of irradiation. It is observed that the initial decolorization rate depends significantly on the initial dye concentration and decreases with increasing dye concentration. Similar results (not shown) were observed at pH 12 with the difference that in all cases the photoreaction was much faster and complete decolorization was achiened.

This dependence on the initial dye concentration could again be related to the formation of several monolayers of adsorbed dye on the TiO_2 surface which is favored at high dye concentrations, thus inhibiting the reaction of adsorbed molecules with the photoinduced positive holes or hydroxyl radicals. In addition, it should be taken into accound that the incident photons can be absorbed either by the TiO_2 or by AO7 molecules present in the solution. Increasing dye concentration leads to an increase of the amount of photons that are adsorbed by the dye molecules and never reach the photocatalyst surface.

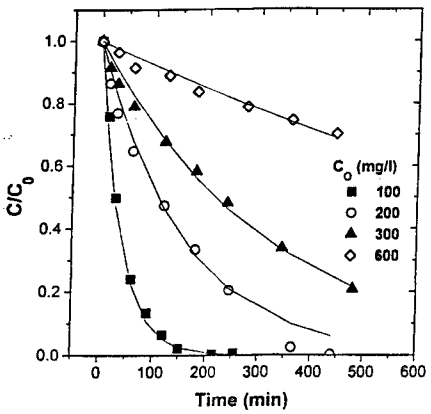


Figure 3. Effect of the initial concentration on the degradation of AO7 at pH 6.

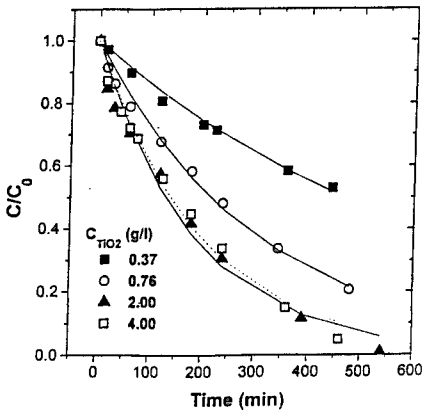


Figure 4. Effect of the photocatalyst concentration on the degradation rate of AO7 at pH 6.

3.1.3. Effect of TiO_2-concentration

The effect of TiO_2 concentration on the degradation rate of AO7 at pH 6 is presented in Fig. 4 where the normalized dye concentration is plotted against time of irradiation. It is observed that time required for decolorization decreases with increasing catalyst concentration, until it reaches a plateu, at concentrations higher than 2 g/l. This is due to the "shielding effect" of the suspended TiO_2 layers located closer to the radiation source and cause a reduction of the penetration of light which is obviously more significant as the photocatalyst concentration increases.

3.1.4. Effect of the radiation range

The effect of the spectral range of incident radiation on the AO7 degradation rate is shown in Fig.5, where the dye concentration is plotted against time of irradiation. It is observed that no decolorization takes place in dark, indicating that the process is photo-induced. When a filter which cuts-off ultra violet light (λ<400 nm) from the light source is used, AO7 degradation takes place to a small but appreciable extent, indicating that the mechanism involving photosensitized electron injection is also operable here leading to charge separation with light of less than band energy.

3.1.5. COD removal

The results of the experiments presented in the previous paragraphs show that the decolorization rate of AO7 with photocatalytic methods is relatively high. The decolorization of AO7, though, does not mean that the COD of the solution decreases with the same rate. This is shown in Fig. 6 where the decolorization of AO7 and COD removal are plotted against the time of irradiation. It is observed that the decolorization rate is much greater than the decrease of the COD. This is due to the formation of smaller uncolored compounds during the degradation of AO7 which continue to contribute to the COD of the solution. To degrade these smaller compounds a longer irradation time is required. It should be noted here that if these intermediates are biodegradable, then standard biological methods could be used in combination with photocatalytic processes for the complete mineralization of dye solutions.

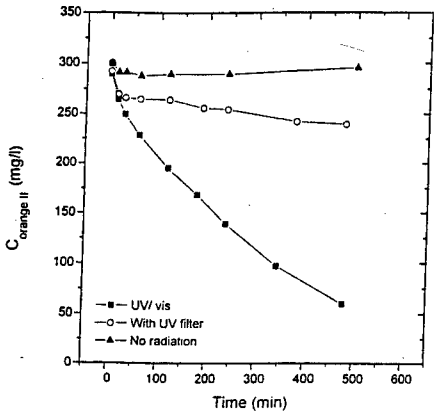


Figure 5. Effect of the spectral range of incident radiation on the degradation rate of AO7 at pH 6.

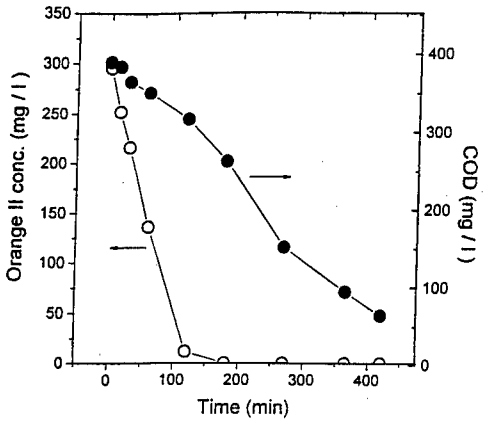


Figure 6. Degradation of AO7 and decrease of COD as a function of time of irradiation at pH 6.

3.2. Influence of Altervalent Cation Doping on the degradation Rate of AO7

The effect of altervalent cation doping of TiO_2 on the decolorization rate of AO7 is shown in Fig. 7. It is observed that upon doping with WO_3 the decolorization rate of AO7 increases with increasing the amount of the dopant up to 4 wt. %, beyond which it reaches a plateau, with a decreasing tendency. On the contrary, doping with CaO results in a decrease of the decolorization rate with increasing dopant concentration. The initial reaction rate was calculated for each curve presented in Fig. 7 and the results are shown in Fig. 8 where the degradation rate of AO7 per gram of catalyst is plotted against the dopant concentration. It is observed that the initial degradation rate is more than double over W^{6+}-doped TiO_2 and almost half over the Ca^{2+}-doped TiO_2 compared to the undoped photocatalyst.

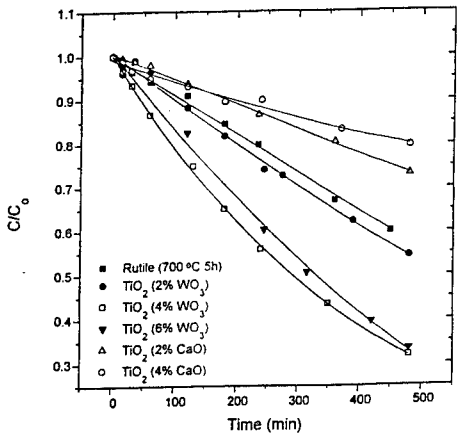


Figure 7. Effect of dopant type and concentration on the degradation rate of AO7 at pH 6.

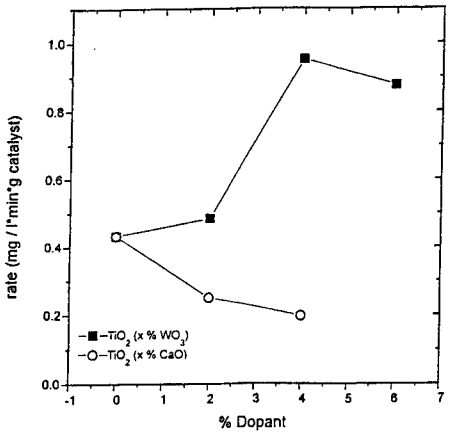


Figure 8. Influence of dopant type and concentration in the TiO_2 matrix on the initial degradation rate of AO7. (Data obtained from Fig. 7)

This behavior can be explained by taking into account the effects induced by altervalent cation doping of TiO_2 on its bulk electronic structure (position of Fermi energy level, formation of new energy levels by interaction of an interstitial dopant with the semiconductor lattice, electron conductivity in the bulk semiconductor) and surface properties (thickness of the spacecharge layer, existence and concentration of surface states, decomposition potentials affecting the photocorrosion process) [4]. Doping of TiO_2 with cations of valence higher than that of the parent Ti^{4+} cation results in increased concentration of electrons in the conduction band, as illustrated by the following defect site reaction:

$$WO_3 \leftrightarrow W[Ti]^{2+} + TiO_2 + \tfrac{1}{2}\, O_2(g) + 2e^-$$

An upward shift of the Fermi energy level is also expected, and, consequently, a cathodic shift of the flat band potential, toward negative values with respect to the NHE potential. As the n-dopant concentration increases the surface barrier becomes higher and the space charge region narrower. The electron-hole pairs photogenerated within this region are efficiently separated by the large electric field traversing the barrier, before having the chance to recombine.

When TiO_2 is doped with lower valence cations the exact oposite behavior is expected. In this case, doping results in increased concentration of holes in the valence band, as illustrated by the following defect site reaction:

$$CaO + ½\ O_2(g) + 2e^- \leftrightarrow Ca[Ti]^{2-} + TiO_2$$

Furthermore, the Fermi energy level is shifted to lower values. This shift affects the position of the flat-band potential of TiO_2 which is shifted anodically, toward positive values with respect to the NHE potential. As the p-dopant concentration is increased, the surface barrier is lowered and the space charge region becomes progressively thicker. The transient time across the barrier is increased and the probability of the carriers recombining is enhanced, thus leading to decreased photoreaction rates.

CONCLUSIONS

The following conclusions can be drawn from the results of the present study:

1. The degradation rate of AO7 depends on the initial pH of the solution, the initial concentration of the photocatalyst, the initial dye concentration, the intensity and spectral range of the incident light.

2. Photocatalytic processes, with the use of solar radiation and TiO_2 as catalyst, can be efficiently applied for the degradation of non-biodegradable organic azo-dyes. Complete decolorization of aqueous solutions of AO7 and substantial decrease of the COD can be achieved with satisfactory rates with the use of optimal operational parameters.

3. Doping of TiO_2 with higher valence cations (W^{6+}) than that of the parent cation (Ti^{4+}) enhances the degradation rate of AO7, while doping with cation of lower valence (Ca^{2+}) reduces the degradation rate of AO7. These effects depend on dopant concentration

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USE OF IONIZING RADIATION FOR THE TREATMENT OF OLIVE MILL WASTES (OMW)

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ABSTRACT

Olive Mill Wastes (OMW), a phytotoxic highly polluting effluent that results during the production of olive oil, was treated with the use of ionizing radiation. Ionizing radiation, is using high energy photons, resulting in the formation of powerful oxidants, which attack and oxidize the organic matter. Overall, the COD was reduced by about 10% when OMW was radiated up to 5 mRads and by about 20% with the addition of hydrogen peroxide, which causes the production of more hydroxyl radicals. The phenolics which constitute the major toxic factor in OMW were largely affected by radiation and the hydrogen peroxide addition had a significant effect on their destruction, especially at very high doses. Filtration of OMW reduced the variability of the various measurements and removed 60-70 % of the COD. The use of ionizing radiation for the treatment of this effluent will require relatively high doses. Its potential application does not seem to be practical, except as a pretreatment and should be evaluated against other pretreatment methods.

ΕΦΑΡΜΟΓΗ ΙΟΝΙΖΟΥΣΑΣ ΑΚΤΙΝΟΒΟΛΙΑΣ ΓΙΑ ΤΗΝ ΕΠΕΞΕΡΓΑΣΙΑ ΑΠΟΒΛΗΤΩΝ ΕΛΑΙΟΥΡΓΕΙΩΝ

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ΠΕΡΙΛΗΨΗ

Απόνερα ελαιοτριβείων (OMW) ένα φυτοτοξικό απόβλητο που προκύπτει κατά την παραγωγή του ελαιολάδου, υπεβλήθη σε ιονίζουσα ακτινοβολία. Η Ιονίζουσα ακτινοβολία χρησιμοποιεί φωτόνια υψηλής ενέργειας, που προκαλούν την δημιουργία ισχυρών οξειδωτικών που οξειδώνουν την οργανική ουσία. Συνολικά το COD ελαττώθηκε κατά περίπου 10% με ακτινοβολία μέχρι 5 MRads και κατά 20% με την προσθήκη υπεροξειδίου του υδρογόνου που προκαλεί την παραγωγή περισσοτέρων ριζών υδροξυλίων. Οι φαινόλες που αποτελούν και το κυριότερο τοξικό παράγοντα στα OMW επηρεάστηκαν δραστικά από την ακτινοβολία. Η προσθήκη H_2O_2 είχε σημαντική επίδραση στην καταστροφή τους ειδικότερα σε πολύ υψηλές δόσεις. Η διήθηση των OMW ελάττωσε την παραλλακτικότητα των διαφόρων μετρήσεων και του COD κατά 70%. Η χρήση ιονίζουσας ακτινοβολίας για την επεξεργασία OMW απαιτεί σχετικά υψηλές δόσεις. Η πιθανή εφαρμογή της μεθόδου δεν φαίνεται να είναι πρακτική εκτός σαν προεπεξεργασία και θα πρέπει να συνεκτιμηθεί έναντι άλλων μεθόδων προεπεξεργασίας.

1. INTRODUCTION

Many industries, such as olive oil industry, tanneries, pulp and paper mill, pharmaceutical e.t.c. discharge wastewaters containing certain pollulants which cause serious environmental pollution. The usual treatment methods before these wastewaters are disposed are biological processes which remove a large fraction of BOD and readily biodegradable organics. However there are many wastes which contain refractory and sometimes toxic pollutants which are poorly or non biodegradable and therefore often remain in the effluent from biological treatment processes [2,11].

Examples of such wastes may include, phenolic compounds from the olive mills, high molecular weight organics such as lignin and tannic acid from Kraft mills, vinasse from the alcohol industries, tannins and proteins from tannery waste liquors, antibiotics (chlortetracycline) and chelating agents (EDTA) from pharmaceutical and electroplating industries and many others.

These refractory pollutants depress biological treatment efficiency and usually require a different pretreatment process. In recent years advanced oxidation technologies (AOT), have shown to be promising for such wastewater treatment and in many cases rapid and simple to use. Advanced oxidation processes have been applied for decomposing tannery waste liquors [8], olive mill wastes [7], Vinasse [14], EDTA [10], aniline [9], color related compounds [12] and removal of refractory pollutants in landfill leachate [4]. Olive waste is a toxic effluent that results during the production of olive oil. Various treatment methods worldwide which have been practiced till now for its detoxification and management have shown to be ineffective or very costly. [7]. Therefore it is considered a major pollutant, high in COD levels (can reach 200 g l^{-1}) and particularly phytotoxic, mainly due to its phenolic compounds. These phenolics result in antimicrobial activities, which is an obstacle to biological treatment of OMW, [15]. The characteristics of OMW with respect to its polluling capacity are: (in g l^{-1}), COD: 45-200, BOD_5: 35-100, Total solids 24-120, Mineral solids: 5-15, Total phenolics: 2-15, Fat: 0.5-1.0, pH: 4.5-5.2 [1]. One process which has received recent attention world-wide for the treatment of wastewaters, is the use of high energy ionizing radiation. The irradiation of aqueous solutions with high energy electrons or energetic photons such as gamma rays leads to the formation of clusters of ions along the path of the ionizing particles [17]. Next the ions begin to diffuse and interact with wastewaters on impact. During this interaction several reactive species are formed which attack both living and non living structures to promote their oxidation, dissociation and final degradation [16,6,5]. The principal oxidant formed upon irradiation is the hydroxyl radical ($^{\bullet}OH$) which is a very powerful oxidant against organic molecules. In addition, hydrogen peroxide, a stable oxidant is formed in the wastewater. The purpose of this study was to investigate the effects of radiation on Olive Mill Wastes (OMW) and the treatment efficiency using high energy ionizing radiation.

2. MATERIALS AND METHODS

Olive mill wastes (OMW) was brought from an olive mill near Athens, Greece and was kept frozen (-18 °C) until the experiment time when it was defrosted. In this study a ^{60}Co source of 5000 Ci was used to assess the radiation effects on OMW [17]. Water molecules from OMW are ionized upon interaction with photons from ^{60}Co. The liberated electrons from this ionization have sufficient energy to ionize further molecules, leading to the formation of cluster of ions (spurs) along the path of the ionizing particle [5]. Samples of OMW were defrosted and were irradiated in 47 ml vials at precalculated times and distances from the source to give the desired dose. The doses applied varied from 0 to 5 MRads.

To another set of samples hydrogen peroxide 1.5% (v/v) was added to enhance the effect of radiation with the production of more hydroxyl radicals [16]. OMW was also passed through a Whatman #1 coarse filter by vacuum filtration in order to remove most of the particulate solid matter. The filtered samples were then subjected to the same treatments as the non filtered ones.

This procedure was used to simulate the removal of the particular matter by mere sedimentation which occurs as a method of treatment in the open evaporating ponds [7]. The total phenolics were determined according to Slinkard and Singleton, 1977. [13] The COD was determined using an Hach COD system in accordance with standard methods (Hach Company, 1980).

Samples were also analyzed by direct spectroscopy using a Hewlett-Packard 8452A diode array spectrophotometer at various dilutions and "a phenol indicator" was determined at 278 nm. The experiments evaluated changes in COD and phenolics to asses the effects of irradiation dose to phenolics and COD.

3. RESULTS AND DISCUSSION

The results of five radiation doses on total phenolics of OMW are shown in Fig.1.There was an overall increase in the amounts of phenols from 0 to 5 MRads irradiation in the original OMW as well as in the OMW treated with hydrogen peroxide. The phenolics decreased temporarily after 1 and 4 MRads in the OMW and just after 3 MRads treatment in the samples with hydrogen peroxide.

This was probably due to the fact that OMW being a complex heterogeneous substance released more phenols into solution after irradiation due to breaking of larger compounds, before their degradation by ionization was manifested.

A similar effect was evidenced when the OMW was filtered up to 3 MRads (Fig.2).

Beyond this irradiation levels there was a gradual destruction of phenolics due to their oxidation by the oxidant species produced during the radiolysis process.

Figure 1: Effect of irradiation on phenolics of Olive Mill Wastes (OMW).

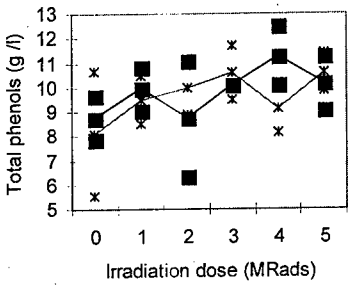


Figure 2: Effect of irradiation on filtrated Olive Mill Wastes (OMW).

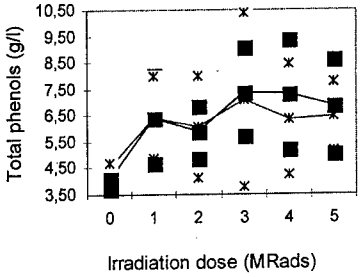


Figure 3. Spectrum of 1/100 solution of Olive Mill Wastes (OMW)

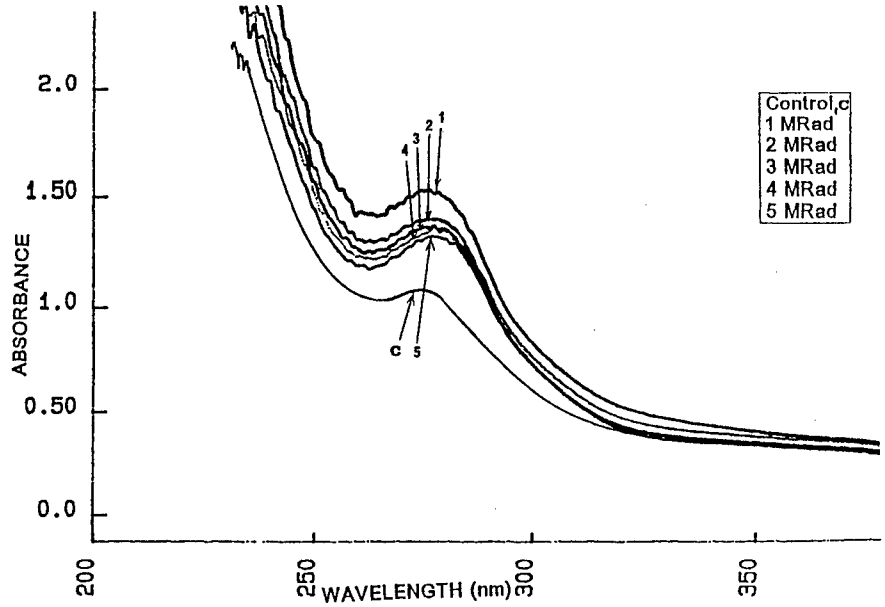


Figure 4. Spectrum of 1/100 solution of Olive Mill Wastes (OMW) plus 1.5% (v/v) hydrogen peroxide.

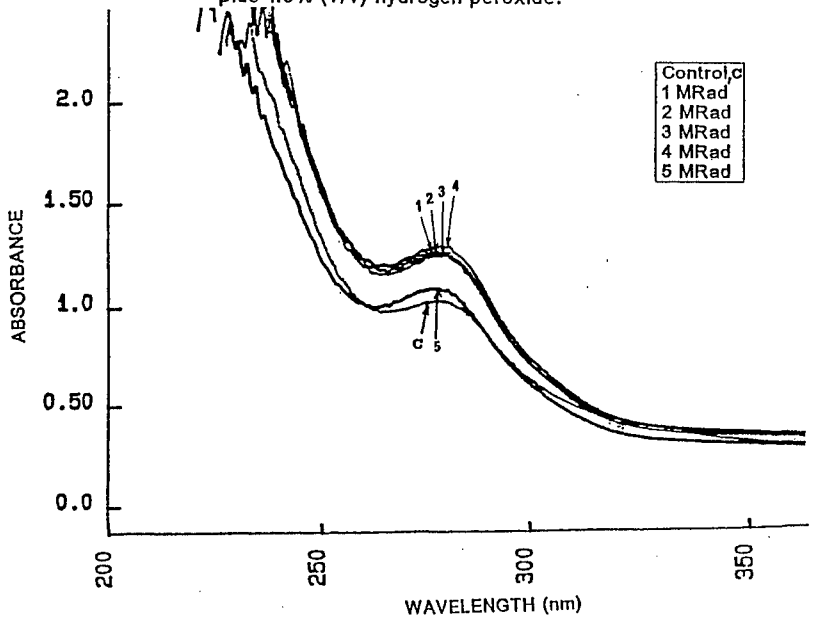


Figure 5: "Phenol indicator" (absorbance at 278) vs irradiation on filtrated Olive Mill Wastes (OMW).

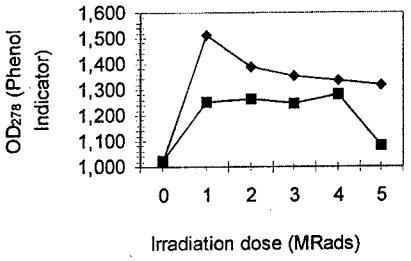


Figure 6:COD of OMW vs absorbed radiation dose

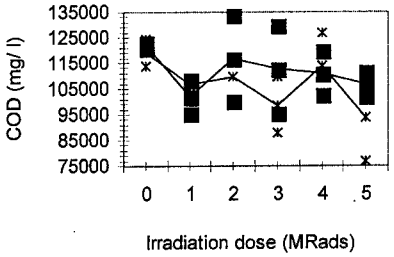
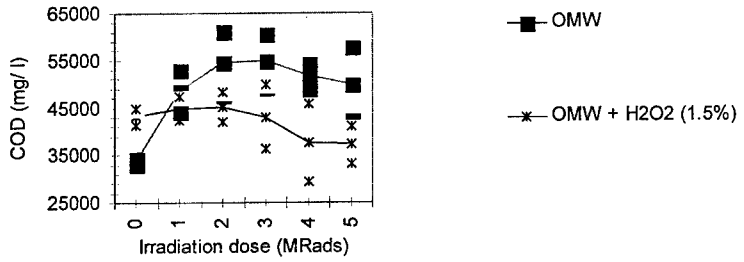


Figure 7: COD of filtrated OMW vs absorbed radiation dose.



The destruction of phenolics was higher in the peroxide treated samples compared to the non treated ones, most likely due to higher release of HO• in the latter, according to the equation: $e^- + H_2O_2 \rightarrow HO^\bullet + HO^\bullet$

When a spectrum was taken of 10^{-2} solutions of the irradiated filtered samples at 200-500 nm wavelength range, a distinct peak at 278 nm was noticed. This corresponds to compounds having benzolic ring and in the case of OMW are most likely the phenolics.

The concentration of phenolics is proportional to the absorbance, thus any changes due to irradiation would be reflected on the spectra after irradiation. It is observed from figures 3 and 4 that as radiation dose is increased the absorbance of phenolics in solution increases.

Interestingly enough the irradiated samples taken the highest dose (5 MRads) showed peak hights, higher than the non irradiated controls (Fig.3 & 4). The results of the absorbances at 278 nm (peak hights) represent a different way of expressing a "phenol indicator" and are ploted in Fig. 5. This may be a rough approach for the evaluation of the phenolics if we consider the various interferences in the measurement of phenolics with the Folin-Ciocalteu phenol reagent from the elements found in the OMW [3]. In the filtered OMW after a sharp increase of phenols at 1 MRad dose probably

due to liberation of phenols from the radiation of particulates which passed in the filtrate there was a rapid decrease at 2 MRads followed by a gradual decrease till 5 MRads. In the peroxide treated samples, where the actual peak hights were much lower than the untreated ones, there was practically very little change from 1-4 MRads and a rapid decrease there after.

Fig.6, shows the results of radiation on COD of the OMW. There was an overall removal of the COD of the order of 10% in the OMW and about 20% when hydrogen peroxide was added. However the overall trent of decline was not statistically significant most likely due to a great variability and fluctuations in the results indicating that some compounds were broken while others were being formed, something which was expected in a highly complex high organic load waste such as OMW. Fig.7, shows the changes in COD of the filtered OMW versus the absorbed radiation doses. The initial increase of COD (up to 2 MRads) was probably due to oxidation of particulates which most likely have passed filtration.

The large amounts of Total Suspended Solids in OMW (about 9g/l) can not be measured as COD, until they are progressively disolved through irradiation. After 2-3 Mrad dose the COD was decreased by about 8%, and by 18% in the H_2O_2 treated samples respectively. Therefore the higher degradation by 10% in the H_2O_2 treated OMW continued to occur in the filtrated samples as well.

4. CONCLUSIONS

1. Ionizing Radiation for the treatment of OMW resulted in an overall 10% removal of the COD and about 20 % removal when in the OMW hydrogen peroxide was added.
2. The phenolics were greatly affected by radiation paricularly at very high doses (>3 MRads), and hydrogen peroxide contributed significantly to their destruction. Their initial increase after radiation was probably due to their liberation from the breaking down of the organic matter.
3. Filtration (sedimentation) of the particulate solids in OMW reduced the variability in the measurement of all parameters tested and removed about 60-70% of the COD alone.

The potential application of Ionizing Radiation for the treatment of OMW could only be considered as a pretreatment mainly for the detoxification of phenolics. However this will have to be further evaluated and compared against other methods due to its high energy requirements.

5. ACKNOWLEDGMENTS

The authors would like to acknowledge the Council for International Exchange of Scholars (CIES) and the United States Information Agency (USIA) who made this study possible through the Fulbright Scholar Program. We would also like to thank Dr. Junko Kazumi and Dr. Pete Milne both of the University of Miami for their help and contribution to this work. Finally many thanks to Mr. Prasad Chittaluru, a doctoral student of the same University who did the irradiation of the samples, and to Antonis A. Zorpas and D. Papayannopoulou for writing the manuscript.

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TANNERY WASTEWATER TREATMENT

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ABSTRACT

Chromium tannery wastewater was treated in various biological pilot plant units i.e. one and two stage activated sludge combined with denitrification and activated carbon addition, SBR and anaerobic reactor. COD of treated wastewater insisted on values higher than limitations. The electrochemical processes of electrolysis, ozonation and H_2O_2/UV oxidation were applied to reduce COD to permitted limits.

ΕΠΕΞΕΡΓΑΣΙΑ ΑΠΟΒΛΗΤΩΝ ΕΡΓΟΣΤΑΣΙΩΝ ΔΕΡΜΑΤΩΝ

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ΠΕΡΙΛΗΨΗ

Τα απόβλητα εργοστασίου επεξεργασίας δερμάτων με χρήση χρωμίου επεξεργάστηκαν σε διάφορες βιολογικές πιλοτικές μονάδες όπως ενός και δύο σταδίων ενεργού ιλύος σε συνδυασμό με απονιτροποίηση και ενεργό άνθρακα, SBR και αναερόβιο αντιδραστήρα. Το τελικό COD είχε τιμή υψηλότερη των προδιαγραφών. Εφαρμόστηκαν οι ηλεκτροχημικές μέθοδοι της ηλεκτρόλυσης, του οζονισμού και της οξείδωσης με H_2O_2/UV για τη μείωση του COD σε αποδεκτά όρια.

1. INTRODUCTION

Wastewater characteristics of Hellenic Tannery company in Patras are shown in Table 1. The wastewater is treated in the existed wastewater treatment plant as follows : The total wastewater except the unhairing and lime splitting wastewater flows to the entrance of the plant. Unhairing and lime splitting wastewater flows to a sump and then is pumped to the sulfides catalytic oxidation unit. The oxidation of sulfides is carried out with aeration and $MnSO_4$. H_2O addition. The oxidized wastewater flows to the entrance of the treatment plant and is combined with total wastewater. Wastewater is treated by coagulation with $Ca(OH)_2$ and $FeClSO_4$ and then by extended aeration. The characteristics of treated effluents are : BOD_5 40 -100 mg/l, COD 400 - 600 mg/l, $Cr^{3+} < 0.1$ mg/l, NO_3^- N 80 - 120 mg/l. The problems of the existed wastewater treatment plant (WTP) are : The effluent BOD_5, COD and NO_3^- - N values are well above limits permitted (30 mg/l, 120 mg/l and 10 mg/l respectively), while the treatment cost is very high. In order to solve the above problems a research was carried out to find the most economic and effective treatment method.
Biological treatment methods have been applied to remove most of the organic load of tannery wastewater (1,2,3,4). COD/BOD_5 ratio in tannery wastewater is higher than 3. That means that non biodegradable COD remains after biological treatment. The value of COD remained is above limits permitted and in order to reduce it electrochemical processes could be applied (5,6,7,8,9,10,11).
The biological treatment performance was determined in pilot plant units of one and two stage activated sludge in combination with denitrification, of SBR and of anaerobic reactor.
For the purification of wastewater after biological treatment electrolysis, hydrogen peroxide in combination with UV and catalyst and ozone were used.

TABLE 1. Characteristics of Hellenic Tannery wastewater.

Parameter	No of measurements	Value (mg/l)
BOD_5	17	920
COD	25	3,100
SS	164	1,550
Cr^{3+}	12	2.8
$S^=$	32	< 10
pH	25	7.3 - 8.6
Total N	12	250
SO_4^-	12	225
Cl^-	12	1,040

2. MATERIALS AND METHODS

2.1. Wastewater

The wastewater used was taken every week after the equalization tank of the existed WTP and stored in a refrigerator at 3 - 4 °C. The characteristics of the wastewater sampled every week for a period of seven months are shown in table 1. 40 mg/l of KH_2PO_4 was added before feeding to the biological treatment units.

2.2. Pilot Plants

2.2.1. One stage activated sludge unit. This unit consisted of the following : Aeration tank of 7.8 l volume made of plexiglass ; Settling tank of 5.4 l volume made of plexiglass ; feed and sludge recirculation systems of multi - head Cole - Parmer peristaltic pumps. Feed rate of 5 l/d and adjustable recirculation ratio 1.5 : 1 ; Control panel.
2.2.2. Two - stage activated sludge unit. The purpose of this operation was to check if it was possible to operate the unit with the reported high values of MLSS, the long - term stability of the

unit fed with new wastewater and to collect enough data on COD and BOD_5 removal in order to compare them with results of the existed chemical - biological WTP. This unit consisted of the following : the first stage was the one stage unit described above. The second stage was similar to the first stage. The aeration tank volume was 4.6 l and the settling tank volume was 3.4 l. A cole parmer peristaltic pump was used for sludge recycling from the settling tank to the aeration tank of the second stage. The flow rates of the recirculation pumps were 14.1 l and 24.25 l/d for the first and second stage respectively.

2.2.3. Denitrification - two stage activated sludge unit. The purpose of this operation was to check if it was possible to remove the nitrogen in a single biological system. The unit consisted of the denitrification tank of 1.3 l volume followed by the two - stage activated sludge unit mentioned above. The feed flowrate of the peristaltic pump to the denitrification tank was 5 l/d. The recycling flowrate of the peristaltic pump of the first stage settling tank sludge to the denitrification tank was 20 l/d and of the second stage settling tank sludge to the second stage aeration tank was adjustable to 5 - 20 l/d. 100 mg/l powder activated carbon (Carrier biology) was added daily for a period of 25 days in the second stage aeration tank. The purpose of carrier biology was to check if an enhancement in COD and NO_3^--N removal takes place.

2.2.4. Sequencing Batch Reactor (SBR) Unit. The Sequencing Batch Reactor is an activated sludge process in which all treatment steps take place in a single reactor. The unit is consisted of the following : SRR tank of 12.5 l volume ; Peristaltic Cole - Parmer feed pump with an adjusted flowrate of 4.14 l/d ; Two electrovalves to control the feed of air and the discharge of effluent respectively ; Electrical mixer for the SBR mixing ; Control panel with four timers to control the operation of wastewater feeding, air feeding , SBR mixing and effluent discharging.

2.2.5. Anaerobic reactors. Two units of anaerobic reactors were used. Each unit consisted of the following : one anaerobic reactor of 5.0 l volume made of glass submerged in an automatically temperature controlled waterbath ; A glass tank of 5.0 l volume for CO_2 and H_2S removal. The tank was filled with 10 % NaOH solution to absorb CO_2 and H_2S ; A biogass or methane meter. This was a glass cylinder of 2.0 l volume inverted in a pH 2.0 solution and filled with this solution. The reactors were filled with three liters of granulated anaerobic sludge taken from a UASB reactor treating currants finishing wastewater.

2.2.6. Electrolytic apparatus. Electrolysis was conducted using a voltameter (Yokoyama Electric Works Ltd, Japan). The electrolytic cell was according to literature (6) and consisted of a glass vessel of 17.5 x 20 x 5.5 cm (length x depth x width) with a pair of electrodes, a steel cathode and a graphite anode. The steel cathode was a plate of 17.5 x 20 x 0.5 cm dimensions and was placed near the wall surface. The graphite anode was a plate of 17.5 x 20 x 2 cm dimensions. The level of the wastewater surface was 18 cm and the net volume of wastewater was 1000 ml. The tests were performed in batch. The surface of the anode was F = 6.84 dm^2 and the sample volume /anodic surface ratio was 1.461 which according to literature was the best for tannery wastewater (6).

2.2.7. Ozonator. A small ozone generator was constructed for decolorization experiments. Description of the ozonator is given elsewhere (15). The production of ozone by the ozonator was about 300 mg per hour. For the decolorization curves and the COD removal curves of wastewater 1500 ml bottles were used.

2.2.8. H_2O_2 /UV reactor. For the tests with UV - radiation a low-pressure lamp 15 W (Heraeus TNN 15/32) was used. The reactor was made of glass and had a net maximum volume of 2 l. Mixing is accomplished with a magnetic stirrer. A quartz sleeve, which housed the lamp, was cooled to maintain the temperature in the reactor.

2.3. Starting Up of biological reactors

For the first filling of the tanks biological sludge from the aeration tank of the existed WTP was used. MLSS were allowed to settle and the supernatant was discharged. MLSS concentration used was higher than 5000 mg/l.

2.4. Analyses

The daily control of the biological reactors was carried out by measuring the following parameters : feed and recycle flow rates, pH, BOD_5, COD, SS, MLSS, dissolved oxygen, NO_3^- - N, Cr^{3+} and electrical conductivity. Analysis of BOD_5, COD, SS, NO_3^- - N, Cr^{3+} was made by Hach methods. BOD_5 was carried out as by standard methods using five bottles of different dilution for each measurement and calculating the slope of oxygen consumption versus volume of wastewater as by Hach method. COD was carried out by digesting samples in a Hach COD digestor and then using a Hach DR - 2000 spectrophotometer. SS, MLSS, NO_3^- -N and Cr^{3+} were measured in the Hach DR - 2000 spectrophotometer. pH, D.O. and electrical conductivity were measured with laboratory relative instruments. H_2S was measured by oxidation with I_2 and measuring the rest of I_2 with $Na_2S_2O_3$. Microscopic analysis was carried out daily in a hund microscope. H_2O_2 in water was measured according to DIN 38409/part 15.

3. RESULTS AND DISCUSSION

3.1. Biological treatment

The results of one stage activated sludge unit operation are shown in Fig 1. Influent SS varied from 1,000 mg/l to 3,500 mg/l with an average of 1,500 mg/l. MLSS in aeration tank varied from 6,000 mg/l to 11,500 mg/l with an average of 9,000 mg/l. Influent pH varied from 7.3 to 8.6. Influent COD varied from 1,500 mg/l to 5,000 mg/l with an average of 3,100 mg/l. Effluent COD average was 780 mg/l. The average COD removal was 75 %. Influent BOD_5 varied from 500 mg/l to 1,750 mg/l with an average of 930 mg/l. Effluent BOD_5 average was 82 mg/l. The average BOD_5 removal was 91 %. The average F/M ratio was 0.066.

The results of two stage activated sludge unit operation are shown in Fig 1. Before the addition of powder activated carbon in the aeration tank of the second stage the results in the effluent from the second stage settling tank were : Average COD 677 mg/l and average BOD_5 29 mg/l. The total COD and BOD_5 removal for the two stage activated sludge unit was 78 % and 97 %, respectively. Bacteria population consisted mainly from Pleuronema. Stylonyehia bacteria were also present. After addition of powder activated carbon (days 55 - 80) the total COD and BOD_5 removal were increased to 83 % and 97.5 % respectively. The results of the denitrification - two stage activated sludge unit (days 70 - 120) are shown in Fig 1. The average influent BOD_5 and COD was 1,058 mg/l and 2,765 mg/l respectively.The average effluent BOD_5 and COD was 16 mg/l and 500 mg/l respectively. The total BOD_5 and COD removal was 98.5 % and 82 % respectively. The average influent Cr^{3+} was 2.9 mg/l and the average effluent Cr^{3+} from the first stage activated sludge settling tank was 0.04 mg/l. The average removal of Cr^{3+} after denitrification and first stage activated sludge was 98.6 %.

The effluent NO_3^- -N concentration from the first and second stage activated sludge after denitrification and nitrification was 25.5 mg/l and 6.8 mg/l respectively.

The results of the Sequencing Batch Reactor are shown in Fig. 2. The average influent BOD_5, COD, SS and Cr^{3+} was 1,006 mg/l, 2,180 mg/l, 1,100 mg/l and 3,1 mg/l respectively. The average effluent BOD_5, COD, Cr^{3+} and NO_3^- -N was 39 mg/l, 457 mg/l, 0.12 mg/l and 15.2 mg/l respectively. Average MLSS was 10,500 mg/l. The efficiency of the SBR could be improved by applying different cycles of operation.

The anaerobic reactors were controlled at 30 °C. For a period of 20 days each reactor was fed with 250 ml of wastewater. pH was controlled at 7.7 - 7.8 with NaOH. Before the addition of wastewater 250 ml supernatant was removed. After the acclimation period one reactor was loaded with 1 Kg COD/m^3 d. The pH was decreased to 6.8. Biogass production and COD removal were rapidly decreased and gradually the system failed. Sulfide concentration was 206 mg/l. The second reactor was loaded with 1 Kg COD/ m^3 d but the pH was controlled at 7.7 - 7.8 with NaOH. The load

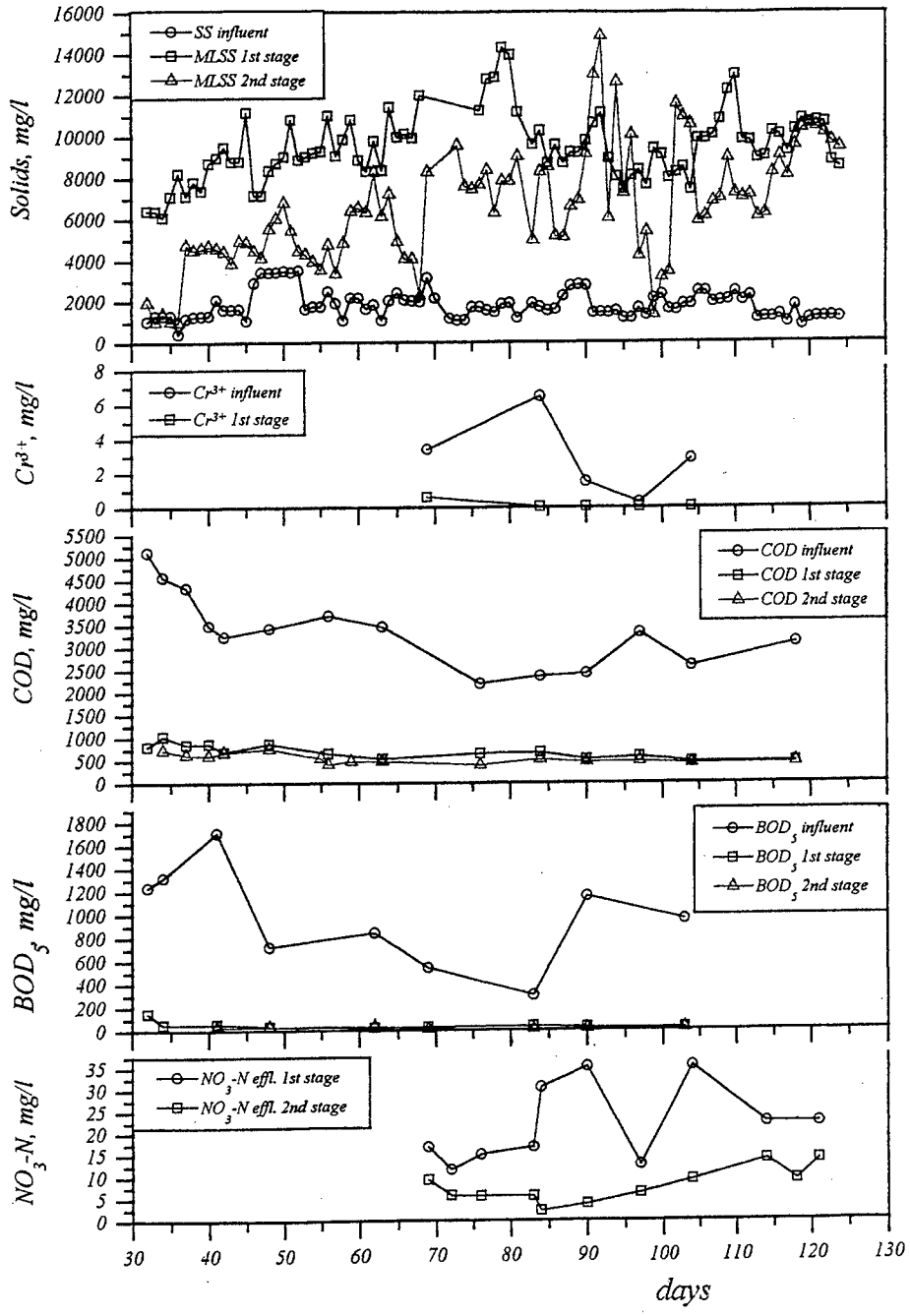


Figure 1. Results of one and two stage activated sludge units.

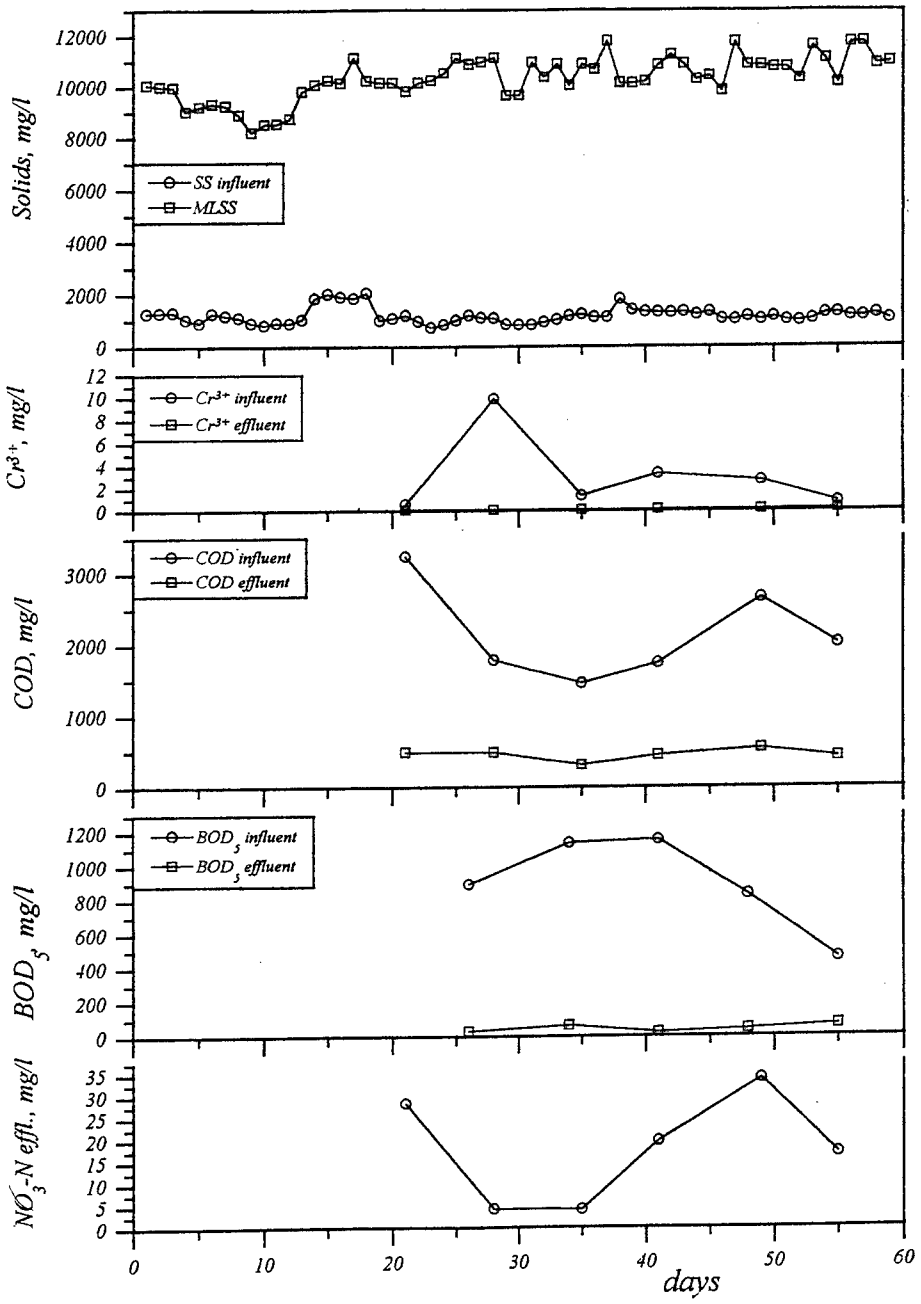


Figure 2. Results of the SBR unit.

gradually increased to 1.5 Kg COD / m^3 d. Methane production was approximately 610 ml/d and 480 ml/d for each load respectively. NaOH consumption for pH control was 0.35 - 0.40 g/l. It seems that at low pH the toxicity of free dissolved Hydrogen sulfide is high enough for the system to fail. At pH 6,8 the percentage of free undissosiated H_2S is 60 % or 125 mg/l. The inhibition of methanogenesis at this concentration is approximately 70 % (13,14). At higher pH values inhibition of free H_2S does not exist but the anaerobic treatment does not seem to be a promising process.
The results of the above reactors show the following : Removal of BOD_5 and nitrogen can be complete for the denitrification - two stage activated sludge and Sequencing Batch Reactor systems with final values of BOD_5 and NO_3^- - N acceptable for discharge. Addition of powder activated carbon on the aeration tank of the second stage of activated sludge does not improve the COD removal but improves the NO_3^- -N removal. Removal of COD to acceptable values for discharge i.e. 120 mg/l is not possible to be achieved by biological treatment.

3.2. Electrochemical post - treatment

3.2.1. Electrolysis performance. Three sets of electrolysis tests were carried out with different current density. The results are shown in Figure 3. Removal of COD versus electrolysis time for current density of 0.44, 0.73 and 1.15 A/dm^2 and voltage 4.2, 5.4 and 5.8 V respectively is shown. Reaction time for COD removal decreases as current density increases. The limit value of COD equal to 120 mg/l is reached by consuming 44.1 kWh / m^3, 40.5 kWh / m^3 and 34.8 kWh / m^3 for the three current densities respectively.

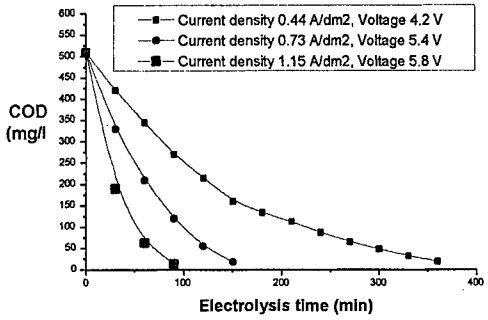


Figure 3. COD removal by electrolysis.

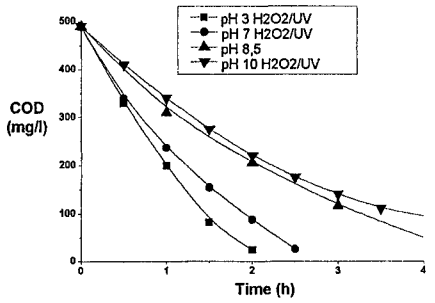


Figure 4. COD removal by ozonation and by H2O2 / UV radiation.

3.2.2. Ozonation performance. One set of ozonation tests was carried out. The results are shown in Fig. 4. The initial pH of the samples was 8.5. The limit value for COD is reached after three hours of exposure. The amount of ozone absorbed by the samples was 2.4 g/g COD removed.The energy required for ozone production to reach the limit value of COD equal to 120 mg/l is estimated to be 26 - 30 kWh / m^3 (12).
3.2.3. H_2O_2 / UV performance. Three sets of tests were carried out for three different initial values of pH 3,7 and 10. In each sample of 2 l 20 mg Fe^{++} and 2,000 mg H_2O_2 were added. The results after exposure to UV radiation are shown in Fig. 4. In order to reach the limit value for COD 120 mg/l an exposure time of 1.25, 1.75 and 3.5 hours is required for initial pH 3, 7 and 10 respectively. The H_2O_2 reacted was 1.8, 2.0 and 2.4 g/g COD removed respectively for the different values of initial pH. It is estimated that the amount of H_2O_2 required is equal to 0.7 Kg/m^3, 0.74 Kg/m^3 and 0.9 Kg/m^3 and the energy needed for UV radiation is 10, 13.5 and 26 kWh / m^3 for wastewater of initial

pH 3, 7 and 10 respectively. The difference in reaction rate and H_2O_2 consumption at low pH is due to lower concentration of radical scavenger carbonate / hydrogen carbonate.

4. CONCLUSIONS

Biological methods are effective in BOD_5 and nitrogen removal to acceptable values. COD removal is not possible to be achieved by biological treatment.
By applying electrochemical methods it is possible to decrease COD to acceptable values but the treatment cost is enormous.

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CURRANT WASTEWATER TREATMENT

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ABSTRACT

There are about 30 currant and sultana finishing plants in Greece. Methods of washing- water use and wastewater treatment and analysis are described. A case study of currant wastewater treatment is analyzed. Chemical precipitation, acidification, methanization, extended aeration, evapotranspiration are used. COD and BOD_5 removal is 98,9 % and complete respectively. The parameteres of COD and colour exceed the acceptable values for treated wastewater to be used for irrigation or underground aquifer recharge. Advanced oxidation of treated effluent using physicochemical processes was applied to decrease COD and colour to acceptable values.

ΕΠΕΞΕΡΓΑΣΙΑ ΑΠΟΒΛΗΤΩΝ ΒΙΟΜΗΧΑΝΙΩΝ ΕΠΕΞΕΡΓΑΣΙΑΣ ΣΤΑΦΙΔΑΣ

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ΠΕΡΙΛΗΨΗ

Στην Ελλάδα λειτουργούν περίπου 30 εργοστάσια επεξεργασίας κορινθιακής σταφίδας και σουλτανίνας. Περιγράφονται οι μέθοδοι πλυσίματος, η χρήση νερού, η επεξεργασία και οι αναλύσεις των αποβλήτων. Αναλύεται η μέθοδος επεξεργασίας των αποβλήτων ενός αντιπροσωπευτικού εργοστασίου. Χρησιμοποιείται χημική ιζηματοποίηση και κροκίδωση, οξυγένεση, μεθανογένεση, παρατεταμένος αερισμός και εξατμισοδιαπνοή. Η απομάκρυνση του COD και του BOD_5 είναι 98,9 % και ολική αντίστοιχα. Οι παράμετροι του COD και του χρώματος υπερβαίνουν τις αποδεκτές τιμές επεξεργασμένων αποβλήτων για χρήση για άρδευση ή επαναφόρτιση του υπόγειου υδροφορέα. Εφαρμόστηκε οξείδωση των επεξεργασμένων αποβλήτων με φυσικοχημικές μεθόδους για μείωση του COD και του χρώματος σε αποδεκτές τιμές.

1. INTRODUCTION

The Greek dried vine fruit industry produces two main types of dry grapes : sultanas and currants. The annual finished quantities are 110,000 and 50,000 tons, respectively. The pollution caused by discharging the wastewaters of this industry into the sea is equivalent to populations of 100,000 people and 30,000 people, respectively. There are 30 currant and sultana - finishing plants in Greece.

1.1. Washing process and Water Use.

Up to date there is no washing practice based on research. High water consumption is required in riffle washers or stone traps for product transfering rather than washing. During recent years, due to pollution problems and in order to minimize the quantities of wash water, water recirculation has been used, but in the wrong way. This could be assured only by applying the microbiological control in the final product. There is an optimum position between improved washing and water use reduction by counter - current washing. The washing processes applied today in currant - finishing plants have been reported. The one stage counter - current washing process is the most efficient for the removal of sugars and other impurities from the surface of dry grapes and is practised by some companies(1).

1.2. Wastewater of vine fruit finishing companies.

Wastewater quantities depend on the water use for washing and varies from 0.5 to 10 m^3/t of finished product. Water consumption per ton in Australia varies between 0.4 and 2.0 m^3/t (2) and in USA is 7.5 m^3/t (3). Wastewater composition was described by Gwatkin and Lane (2). It contains mainly glucose and fructose with small concentrations of lipids, minerals and suspended solids. An analysis of wastewater from Greek finishing plants has been given (4).

1.3. Wastewater treatment.

Extensive descriptions of currant finishing wastewater treatment methods have been given (1, 2, 4, 5, 6, 7, 8). Anaerobic treatment was very effective when tried on pilot and semi-industrial plant scale (6).

The UASB reactor seemed to be the most favorable. Limitations associated with the development of the granulated sludge do not exist, since it is developed quite rapidly. The UASB is easy and simple in operation and withstands long periods of stand - still. The requirements for the effluent quality of currants finishing waters can be fulfilled only if several methods of treatment are combined. It is evident that, regardless of the following purification process, it is useful to treat wastewater biologically beforehand. Thus considerable carbon removal can be reached. Only the parameters of COD and colour exceed acceptable values for treated wastewater to be used for irrigation or underground recharge. Acceptable values of COD and colour are 30 - 130 mg/l and 10 - 100 co-pt units respectively.

Using physicochemical oxidation processes it could be possible to reach the limits for reuse of treated wastewater (9).

2. METHODS

2.1. Wastewater.

The mean composition of " Belousis " currant finishing wastewater is shown in Table 1.

2.2. Full Scale Wastewater Treatment Plant.

Based on the results of a long research period (6) a full scale wastewater treatment plant was designed and constructed two years ago for the Belousis Company. It includes removal of suspended

solids by chemical coagulation and settling, acidification reactor, UASB reactor, extended aeration and evapotranspiration or irrigation or underground recharge. The basic design characteristics of the plant are shown in Table 2.

TABLE 1. Characteristics of " Belousis " Currant Company wastewater

Parameter	Average value
Flowrate (m^3/t of finished product)	1.2
BOD_5 (mg/l)	11,600
COD (mg/l)	16,580
pH	5
Suspended solids (mg/l)	2,300
Total N (mg/l)	80
Total P (mg/l)	25
Colour (Co- Pt units)	650

TABLE 2. Basic design characteristics of the wastewater treatment plant.

Parameter	Value
Daily currants production	40 t
Wastewater flowrate	1.2 m^3/t
Daily wastewater flowrate	48 m^3/d
Daily COD load	829 Kg
Daily BOD_5 load	583 Kg
Acidification reactor volume	250 m^3
UASB reactor volume	150 m^3
Extended aeration tank volume	200 m^3
Settling tank volume	20 m^3
COD loading	5 Kg COD/m^3/d
COD removal in anaerobic stage	95 %
Biogas production	0.41 - 0.59 m^3/Kg COD
Average methane content of biogas	75 %
COD removal in aerobic stage	80 %

2.3. Electrolytic apparatus.

Electrolysis was conducted using a voltameter (Yokoyama Electric Works Ltd, Japan). The electrolytic cell was consisted of a glass vessel of 17.5 x 20 x 5.5 cm (length x depth x width) with a pair of electrodes, a steel cathode and a graphite anode. The steel cathode was a plate of 17.5 x 20 x 0.5 cm and was placed near the wall surface. The graphite anode was a plate of 17.5 x 20 x 2 cm. The level of the wastewater surface was 18 cm and the net volume of wastewater was 1000 ml. The tests were performed in batch. The surface of the anode was F = 6.84 dm^2 and the sample volume /anodic surface ratio was 1.461. Three sets of tests were carried out for COD and colour removal. In each sample of effluent 500 mg/l of NaCl were added.

2.4. Ozonator.

A small ozone generator was constructed for decolorization experiments and it is described elsewhere (9). The production of ozone by the ozonator was about 300 mg per hour. For the decolorization curves and the COD removal curves of wastewater 1500 ml bottles were used. All the bottles used had a sampling stopcock above the bottom. The ozonation tests were batch. The contact time cycle of ozone for reference and sample bottles was one hour. After each hourly exposure samples were

taken and analyzed for ozone consumption, COD and colour reduction. The total contact time for reference and sample bottles was four hours. Initial pH of samples tested was regulated to 7.5.

2.5. H_2O_2 /UV reactor.

For the tests with UV - radiation a 15 W low-pressure lamp (Heraeus TNN 15/32) was used.
The reactor was made of glass and had a net maximum volume of 2 l. Mixing was accomplished with a magnetic stirrer. A quartz sleeve, which housed the lamp, was cooled to maintain the temperature in the reactor.
H_2O_2 and Fe^{2+} catalyst was added in each sample before it was exposed to UV radiation. H_2O_2 / UV tests were batch. Total exposure time of wastewater samples to UV radiation was 2 hours. Every half an hour samples were taken from the reactor and analyzed for H_2O_2 consumption, COD and colour reduction. The influence of the initial wastewater pH to the process efficiency was tested. Initial pH of 7.5 and 3.0 was regulated with diluted HCl.

2.6. Analyses.

COD and colour were measured with a Hach spectrophotometer DR - 2000. Alkalinity was determined by the method developed by Ripley (11). Gas analyses were performed by withdrawing gas samples from an in - line gas sampling port. The biogas was analysed for methane. The gas chromatograph used for the gas analyses was a Beckman model GC - 2A. Total Kjeldahl nitrogen concentration was determined according to the method outlined by EPA (10). H_2O_2 in water was measured according to DIN 38409 / part 15.

3. RESULTS AND DISCUSSION

3.1. Biological treatment

3.1.1. UASB reactor start up. Construction of the treatment plant was completed in June 1995.The system was started using 60 m^3 anaerobic sludge from the nearby University Sewage treatment plant. This quantity of sludge represented 40 % of the total volume of the reactor. The filling of the reactor with wastewater was completed in approximately 20 days. Samples from the second sampling valve (~ 2.4 m height of 6.0 m total height) were analysed. The ratio COD : N : P was kept constant by adding $(NH_4)_2HPO_4$ and NH_2CONH_2. Fe and micronutrients were also added. The start up went very smoothly.

3.1.2. UASB reactor loading and COD removal. Average reactor loading and COD removal during the almost two years of operation were 4.7 Kgs COD/m^3 d and 95.5 % respectively.

3.1.3. UASB reactor pH and Alkalinity.The pH of the reactor was controlled between 6.7-7.0 by adding 80-90 meq/l alkalinity in the raw wastewater.
The ratio IA : IP (Intermediate alkalinity to partial alkalinity), which is analogous to VA : ALK ratio, was constantly very low (0.15- 0.3).

3.1.4. UASB reactor biogas production. The average biogas production was 0.46 m^3/Kg COD removed with a range of 0.41 to 0.59 m^3/Kg COD removed. The average methane content of biogas was 75 % and the average methane production was 0.34 m^3/Kg COD removed.

3.1.5. Intermittent Operation of UASB. The currants finishing plant is in operation for only about 120 days per year. There are often long periods of wastewater feeding interuption. Up to date periods of two months stand-still have not had any adverse effect on system performance.

3.1.6. UASB reactor temperature. The temperature in UASB reactor was controlled at 20 °C during the winter months when the average outside temperature was 13 °C. During the rest of the year temperature was controlled by the wastewater temperature. Outside average temperature was 23 °C. During summertime, the temperature of the wastewater was increased to 35 ° - 40 °C in the mild steel acidification tank.

3.1.7. Extended aeration system performance. F/M in aeration tank was kept at 0.05. The average MLVSS were 600 mg/l. The average BOD_5 and COD removal in the extended aeration system was 95 % and 75 % respectively.

3.1.8. Final effluent characteristics. The final effluent of the plant had the characteristics shown in Table 3. The remaining COD and colour were due to non - biodegradable colouring substances of currants which were combined with tannin. Colour was pH dependent.

3.2. Physicochemical post - treatment.

3.2.1. Electrolysis performance. Three sets of electrolysis tests were carried out with different current density. The results are shown in Fig. 1 and 2 . Removal of COD and colour versus electrolysis time for current density of 0.44, 0.73 and 1.15 A/dm^2 and Voltage 4.2 , 5.4 and 5.8 V respectively is shown. Reaction time for COD and colour removal decreases as current density increases. The energy consumed for electrolysis was 63 Wh, 90 Wh and 76 Wh/g COD removed respectively. In order to reach the colour value of 10 co-pt units an energy amount of 46 kWh/m^3 is required.

TABLE 3. : Characteristics of the effluent from the UASB - aeration plant.

Parameter	Average value
COD (mg/l)	185
BOD_5 (mg/l)	6
SS (mg/l)	14
pH	7.5 - 8.5
Nitrate - N (mg/l)	27
Total - N (mg/l)	33
Colour (Co - pt units)	270

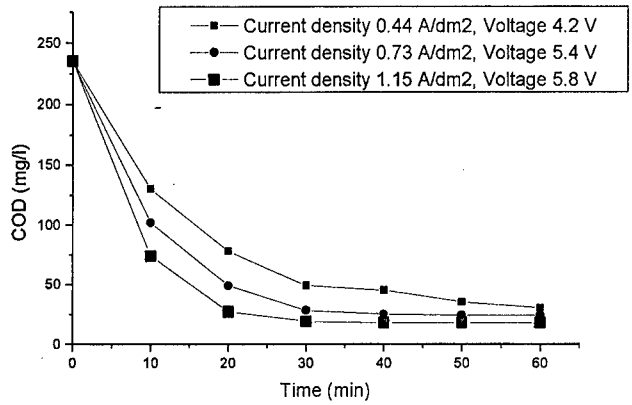


Figure 1. COD removal by electrolysis.

3.2.2. Ozonation performance. Two samples of wastewater of initial pH 7.5 and initial COD 235 mg/l and 180 mg/l respectively were ozonated for four hours. The results are shown in Figure 3. The amount of ozone absorbed by the samples was 2.2 and 2.6 g/g COD removed. The precision of the ozonation process was determined by treating five replicate samples of wastewater having initial pH

and COD 7.5 and 220 mg/l respectively for three hours. The amount of ozone absorbed by the samples was measured. The average ozone consumption was 2.3 g/g COD removed. The coefficient of variation for the five measurements was 6.6 %.
The daily amount of ozone required for treating the wastewater of this case study on a full - scale would be 18.7 Kg. An ozonator with a capacity of 0.8 Kg O_3/h would be appropriate for this case. The total energy required for such a small ozonator would be approximately 1.000 kWh/d. (12).

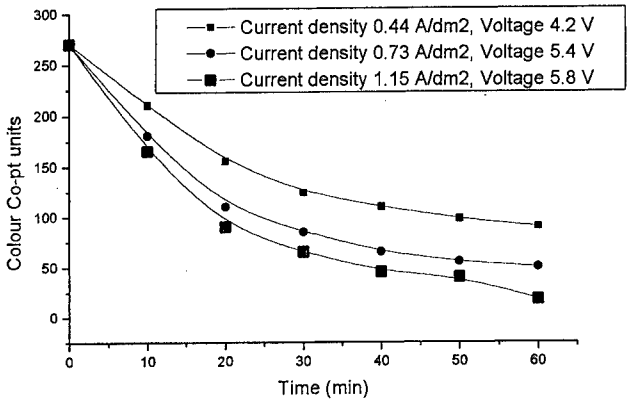


Figure 2. Color removal by electrolysis.

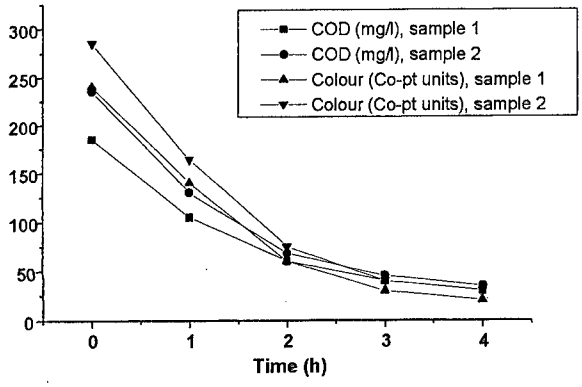


Figure 3. COD and colour removal by ozonation.

3.2.3. H_2O_2/ UV performance. 10 mg Fe^{++} and 200 mg H_2O_2 were added to each sample of 2 l. The pH of the two samples treated was 7.5. The results after exposure to UV radiation are shown in Fig. 4. The H_2O_2 reacted for the two samples was 1.8 g and 2.3 g / g COD removed. The energy consumed for UV radiation of the two samples was 59.2 Wh and 77.6 Wh / g COD removed. The daily amount of H_2O_2 and energy required for full - scale

treatment at pH 7.5 would be approximately 18 Kgs and 500 kWh respectively. The results for two samples of pH 3.0 after exposure to UV radiation are shown in Fig. 5. The H_2O_2 reacted for the two samples was 1.6 g and 2.0 g/g COD removed. The energy consumed for UV radiation for the two samples was 62.0 Wh and 66.7 Wh / g COD removed. The daily amount of H_2O_2 and energy required for full - scale use at pH 3,0 would be approximately 13 Kgs and 430 kWh respectively.

3.2.4.

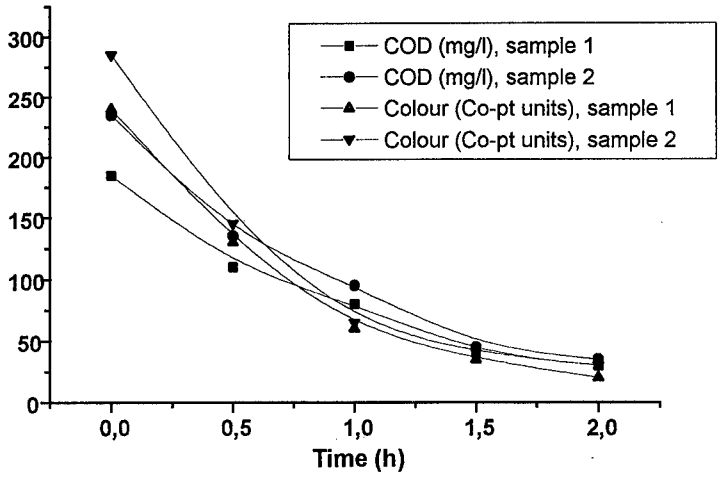


Figure 4. COD and colour removal by H_2O_2/UV at pH 7.5

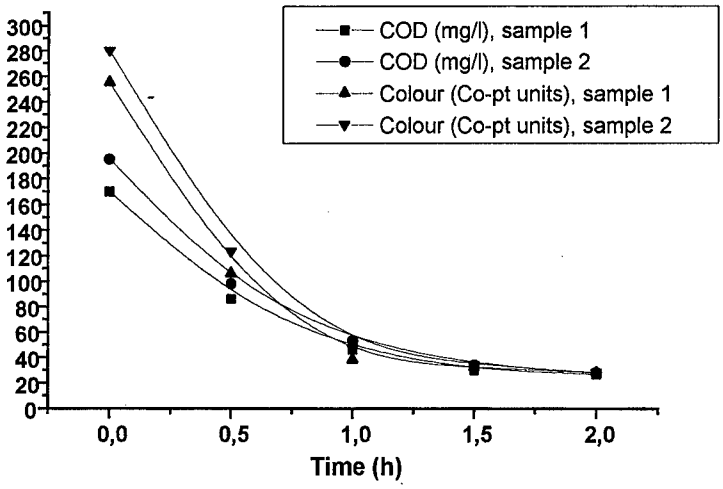


Figure 5. COD and colour removal by H_2O_2/UV at pH 3.0

The difference in reaction rate and H_2O_2 consumption at pH 3.0 compared to pH 7.5 was due to the low concentration of radical scavenger carbonate / hydrogen carbonate. The profit gained in H_2O_2

and energy at low pH would be approximately lost for pH control. The precision of the H_2O_2/UV process was determined by treating five replicate samples of wastewater having initial pH and COD 7.5 and 220 mg/l respectively for 1.5 hours. The amount of H_2O_2 reacted was measured. The average H_2O_2 reacted was 2.1 g/g COD removed. The coefficient of variation for the five measurements was 7,5 %.

3.2.4. Comparison of post - treatment methods costs. Oxidation with ozone is more expensive than with H_2O_2/UV and with electrolysis. Electrolysis and H_2O_2/UV methods have almost the same total cost but electrolysis requires addition of NaCl which impairs the quality of treated wastewater.

4. CONCLUSIONS

The biological treatment of currant wastewater is simple and very effective. The advanced oxidation of biologically treated effluent with electrochemical processes is also effective but expensive. Ozonation is more expensive than H_2O_2/UV radiation and electrolysis. Electrolysis impairs the quality of the treated wastewater due to the NaCl addition. It is estimated that half of the total cost for biologically removing 99 % of the total daily amount of COD is equal to the oxidation cost for removing the remaining 1 % of the total daily amount of COD by H_2O_2/UV radiation method.

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RECIRCULATION OF CURRANT-FINISHING WASTE WATERS AND ITS EFFECT ON THEIR COMPOSITION AND PRODUCT QUALITY

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ABSTRACT

Characteristics of effluent from a laboratory scale currant washing plant, are presented in relation to the recycling ratio of the effluent after clarification by chemical treatment and sedimentation. It was found that the increase of the recycling ratio from 0 to 95% increased the BOD of the effluent from 681 to 5378 mg/l, the COD from 3808 to 43722 mg/l, the Total Suspended Solids from 12,3 to 57.7 g/l, the total sugars from 2,57 to 42.13 g/l, the total phosphorous from 0,79 to 5,13 mg/l, the total kjeldahl nitrogen from 7,36 to 51,9 mg/l, the total phenolic compounds from 0.095 to 1,13 g/l while it decreased the fresh water used from 6.0 to 0.3 kg per kg of processed currants and the total sugar wastes from 15.4 to 12.6 g per kg of processed currants.

ΕΠΙΔΡΑΣΗ ΤΗΣ ΑΝΑΚΥΚΛΩΣΗΣ ΥΓΡΩΝ ΑΠΟΒΛΗΤΩΝ ΕΠΕΞΕΡΓΑΣΙΑΣ ΣΤΑΦΙΔΑΣ ΣΤΗ ΣΥΣΤΑΣΗ ΤΟΥΣ & ΤΗΝ ΠΟΙΟΤΗΤΑ ΤΟΥ ΠΡΟΪΟΝΤΟΣ

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ΠΕΡΙΛΗΨΗ

Η παρούσα εργασία αναφέρεται σε μια μονάδα έκπλυσης της σταφίδας και στο ρυθμό ανακύκλωσης του υγρού έκπλυσης μετά την διαλεύκανση του με χημική επεξεργασία. Βρέθηκε ότι η αύξηση του ρυθμό ανακύκλωσης από 0 σε 95 % έχει ως αποτέλεσμα την αύξηση του BOD του υγρού από 681 σε 5378 mg/l, του COD από 3808 σε 43722 mg/l, των ολικών αιωρούμενων στερεών από 12,3 σε 57,7 g/l, των ολικών σακχάρων από 2,57 σε 42,13 g/l, του ολικού φωσφόρου από 0,79 σε 5,13 mg/l, την αύξηση του αζώτου Kjeldahl από 7,36 σε 51,19 mg/l, την αύξηση των φαινολικών ενώσεων από 0,095 σε 1,13 g/l. Ταυτόχρονα0 μειώθηκε η χρήση καθαρού νερού από 6,0 σε 3,0 Kg ανά Kg σταφίδας καθώς επίσης και η ολική ποσότητα αποβλήτων σακχάρων από 15,4 σε 12,6 g ανά Kg σταφίδας.

1. INDRODUCTION

The Currant-Finishing Wastewaters (CFW) in Greece are estimated to be from 4-6 m3 per tn of proceed currants. The annual production of currants in Greece is about 80.000 tn for sultanas and 87.000 tn for currants of Corinthian type. Thus the corresponding CFW are of the order of 400.000 and 500.000 tn respectively per year (Israilides et al., 1982). These are disposed of into the sea causing environmental pollution equivalent to 130.000 population in total (Athanasopoulos, 1990).

The CFW are produced during the washing of currants. This is done by spraying fresh and recycled water in a primary washing unit following by a SO_2 applying unit for sterilization and decolourisation of currants. After this there is a second washing unit where the currants are finally being washed with fresh water only (Figure 1). The water used for washing goes through a fine rotation screen for the removal of suspended solids. One part of this screening wastewater is reused for washing and another is rejected as CFW. The reusing wastewater is usually about 20-30% of fresh water. At any time the ratio of washing water and raw currants introduced in the primary washing unit is about 10/1 to 15/1(weight per weight) (Athanasopoulos et al., 1987).

The CFW contain mainly sugars, tannins and colloidal suspended solids. Sugar concentration in the CFW, which is mainly glucose and fructose, is ranging between 10-30 g/l , while average COD values were reported at 20.000 - 30.000 mg/l with a COD/BOD_5 ratio of around 10 (Athanasopoulos et al., 1989). The high COD/BOD_5 ratio indicates a strong toxicity of CFW probably due to the presence of tannins extracted from the grape skin and from the use of SO_2 during processing. A small amount of lipids is present in CFW. The level of Total Kjeldahl Nitrogen (TKN) varies from 50-100 mg/l and tends to follow the COD. The pH of CFW is slightly acidic. Among the common type of treatments of CFW, aerobic biological oxidation (biofiltration/activated sludge) is considered expensive for both capital and operational costs. Alternatively anaerobic digestion of CFW seems to be more advantageous than aerobic treatment due to the fact that it requires lower energy. However, for an effective application of this process two major problems must be overcome: the short seasonal operation of the industry (only three months per year) and the low rate of CFW anaerobic biodegradation due to the toxicity of the substrate (Athanasopoulos et al, 1989; 1990).

This paper reports on the possibility of complete recirculation of CFW in an effort to remove suspended and colloid particles minimize water volume and energy under the philosophy of «clean technologies concept» while enhancing the quality and quantity of the final product.

2. MATERIALS AND METHODS

2.1 The laboratory pilot plant

Figure 1 is a simplified flow sheet illustrating the steps of the currant-wash process that were followed in our laboratory scale plant. 0.5 kg curants were washed with 3Kg tab water for 10 min. The mixture was drained on a sieve and the drains were collected and filltered for the removal of suspended solids. One part of the washing was collected and was made up to certain volume with clean water which has rinsed the currants on the sieve. The volume of the removed waste washing (Q_e) or the added water Q_w (Q_e=Q_w) was fixed to a desirable recircculation ratio (r%). The r % is given by the equation:

$$r\% = \frac{Q_e}{3} \times 100 \qquad [1]$$

To the previous mix of waste washing and fresh water with a total volume of 3 l, another 0.5 Kg of currants were added and the same process of washing, draining, filtering removing the same quantity of washings and replenishing with clean water was repeated many times until the measured parameters COD, BOD, TKN, TP, TSS and TS were stabilized. These values correspond to the predetermined ratio r %.

The procedure was repeated for another value of r %. Before each new quantity of currants was introduced the suspended colloidal solids were removed with agglutination - aglomeration and centrifugation. The agglutination was achieved with alum (1% w Al /w suspended solids) followed by addition of lime for pH adjustment at 8.5 and by Praestol-2540 (0.05% w/w). Praestol-2540 is a mildly anionic polyelectrolyte of the polyacrylamide type.

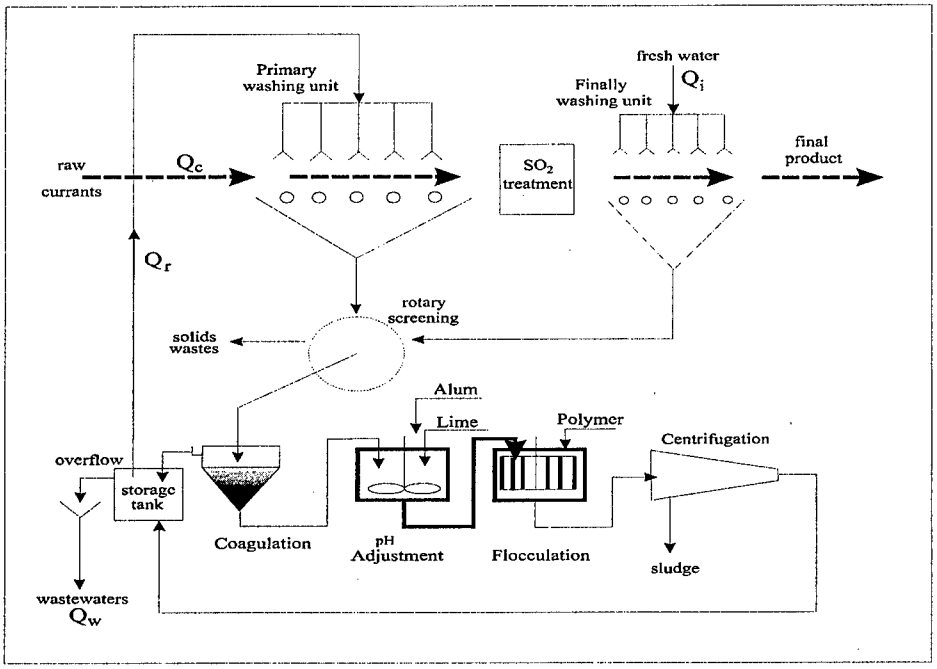


Figure 1: Currant washing and clarification laboratory scale plant

2.2 Methodology

The aim of each experiment was to determine the relation of the applied effluent recycling ratio to the characteristics of the discharged effluent as well as the yield of the washed final product.

2.3 Methods of analysis

COD, BOD_5, TKN and Total Phosphorous determinations were carried out according to the Standard Methods for Examination of Water and Wastewater (AWWA, 1989). The total phenolic compounds were measured with the Folin-Ciocalteu method (Slinkard and Singleton, 1977). Total sugars were determined according the Official Methods of Analysis (AOAC, 1975). The statistical analysis of the results was carried out utilizing techniques given by Taylor (1990).

3. RESULTS AND DISCUSSION

3.1 BOD_5

As shown from in Figure 2, the BOD_5 of the effluent established under steady state conditions of the system was an exponential function of the recycling ratio. Its lower value was about 681 mg/l at r=0%, while its highest value was about 5378 mg/l at r=95%.

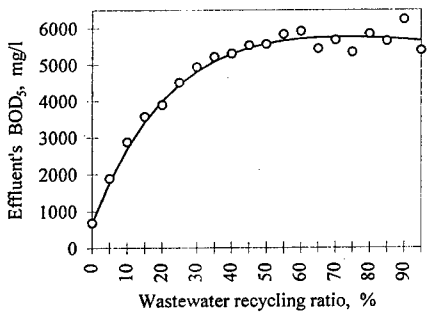


Figure 2: Estimated BOD_5 value of the discharged effluent in relation to the recycling ratio for steady state conditions.

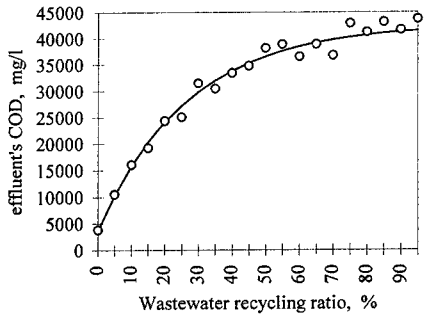


Figure 3: Estimated COD of the discharged effluent in relation to the recycling ratio for steady state conditions.

3.2 COD

As shown in Figure 3, the estimated COD limiting value in relation to recycling ratio follows an exponential function (for r=0% and 95% the COD limiting values are 3808 mg/l and 43722 mg/l respectively).

3.3 COD/BOD_5 ratio

As the recycling ratio increased the COD/BOD ratio limiting value increased almost linearly as shown in Figure 4. It started with a limiting value of 5.6 at r=0% and it reached a value of 7.3 at r=95%. The high value of COD/BOD_5 ratio underlines the poorly biodegradable nature of the residual COD. The increase of this value when the recycling ratio was increased indicates that the effluent became more toxic as substrate for environmental microorganisms, reducing the efficiency

of any biological treatment. This behavior, on the other hand turns out to be an advantage for the currant-wash process because it hinders the biological attack on the pulp during the washing procedure and results in yield and quality enhancement of the produced final product.

3.4 Total Suspended Solids (TSS)

The function between TSS limiting concentrations and recycling ratios is expontential as shown in Figure 5. The TSS limiting concentration at the recycling ratio 0% was 12,3 g/l while at 95% it was 61.7 g/l.

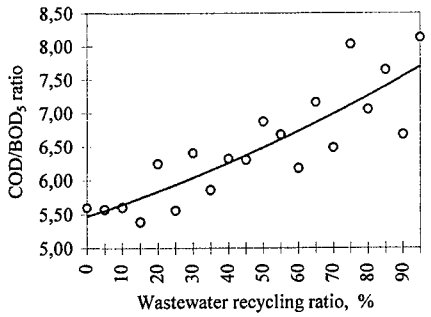


Figure 4: Estimated COD/BOD_5 ratio of the discharged effluent in relation to the recycling ratio for steady state conditions.

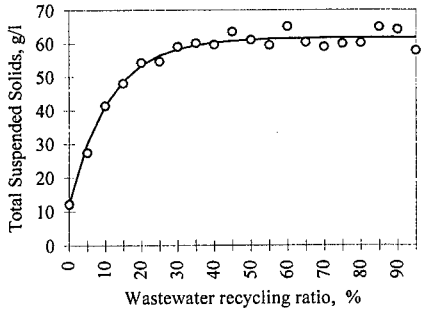


Figure 5: Estimated Total Suspended Solids concentration of the discharged effluent in relation to the recycling ratio for steady state conditions.

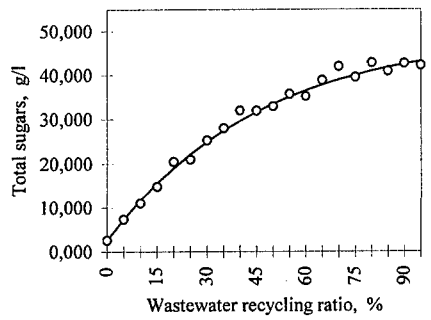


Figure 6: Estimated Total Sugars of the discharged effluent in relation to the recycling ratio for steady state conditions.

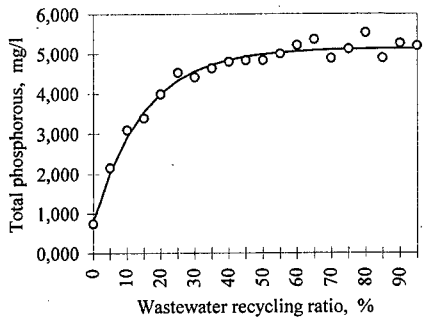


Figure 7: Estimated Total phosphorous of the discharged effluent in relation to the recycling ratio for steady state conditions.

3.5 Total Sugars

The Total Sugars concentration limiting value is related with an exponential function to the recycling ratio (Figure 6), beginning with a concentration of 2.57 g/l at r=0%, while at r=95% the limiting value of this parameter increased to 43.2 mg/l.

3.6 Total phosphorous

As shown in Figure 7 the total phosphorous concentration limiting value was increased as the recycling ratio increased, from 0.73 mg/l at r=0%, to 5.138 at r=95%.

3.7 Total Kjeldahl Nitrogen (TKN)

As shown in Figure 8 the TKN concentration limiting value was increased as the recycling ratio was increased, from 7.6 mg/l at r=0%, to 51.9 mg/l at r=95%.

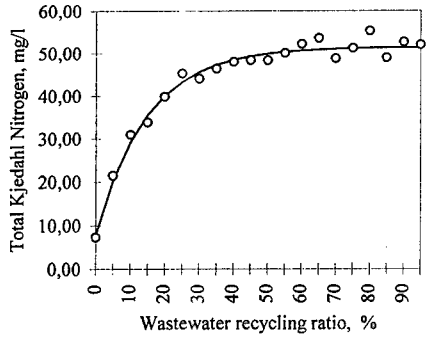


Figure 8: Estimated TNK of the discharged effluent in relation to the recycling ratio for steady state conditions.

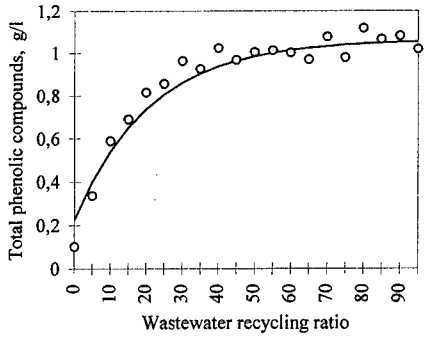


Figure 9: Estimated total phenolic compounds concentrations of the discharged effluent in relation to the recycling ratio for steady state conditions.

3.8 Total phenolic compounds

As shown in Figure 9 the total phenolic concentration limiting value was increased as the recycling ratio was increased, from 0.095 g/l at r=0%, to 1.12 g/l at r=95%.

3.9 Sugars content in final product

The quantity of sugars wasted per kg of processed currants (w/w) in relation to the recycling ratio for steady state conditions is presented in Figure 10. This figure shows that the waste sugars quantities increase up to r=40% and decreased almost linearly whith increasing recycling ratio. At a recycling ratio of 0% and for steady state conditions the waste sugars were 15,4 g/kg while at r=40% and

r=95% were 115.2 and 12.64 g/kg respectively. This decrease of waste sugars leads to an increase of the washed currants yield by 10%.

4. CONCLUSIONS

The effluent from a currant washing process is partially recycled after sludge removal which is effected by chemical treatment. The maximum possible recycling ratio (95%) of the clarified effluent has the following effects on the total process:

- The quality of final product remains unchanged.
- The yield of the total sugars in the final product is increased.
- The sludge yield is reduced.

Additionally if the recycling ratio is more than 90% then the environmental impact, by means of BOD_5, COD and TSS discharge, is reduced.

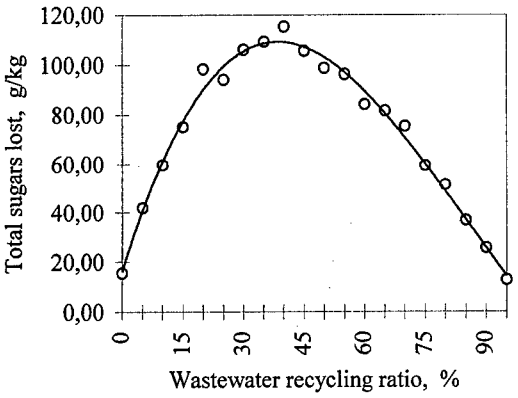


Figure 10: Estimated total sugars waste in relation to the recycling ratio for steady state conditions.

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TOXICITY REDUCTION AND DENITRIFICATION OF MUNICIPAL AND INDUSTRIAL WASTEWATER

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ABSTRACT

A lab scale activated sludge system was used for the treatment of municipal and industrial wastewater from the Greater Thessaloniki Area. Effective treatment achieved by the incorporation of an anoxic basin before the aeration reactor. This anoxic reactor enhanced the denitrification capacity resulting in an effluent with nitrate nitrogen concentration lower than 10 mg/l while maintaining high organic matter removal capacity. While the influent to the reactor had a high toxicity to *Daphnia magna*, the effluent was low in toxicity.

ΕΛΑΤΤΩΣΗ ΤΗΣ ΤΟΞΙΚΟΤΗΤΑΣ ΚΑΙ ΑΠΟΝΙΤΡΟΠΟΙΗΣΗ ΑΣΤΙΚΩΝ ΚΑΙ ΒΙΟΜΗΧΑΝΙΚΩΝ ΑΠΟΒΛΗΤΩΝ

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ΠΕΡΙΛΗΨΗ

Στην εργασία αυτή χρησιμοποιήθηκε ένα σύστημα ενεργού ιλύος σε εργαστηριακή κλίμακα για την επεξεργασία αστικών λυμάτων και βιομηχανικών αποβλήτων από την περιοχή της Θεσσαλονίκης. Ικανοποιητική επεξεργασία των αποβλήτων πραγματοποιήθηκε μετά την εισαγωγή ενός ανοξικού αντιδραστήρα στο σύστημα πριν από την δεξαμενή αερισμού. Με τον τρόπο αυτό βελτιώθηκε η απονιτροποίηση των αποβλήτων και τα παραγόμενα επεξεργασμένα λύματα είχαν συγκέντρωση νιτρικού αζώτου μικρότερη από 10 mg/l, ενώ παράλληλα διατηρήθηκε υψηλό ποσοστό απομάκρυνσης οργανικού φορτίου. Τα επεξεργασμένα απόβλητα παρουσιάζουν μηδαμινή τοξικότητα ως προς την *Daphnia magna*, σε αντίθεση προς τα αρχικά απόβλητα τα οποία έδειξαν υψηλή τοξικότητα.

1. INTRODUCTION

Biological treatment based upon the degradative activity of natural bacterial populations is a common practice for municipal and industrial wastes. Biological treatment of domestic sewage usually results in degradation of the parent compounds into harmless substances and end-products. However, conventional treatment methods cannot always easily be applied to industrial wastes, which contain anthropogenic compounds. Many of these substances resist microbial attack, or are metabolized very slowly, while others may exhibit toxic and inhibitory effects on the bacteria.

In the case that inhibitory substances enter a treatment plant, the receiver is endangered due to [1]:

a) indirect (chronic) effects as a result of the plant biodegradative capacity collapse, which occurs because of the death of part of the microbial population. Especially significant is considered the inhibition to nitrifying bacteria due to their slow growth rate [2]. This means that treatment plants using the nitrification process will take sometime to recover from potential shock loads of inhibitory substances.
b) direct (acute) toxic effects if the toxicant is not removed in the plant and is discharged.

Legislation on toxic discharges of wastewater treatment plants into receivers has focused primarily on specific chemical constituents. However these data alone, do not reflect the toxic effect of effluents on the living microorganisms of the receiver. The US EPA has recommended the combined use of biological and chemical data for the control of toxic substance discharge to receivers[3]. Furthermore, this document included procedures for the evaluation of toxicity problems in receivers and for locating and identifying the responsible point source discharge. Numerous field studies have been conducted to validate the short-term toxicity test procedures [4]. Toxicity tests on untreated and treated wastes can be used to assess the fate of toxic substances during treatment, the pass-through of the overall toxicity in the effluent wastewater and the effect of effluent on the receiver water organisms.

In this work the toxicity of domestic and industrial wastewater from Thessaloniki area is evaluated, in order to assess the feasibility of coupling a lab-scale waste treatment system with effluent toxicity assays, and to determine the capacity of the treatment system for the toxicity reduction and the denitrification of the influents. The results of this investigation will be used for the prediction of the operation of the Thessaloniki wastewater treatment plant during the intended co-treatment of domestic and industrial wastewater.

2. EXPERIMENTAL

Domestic wastewater used in this study was obtained from the influent of municipal wastewater treatment plant of Thessaloniki, which treats about 60,000 m^3/day of wastewater. Industrial wastewater was collected from the wastewater treatment plant of the Thessaloniki Industrial Area which treats approximately 10,000 m^3/day of industrial effluents. Both samples were collected, characterized and stored in a refrigerator at 4°C, to retard biological decomposition, or used immediately in the lab-scale treatment unit.

All experiments were conducted in a bench-scale, continuous flow, activated sludge system consisting of an aeration-sedimentation basin and an anoxic reactor. The treatment system is shown in Figure 1. The aeration-sedimentation tank was a 12 l reactor with adjustable buffles that separated the aeration and clarifier sections. Air was supplied to the system through two ceramic porous diffusers located at the bottom of the reactor.

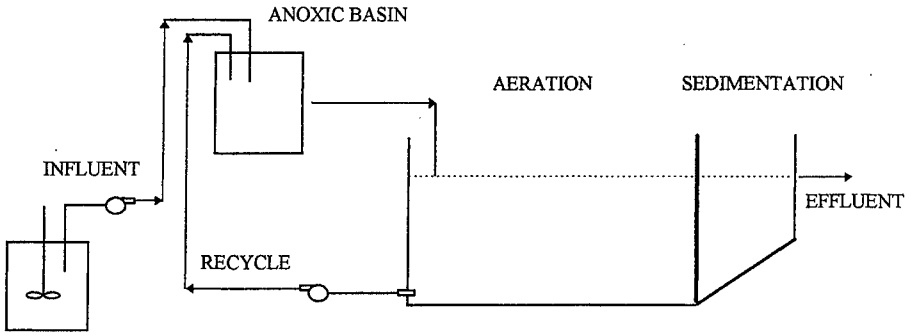


Figure 1. Schematic of the lab scale activated sludge system.

The anoxic basin was a 2 l cylindrical Plexiglas reactor. Feed and return mixed liquor were pumped by means of a peristaltic pump (Watson Marlow) in a flow of 6 and 24 ml/min respectively. Effluent from the anoxic basin flowed by gravity to the aeration basin. Mechanical mixing was provided by a magnetic stirring bar in the anoxic reactor to maintain the homogeneity of the mixed liquor. 10 l of mixed liquor activated sludge culture were obtained from the aeration tank at the Thessaloniki municipal wastewater treatment plant and were acclimated for a period of one month prior to the experiments. The reactor was maintained at an almost constant temperature of 20°C. Mixed Liquor Suspended Solids (MLSS) were about 2500 mg/l and Mean Cell Residence Time (MCRT) was maintained at 30 h by properly wasting a portion of the mixed liquor from the aeration tank.

Various continuous operating modes of the reactor system were investigated to enhance toxicity reduction and to improve denitrification. The system was operated for at least 2 weeks in a certain mode to reach steady state before collecting samples for measurements. Influent and effluent samples from the anoxic basin were analyzed on a regular basis for COD, BOD_5, SS, ammonia and nitrate nitrogen and total phosphorous, while the contents of the reactor were analyzed for the DO, MLSS and pH. Standard methods of chemical analysis were employed for the characterization of liquid samples [5].

Toxicity monitoring tests of wastewater samples were conducted by using the DAPHTOXKIT bioassays of BioInternational, containing *Daphnia Magna* as the test species. Procedures for the ephippia hatching and the toxicity analysis of the samples were performed in accordance with testing conditions prescribed by OECD Guideline 202 [6]. Mortality (%) of test species after a period of 24 h was used as a toxicity index.

3. RESULTS AND DISCUSSION

Test species of *Daphnia magna* were very sensitive to the samples taken from the Thessaloniki municipal and industrial wastewater. Toxicity values of species after 24 h of exposure to domestic wastewater ranged between 70 to 100%. Industrial wastewater samples showed even higher toxicity and all test species died after the experimental period. The high toxicity of samples, especially that of industrial wastewater, was attributed to the high organic and nutrient loading of wastewater. Chemical analyses of these samples is shown in Table 1. During preliminary experiments, the activated sludge system was operated by continuous feeding of municipal wastewater. In this period, the anoxic reactor had not been included in the system.

TABLE 1. Average chemical analyses of domestic and industrial wastewater.

	Domestic	Industrial
Time period	7/97-1/98	3/96-2/97
BOD_5 (mg/l)	320	680
COD (mg/l)	740	1340
$N\text{-}NH_3$ (mg/l)	42	38
$N\text{-}NO_3$ (mg/l)	7	34
TP (mg/l)	10	22
SS (mg/l)	325	566

Performance as a function of operation time is shown in Figures 2 and 3 in terms of influent and effluent COD-BOD_5, and ammonia-nitrate nitrogen, respectively. The activated sludge system attained a quality discharge over a 2 month period providing an effluent with BOD_5 less than 13 mg/l and COD values around 30-100 mg/l. The organic matter removal efficiency was consistently above 92%. The sludge settleability was good, providing a clear effluent with suspended solids concentration lower than 25 mg/l. The MLSS concentration remained almost constant without sludge wasting due to negligible sludge production as a result of the extended aeration regime established. Although influent characteristics varied, the system performance was nearly steady achieving a high quality effluent due to the high MCRT (30 h). As is shown in Figure 3, the system demonstrated high nitrification capacity and the effluent concentration of ammonia nitrogen was negligible. However the absence of an anoxic denitrification stage resulted in high values of nitrate nitrogen in the effluent, varying between 28 to 41 mg/l.

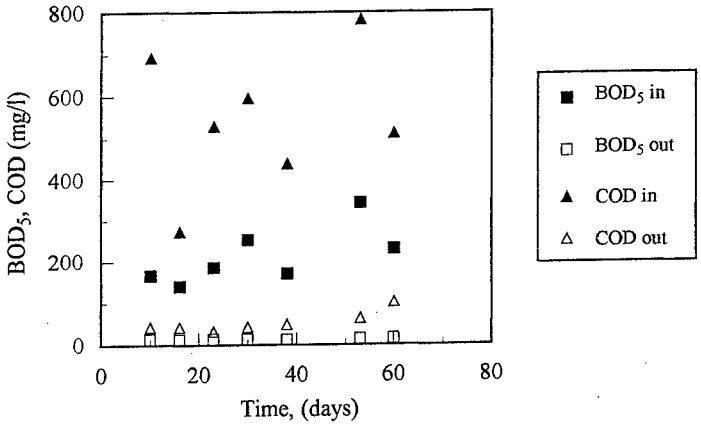


Figure 2. Influent and effluent organic matter concentration during the operation of the activated sludge reactor.

The high effluent concentration of nitrate nitrogen required the incorporation of an anoxic zone for denitrification. If the aerobic zone is placed before the anoxic zone, denitrification can carry over into the clarifier, causing poor settling and a rising sludge (due to nitrogen gas release). In a predenitrification system, rising sludge can be avoided because the anoxic zone is located before the aerobic zone. The nitrified wastewater is then recycled back to the anoxic zone for denitrification. A

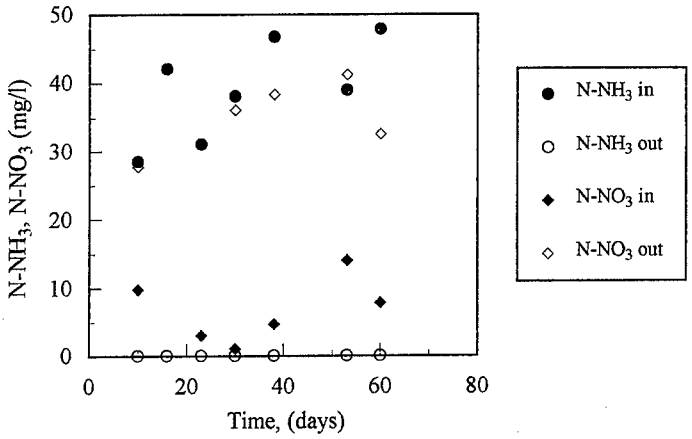


Figure 3. Influent and effluent nitrogen concentration during the operation of the activated sludge reactor.

predenitrification system cannot achieve 100% nitrogen removal because the aerobic zone discharges a portion of the nitrified liquid into the clarifier. Predenitrification systems require a relatively high recycle to influent ratio, for efficient operation. It has been reported that optimum sludge recycle ratios range between 4:1 to 6:1 [7]. Taking these considerations into account, an anoxic reactor was placed before the aeration tank of the lab system, where the Mean Cell Residence Time was 1.5 hours and the recycle to influent ratio was maintained at a value of 4:1.

The BOD_5 and COD concentrations of the influent, effluent and of the anoxic reactor, after the incorporation of the denitrification stage into the system, are shown in Figure 4 as a function of operation time, while the corresponding ammonia and nitrate nitrogen concentrations are presented in Figure 5. Figure 4 shows that the system achieved and maintained an effective removal of organic matter during this one month period. This figure also shows that a considerable amount of organic matter is removed from the liquid phase in the anoxic denitrification basin.

The organic matter concentration in the anoxic basin, would be approximately 20% of the influent concentration, taking in mind that the ratio of recycle to influent was 4:1. However the actual organic matter concentrations measured in the anoxic basin were lower than the estimated ones. Aerobic biologic degradation of organic matter, however, does not happen in the basin, since the dissolved oxygen concentration measured in it was negligible. The increased substrate removal in the anoxic basin could be attributed to a physical chemical adsorption of organics on the surface of micro-organism particle [8], or to an intracellular bacteria storage mechanism [9].

Increased nitrification capacity was also observed during this period and effluent ammonia nitrogen level measured was negligible. However, the effluent nitrate nitrogen concentrations were high and ranged between 25 to 33 mg/l, even after the operation of the anoxic reaction.

The low BOD_5 values measured in the anoxic basin indicated the necessity of an external carbon source. Methanol was chosen as an external carbon source as it was found to be an effective agent for denitrification treatment of high-ammonia wastewater [10]. Methanol was added in a concentration of 85 mg/l of the total mixture fed to the anoxic basin (influent and recycle).

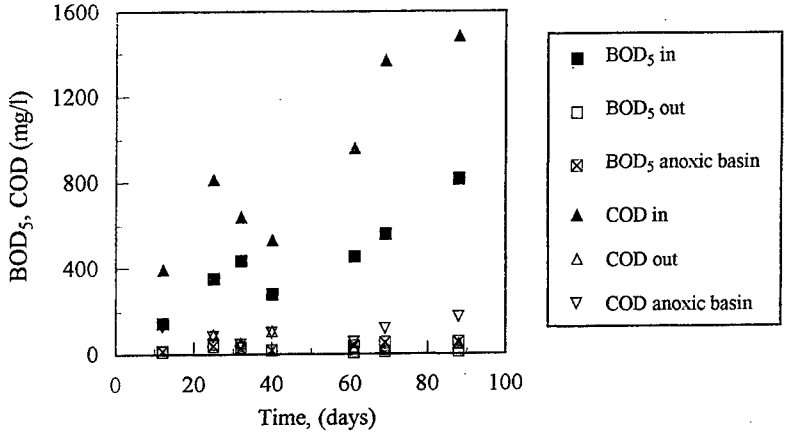


Figure 4. System influent, effluent and anoxic basin organic matter concentration during operation of the activated sludge and the anoxic reactor (methanol addition: 85 mg/l after 40 days, and 150 mg/l after 62 days).

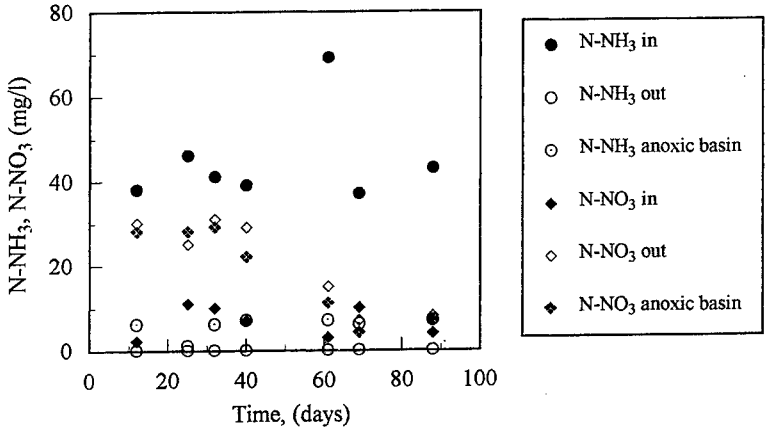


Figure 5. System influent, effluent and anoxic basin nitrogen concentration during operation of the activated sludge and the anoxic reactor (methanol addition: 85 mg/l after 40 days, and 150 mg/l after 62 days).

The required methanol concentration was estimated from theoretical calculations [11]. Chemical analysis of the effluent after 20 days of operation under methanol dosing, showed a better performance of the system compared to the performance without methanol addition. The results of Figures 4 and 5 show that methanol addition resulted in the decrease of nitrate nitrogen to a value of 15 mg/l, while maintaining the effective removal capacity of organic matter. Methanol promoted the production of large quantities of MLSS during the aeration cycle, and sludge wastage was needed frequently.

In order to increase the denitrification capacity of the system, its performance was also examined with the addition of a higher methanol concentration (150 mg/l), and the results have been included in Figures 4 and 5. With this methanol dosage, an effluent nitrate nitrogen concentration lower than 10 mg/l was achieved, and the total nitrogen removal was approximately 85%.

The activated sludge-anoxic reactor system was next used for the co-treatment of a mixture containing 90% v/v domestic wastewater and 10% v/v industrial wastewater. Results for a one month operation, shown in Figures 6 and 7, indicate an effective system performance with an effluent BOD_5 lower than 10 mg/l, and nitrate nitrogen lower than 10 mg/l.

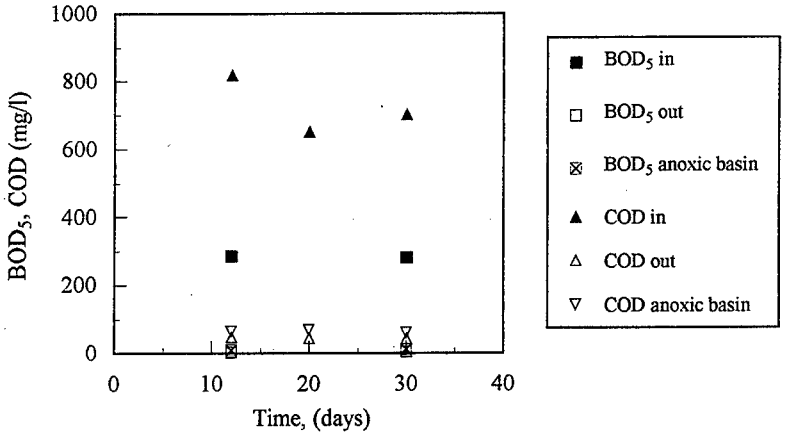


Figure 6. System influent, effluent and anoxic basin organic matter concentration during co-treatment of municipal and industrial wastewater (methanol addition: 150 mg/l).

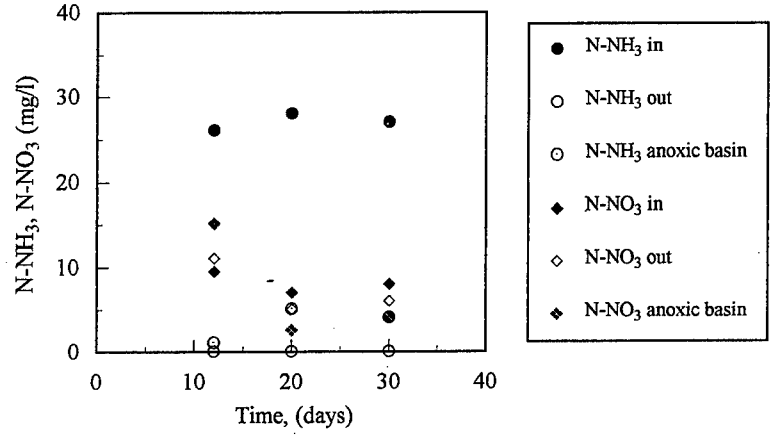


Figure 7. System influent, effluent and anoxic basin organic matter concentration during co-treatment of municipal and industrial wastewater (methanol addition: 150 mg/l).

The toxicity of the lab-scale system effluent and of the anoxic reactor liquor was examined, for both domestic and domestic-industrial wastewater feeds, using *Daphnia magna*. All samples did not show any toxic affect, as the test species survived after 24 h and 48 h of exposure. These data indicate that the treatment plant was able not only to reduce the loadings of the wastewater but also to produce an influent of negligible toxicity.

4. CONCLUSIONS

A laboratory scale, continuous flow activated sludge reactor was used in this work for the treatment of municipal and industrial wastewater from the Thessaloniki Greater Area. The raw municipal and industrial wastewater showed both high toxicity to sensitive *Daphnia magna* due to their high organic and nutrient loading.

An effective system performance in terms of organic matter and total nitrogen removal was achieved after the incorporation of an anoxic basin before the aeration reactor and the addition of methanol as an external carbon source. The treated effluent BOD_5 and nitrate nitrogen concentrations were lower than 10 mg/l and its toxic properties to *Daphnia magna* were negligible.

Acknowledgements: This work was financially supported by the Thessaloniki Sewage Authority.

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ESTIMATION OF MERCURY REMOVAL AND INVESTIGATION OF ITS EFFECTS ON THE ACTIVATED SLUDGE PROCESS

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ABSTRACT

The objectives of this paper are: a) the study of the mercury contaminated wastewater input effects at the activated sludge process in an activated sludge pilot plant and b) the estimation of mercury removal at different concentrations. The concentration of inorganic mercury at the inlet of the plant varied from 0 to 100 μg/l $HgCl_2$. The most important physical, chemical and biological parameters of the pilot plant were measured tactically. Consequently, it was possible to describe, in a more detailed way, the effect that mercury's input had on the activated sludge process and to point at the most critical fluctuations of mercury's removal ability from the pilot plant.

ΥΠΟΛΟΓΙΣΜΟΣ ΤΗΣ ΑΠΟΜΑΚΡΥΝΣΗΣ ΤΟΥ ΥΔΡΑΡΓΥΡΟΥ ΚΑΙ ΔΙΕΡΕΥΝΗΣΗ ΤΩΝ ΕΠΙΠΤΩΣΕΩΝ ΤΟΥ ΣΤΗΝ ΔΙΕΡΓΑΣΙΑ ΤΗΣ ΕΝΕΡΓΟΥ ΙΛΥΟΣ

Γ. Παυλογεωργάτος [(1)], Θ. Λέκκας, Β. Γεωργίου, Γ. Σπάχος, Χ. Στεφανούλης, Π. Τριδήμας, Σ. Σαββοπούλου
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ΠΕΡΙΛΗΨΗ

Ο σκοπός της συγκεκριμένης εργασίας είναι: α) η διερεύνηση των επιπτώσεων της εισροής υγρών αποβλήτων ρυπασμένων με υδράργυρο σε μια πιλοτική μονάδα ενεργού ιλύος και β) ο υπολογισμός της απομάκρυνσης του υδραργύρου σε διαφορετικές συγκεντρώσεις εισόδου. Οι συγκεντρώσεις εισόδου του υδραργύρου κυμάνθηκαν από 0 -100 μg/l $HgCl_2$. Οι σημαντικότερες φυσικές, χημικές και βιολογικές παράμετροι της μονάδας ελέγχονταν τακτικά. Έτσι στάθηκε δυνατόν να περιγραφούν με μεγαλύτερη λεπτομέρεια οι επιπτώσεις που έχει η εισροή Hg στην διεργασία της ενεργούς ιλύος αλλά και να καταγραφούν οι σημαντικές διακυμάνσεις στην ικανότητα απομάκρυνσής του από την πιλοτική μονάδα.

1. INTRODUCTION

Mercury has been denoted to be a List I substance of the directive 76/464 of the EU [1] and its presence in effluents is controlled by two European Union directives [2,3]. Inorganic mercury is known to be toxic in micrograms per liter concentrations [4], but it is the organometallic species methylmercury which presents a cause for concern. Even at nanograms per liter doses methylmercury can cause chromosomal damage and abnormalities in the embryon of an exposed mother [4,5].

The sources of mercury detected in municipal wastewater are [6]: cosmetics, surfactants, pesticides, ointments, colors, photographic equipment and pigments. Mercury is also detected in industrial wastes, deriving from: metal industry (Ferric foundries, non-ferric foundries, plating industry etc.), chemical industry (organic and petrochemical fitment industry, inorganic fitment industry), paper industry, electronic and electrical equipment industry.

This paper comprises several data and conclusions which derived from the two first periods of a two year research program, which had three goals:
1) The examination of mercury's behavior in an activated sludge pilot plant
2) The examination of the effect that the introduction of wastewater which was contaminated with mercury, (C_{Hg}=0,005 to 0,5 mg/l), had on the activated sludge process.
3) The examination of the conversion of the incoming inorganic mercury ($HgCl_2$) to methylmercury.

During the first two periods that the experiment was conducted, the effects of the introduction of inorganic mercury ($HgCl_2$), in concentrations varying from 5-100 μg/l, into the pilot plant were investigated. Special attention was paid on the effects of inorganic mercury on:
- the removal ability of the organic loading, the nutrients and the suspended solids.
- the concentration and the size distribution of the suspended solids in the aeration tank and at the outlet of the pilot plant and
- the number and speciation of the bacteria in the aeration tank of the plant.

2. MATERIALS AND METHODS

2.1 Synthetic waste :

The wastewater that was introduced in the plant was synthetic, made with the addition of 0.325 gr glucose per liter of water. The nutrients were added, in preassigned periods of time, with the introduction of 0.2 gr thiophosphoric ammonia per liter of water and the addition of several trace elements, which are essential for the regular growth of the microorganisms.

2.2 Activated sludge pilot plant:

In order to achieve our research goal we designed and constructed an activated sludge pilot plant (Figure 1). The operational parameters of the pilot plant are presented in Table 1.

TABLE 1: Operational parameters of the activated sludge pilot plant

Parameter	Value	Parameter	Value
V_{AT*}	80 lt	COD in	300-400 mg/l
V_{PT**}	40 lt	Cfertilizer	0,2 gr/lt
Θ	5 h	Q	200 lt/d
Θc	7 d	Q/Qr	1
Height $_{AT*}$	52 cm	Width $_{AT*}$	46 cm
Length $_{AT*}$	56 cm	A_{AT*}	257 cm^2

AT* : Aeration Tank PT** : Precipitation Tank

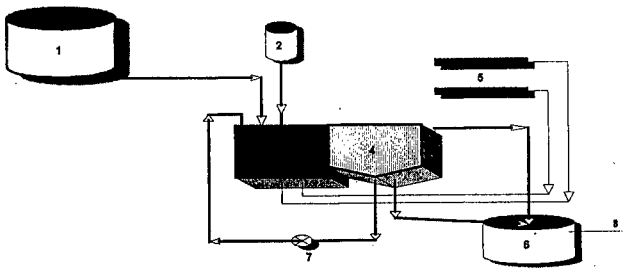


Figure 1: Scheme of the activated sludge pilot plant: 1. Mixture tank of glucose and fertilizer 2. Mercury tank 3. Aeration tank 4. Precipitation tank 5. Aeration pumps 6. Treatment wastes tank 7. Return sludge pump 8. Outlet of the plant.

2.3 Control parameters of the activated sludge pilot plant

During the experiment, several physical, chemical and biological parameters were measured and controlled, on a daily basis (TABLE 2).

TABLE 2 : Parameters measured during the experiment and sample locations

No	Parameter	Analy-tical method	Instruments	Sampling sites [(a)]
1	Total Hg concentration	[7]	Perkin Elmer Atomic Absorption spectophotometer, model 5100 ZL + Flow Injection System (Perkin Elmer FIAS 100).	I,A,O,S
2	Dissolved and particulate Hg	[7]	The same as No 1 parameter	A,O,S
3	Organic and inorganic Çg	[8]	The same as No 1 parameter	A,O,S
4	COD	[7]	Taxen instrument, model VELP-MD6	I, O
5	SCOD	[7]	The same as No 4 parameter	O
6	TOC	[7]	Malvern instrument, model DC - 190	I,O
7	MLSS, SS	[7]	-	A,O
8	Total concentration (% v/v) and distribu-tion of the size of the particulate matter		Mastersizer E by Malvern Instruments Ltd	A,O
9	NH_4	[9]	UV – visible Spectrophotometer model Varian Cary 1E	A,O
10	PO_4	[9]	The same as No 9 parameter	A,O
11	Total number of bacteria (coccoids + rods)	[10]	Inverted microscope Leitz (1000X)	A
12	T	[7]	Thermometers with 0,1 ^{O}C precision	E,A,P
13	PH	[7]	Portable pH-meter by Hanna instruments	A,P
14	DO	[7]	Portable DO-meter by Hanna Instruments	A,P

(a): I: Inlet of the plant, O: Outlet of the plant, A: Aeration tank, P: Precipitation tank, S: Sewage sludge E: Environment.

2.4 Reagents

All samples taken in order to measure the parameters shown in Table 2 were placed in plastic bottles, of different volumes, made by high density linear polyethylene. The mercury introduced into the pilot plant and the determination of the mercury samples was conducted with the use of a standard solution of 1000 mg/l $HgCl_2$ (Merck). All reagents used had analytical purity and they were low in mercury concentrations. The water used was high purity water, type 1, from Milli PO5/MilliQ 185 by Millipore.

2.5 Sampling strategy

At the first introduction of mercury into the plant and every time that the concentration of mercury was increased samples were taken every 2 hours in order to control all parameters selected (Table 2), for the first 48 hours of the experiment. After the first two days had passed, the sampling took place every 5 h (this value is equal to the hydraulic retention time of the pilot plant). The concentration of mercury that was introduced into the pilot plant was increased at least two days after the parameters under control (Table 2) had become stable. The initial fluctuation of the parameters was due to the increase of mercury's concentration introduced into the plant.

The first two periods of the experiment lasted for a period of four months. During this period all mercury concentrations tested were introduced into the pilot plant twice. The pilot plant's operation was interrupted between the two replicates also, maintenance of the pilot plant took place. After the maintenance and cleaning of the system's parts had taken place, the plant was reset in operation and the selected parameters were controlled, for at least 15 days until a steady and high performance was accomplished, before the contaminated wastewater was introduced.

3. RESULTS AND DISCUSSION

The mean values and standard deviation of the most important parameters controlled during the experiment was conducted, are presented in Table 3. Here are presented the values measured during the first period of the experiment, before the contaminated wastewater was introduced into the plant (Period A) and the values of the same parameters after the contaminated wastewater was introduced into the plant, in concentrations varying from the smallest to the highest one used for the experiment (Period B).

TABLE 3: Mean values and Relative Standard Deviation (R.S.D.) of the parameters checked during the experiment

	Period A (45 days)		Period B (94 days)			
	C =0 μg/l $HgCl_2$		C =10 μg/l $HgCl_2$		C =100 μg/l $HgCl_2$	
	Mean	R.S.D. (%)	Mean	R.S.D. (%)	Mean	R.S.D (%)
COD in (mg/l)	304	5	337	6	331	7
COD RA (%) [1]	84	6	85	7	87	6
TOC RA (%)[1]	75	11	95	4	95	3
MLSS RA (%)[1]	73	15	56	17	84	11
Coccoids (Bact/ml)	$8,5*10^6$	48	$6,7*10^6$	55	$15,1*10^6$	59
Rods (Bact/ml)	$2,1*10^6$	88	$2,4*10^6$	78	$6,6*10^6$	77
Total bacteria (Bact/ml)	$10,6*10^6$	53	$9,5*10^6$	58	$21,7*10^6$	61
T (^{0}C)	25	12	25	12	26	13
$PH_{A.T.}$ [2]	7,4	20	7,3	21	7,5	29
D.O. (mg/l O_2) $_{A.T.}$ [2]	3	34	3	31	3	32

(1): RA, Removal Ability, (2): AT, Aeration Tank

3.1 Estimation of mercury's removal ability from the pilot plant

The affinity of mercury for both inorganic [11] and organic particulate matter [12], through adsorption and complexation, explains its comparatively efficient removal during sedimentation. Several authors have reported mercury removals of > 50 % during primary sedimentation. The majority of authors have reported higher mercury removals during activated sludge treatment than during primary sedimentation [13,14]. The different factors affecting the removal ability of metals in the activated sludge process, have been widely discussed elsewhere [15,16].

As it has already been stated, mercury was introduced into the pilot plant as $HgCl_2$, in a solution that was prepared on a daily basis and it was kept in a closed dispenser. The main reason that inorganic mercury was introduced into the plant was to examine mercury's methylation by the existing bacteria in the aeration tank.
As it is apparent in Figure 3, there is a significant fluctuation in mercury's removal ability from the plant. This is attributed to the fact that the recirculation of the plant was interrupted, whereas the start of the recirculation was programmed by an automatic time switch. Consequently, the removal ability of mercury was significantly affected by the time of sampling. However, the fact that the same number of sampling was carried out a while before the beginning, during and after the recirculation for every concentration tested, is worth mentioning.

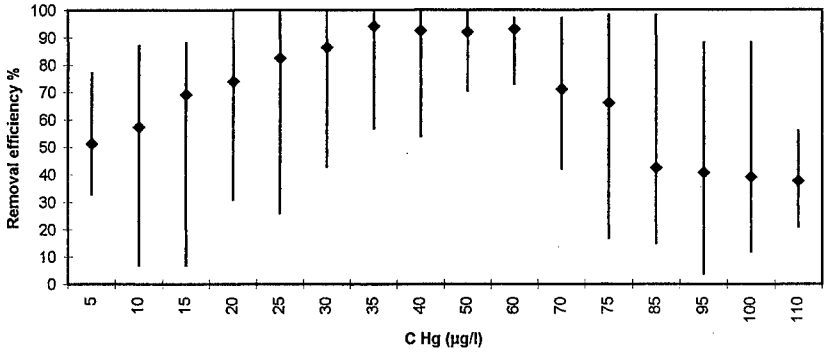


Figure 2: Minimum, mean and maximum values of mercury's removal ability from the pilot plant, at different introductory concentrations of the metal.

3.2 Effects of the contaminated wastewater on the organic loading removal ability

The organic loading control of the pilot plant was conducted by the determination of COD and TOC. Consequently, mercury's effects on the organic loading removal ability are based on the measurements of these two parameters.

The organic loading removal ability was significantly reduced the first 24-36 hours after the introduction of mercury in the aeration tank (the maximum reduction was 10%). According to the available data, this reduction depends on the concentration of the mercury solution introduced into the pilot plant and on whether the pilot plant was already contaminated with mercury or not. That is to say that the performance of the pilot plant depends on whether has already been contaminated with mercury or it's the first time that the contaminated wastewater has been introduced into the plant. This could be explained by the fact that the bacterial community required a specific period of time to adjust to the contaminated environment, which is also confirmed by the control of several

other parameters (such as the values measured for the total number of bacteria and the suspended solids). After the adjustment period had passed, the organic loading removal ability was not only back to normal levels but it also appeared to be slightly increased by 2-5%. This fact can be explained by the increase of the concentration of the large diameter suspended solids (d>122 μm) following the introduction of mercury.

The statistical elaboration of the values obtained from every period that the experiment was conducted, shows that the organic loading removal ability was not significantly different, (results from MANOVA), among the periods that the wastewater was not contaminated with mercury and those that mercury was introduced into the pilot plant.

3.3 Effects of the contaminated wastewater on the size distribution of the suspended solids in the aeration tank

The different concentrations of mercury introduced into the plant did not have a statistically important effect on the concentration of the suspended solids in the aeration tank but on their size distribution (results from MANOVA). More specifically, the introduction of mercury into the pilot plant favoured the generation of large diameter suspended solids (d >122 μm) and restrained the generation of the small diameter suspended solids. This is a very important conclusion, as it indicates a possible way that the bacterial community may react to the disturbance caused by the introduction of the contaminated wastewater.

The higher performance of the pilot plant as far as the removal ability of the solids is concerned and the slight increase of the organic loading removal ability compared with the performance of the first period of the experiment, are attributed to the generation of greater flocs followed by the introduction of mercury into the pilot plant.

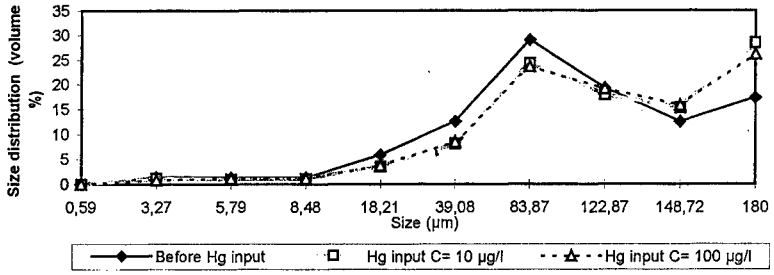


Figure 3: Size distribution of the suspended solids in the aeration tank before and during the introduction of wastewater which was contaminated with mercury.

3.4. Effects of the contaminated wastewater on the bacteria of the aeration tank

The first 36 hours that followed the introduction of mercury into the pilot plant, the total bacterial number in the aeration tank was reduced. More specifically, the number of coccoids was significantly reduced whereas the number of rods was slightly increased. After the first 36 hours had passed, the number of both the bacterial species started to increase and so did, of course, the total bacterial number which was 104% greater at the end of the experiment than the one of the first period (period A) that the experiment was conducted. The growth rate of rods was significantly greater than the one of the coccoids. This is a fact that shows that rods are more tolerant in the contaminated environment than the coccoids.

It is also worth mentioning that although the bacterial number in the aeration tank was doubled after the introduction of the 100 μg/l mercury solution, the organic loading removal ability was not statistically significant compared to the organic loading removal ability of the period A of the experiment. The bacterial determination method that was used in our experiment includes both active and non-active bacteria; this could mean either that the number of the non-active bacteria was significantly increased after the introduction of mercury into the aeration tank or that the bacterial decomposition of the organic loading was decreased. In order to establish which one of the above is correct the ATP of the bacteria should be determined so that the number of the active bacteria can be revealed.

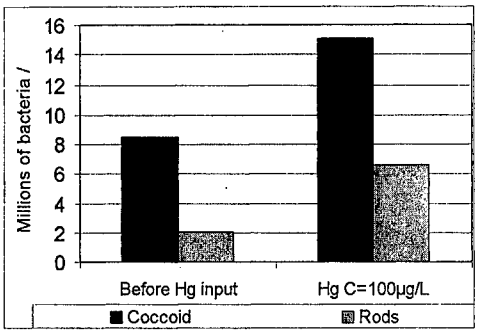


Figure 4: Bacterial number and speciation before and after the introduction of the 100 μg/l mercury solution.

4. CONCLUSIONS

The conclusions that can be drawn from the experiment are:

1. The introduction of wastewater which was contaminated with mercury (maximum concentration 100 μg/l HgCl2) into the pilot plant:

Did not affect in a statistically significant way neither the organic loading removal ability nor the nutrients' removal from the pilot plant. It also didn't affect the concentration of the suspended solids in the aeration tank of the plant.

However, the contaminated wastewater did affect in a statistically significant way:

- the total bacterial number in the aeration tank
- the growth rate of several bacterial species in the aeration tank
- the size distribution of the suspended solids in the aeration tank and at the outlet of the plant.

2. The mean value of the removal of mercury at the concentrations tested was at high levels. At this point it is important to mention that the interrupted sludge recirculation of a plant should be taken into account during the sampling as it affects the estimation of the removal ability of the metal.

3. The adjustment period of microorganisms to mercury, in this experiment, varied from 12 to 36 hours, for all concentrations tested. The adjustment period depended on the concentration of the incoming metal and on whether the pilot plant was already contaminated with mercury or not.

4. The bacterial number in the aeration tank was doubled after the introduction of the 100 μg/l mercury solution, the organic loading removal ability was not statistically significant compared to the organic loading removal ability of the period A of the experiment. This fact could mean either that the number of the non-active bacteria was significantly increased after the introduction of mercury into the aeration tank or that the bacterial decomposition of the organic loading was decreased. In

order to establish which one of the above is correct the ATP of the bacteria should be determined so that the number of the active bacteria can be revealed.
5. The introduction of mercury into the pilot plant favoured the generation of large diameter suspended solids (d >122 μm) and restrained the generation of the small diameter suspended solids. This is a very important conclusion, as it indicates a possible way that the bacterial community may react to the disturbance caused by the introduction of the contaminated wastewater and
6. The rods bacteria are more tolerant in the contaminated environment by mercury than the coccoids bacteria.

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COMPARISON OF DIFFERENT MICROBIAL BIOMASS INDICES AND THEIR IMPACT ON SPOUR ESTIMATION OF WASTEWATER

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ABSTRACT

Experimental data from an aerobic activated sludge pilot plant, where the Total Direct Count (DTC) method of bacteria cells in wastewater was applied, show that, after long acclimatization, MLVSS and $\log_{10}$ of bacteria cells per ml, two independently determined bacteria biomass indices, are linearly related ((r^2=63.5%). Two independent estimations of the specific microbial activity (SPOUR) based on the above indices are, also, linearly related (r^2=89.6%). The accurate determination of SPOUR results in an accurate determination of the sludge biokinetic constants K^0_S και U^0_m. In this way, the prediction of plant performance under various loading conditions and wastewater quality may become more accurate.

ΣΥΓΚΡΙΣΗ ΔΙΑΦΟΡΩΝ ΔΕΙΚΤΩΝ ΜΙΚΡΟΒΙΑΚΗΣ ΒΙΟΜΑΖΑΣ ΚΑΙ Η ΕΠΙΔΡΑΣΗ ΤΟΥΣ ΣΤΗΝ ΕΚΤΙΜΗΣΗ ΤΟΥ SPOUR ΤΩΝ ΛΥΜΑΤΩΝ

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ΠΕΡΙΛΗΨΗ

Πειραματικά αποτελέσματα από αερόβια πιλοτική μονάδα ενεργού ιλύος, όπου εφαρμόσθηκε μία μέθοδος για άμεση μέτρηση βακτηρίων, δείχνουν ότι, μετά από μεγάλο χρόνο εγκλιματισμού, τα MLVSS και ο $\log_{10}$ του αριθμού των κυττάρων των βακτηρίων ανά ml, δύο ανεξάρτητοι δείκτες της μικροβιακής βιομάζας της ιλύος, σχετίζονται γραμμικά (r^2=63.5%). Δύο ανεξάρτητοι υπολογισμοί της ειδικής δραστικότητας της ιλύος (SPOUR) με βάση τους δύο παραπάνω δείκτες σχετίζονται, επίσης, γραμμικά (r^2=89.6%), επιτρέποντας τον ακριβέστερο προσδιορισμό των βιοκινητικών σταθερών K^0_S και U^0_m. Έτσι, μπορεί να επιτευχθεί η ακριβέστερη πρόβλεψη της απόδοσης των μονάδων σε διάφορες συνθήκες φόρτισης και ποιότητας λυμάτων.

1. INTRODUCTION

Activated sludge, one of the most widely used methods for wastewater treatment, is based on the development of bacterial microorganisms to aerobically stabilize wastewaters. Microbial activity can be assessed quite accurately by measuring the Oxygen Uptake Rate (OUR) [1]. Only active microbial biomass uses oxygen during the course of substrate utilization and microbial maintenance. Therefore, the measurements of OUR would reflect the extent of microbial activity of a particular activated sludge. The relation between OUR and substrate concentration resembles the relationship defined by Monod and can be mathematically expressed as follows [2]:

$$OUR = \frac{U^0_m * S * X}{K^0_s + S} \qquad (1)$$

where,
U^0_m = maximum specific OUR
K^0_s = half-rate concentration
S = equilibrium substrate concentration
X = biomass concentration

The biokinetic constants U^0_m and K^0_s reflect the characteristics of a specific activated sludge and can be used to represent its microbial viability. These constants may be determined graphically from experimental data by taking the double reciprocals of the equation (1) and rearrange it to obtain the linear form of Lineweaver-Burk transformation [3]. The exact definition of the biokinetic constants of a sludge is of crucial importance, especially when toxic effluents or wastewater of unknown quality are present in the incoming wastewater.

It follows that, the degree of accuracy of the determination of the constants U^0_m and K^0_s is directly influenced by the degree of accuracy in the measurement of the Specific OUR; this is defined as the OUR/X, whose value is, obviously, influenced by the degree of accuracy of the determination of X. For the determination of the amount of viable microbial biomass (X), Mixed Liquor Suspended Solids (MLSS) and Mixed Liquor Volatile Suspended Solids (MLVSS) are traditionally used. However, in these measures no distinction is made between living cells and debris of either organic or inorganic origin [1]. Furthermore, only part of the organic fraction of the sludge measured as MLVSS is truly viable microbial biomass. It is estimated that 50% of the bacteria are moribund or dead [4]; this percentage may be even higher reaching 90% [5]. As a result, the MLSS and MLVSS measures may be not only crude but also, in some cases, false indices of the active microbial biomass in wastewater.

Numbers of active heterotrophic bacteria can be determined by the Membrane Filter Count method (MFC) which has its own drawbacks and may result in an underestimation of bacterial numbers by several orders of magnitude [6]. However, during the last decades, methods for the Direct Total Count (DTC) of viable bacteria and other microbes in water have been developed with the aid of epifluorescence microscopy techniques. These methods have been routinely used in the fields of aquatic microbiology and ecology [7], but so far, only few attempts have been made to adjust and use them in the field of wastewater technology [8].

In this study, an application of the DTC method in wastewater is presented. Also, comparisons are made between the bacterial counts determined by the DTC method and the MLSS, the MLVSS and the MFC methods, in order to assess their degree of reliability as sludge biomass measures. The degree of influence that these different biomass measures exert on the accuracy of estimation of SPOUR is also evaluated.

2. MATERIALS AND METHODS

2.1 The Pilot reactor process parameters

The data were collected from a laboratory-scale pilot plant (Fig. 1), which consisted of a 40 L

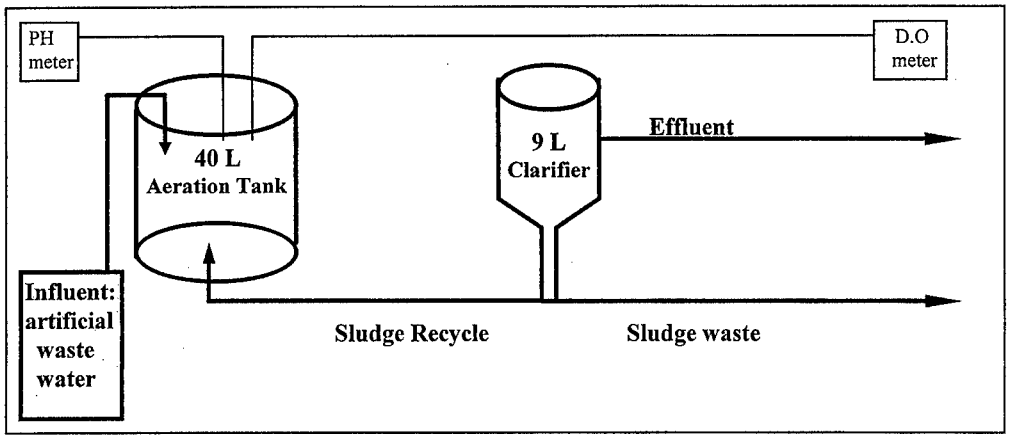


Figure1. Diagrammatic presentation of the aerobic pilot plant.

complete-mixed aerator compartment with double glass walls and a 9 L clarifier with tapered bottom that enabled the settled sludge to be accumulated and pumped back to the aerator tank. The aerator temperature was maintained constant at 23 ^{0}C with the aid of a constant temperature water bath. The seed has been obtained from the city of Xanthi wastewater treatment plant. Synthetic wastewater [2] was prepared fresh daily, with a chemical composition summarized in Table 1. The incoming flow rate was 1.5 L/h resulting in a hydraulic retention time of 27 h. In order to maintain aerobic conditions, an air compressor provided air at a rate of 500 L/h. pH was kept within the range of 7.15-7.25 with the aid of an appropriate electrode and the automatic addition of acid or base. Settled sludge from the clarifier was fed back to the aerator at a rate of 750 ml/h. In summary, the system operating parameters were: COD=250-300 mg/L, total N=32 mg/L, total P=70 mg/L, pH=7.2, influent flow rate=1.5 L/h, recycle ratio=0.5, reactor liquid temperature=23 ^{0}C. Pilot plant performance, in terms of COD removal, ranged from 60% to 85 %.

TABLE 1 Synthetic wastewater composition used in the aerobic pilot plant

Chemicals	Stock solution (g/L)
Dextrose	45.00
Urea	17.50
Nutrient broth	25.00
$MgSO_4$.	5.00
KCl	0.75
NaCl	0.75
$FeCl_3.6H_20$	0.25
K_2HPO4	70.00
KH_2PO4	22.40

Under these conditions, the MLVSS have reached 1.26 g/L, one month after the beginning of the plant operation. Samples were taken from the influent, the mixed liquor and the effluent. The

sample analyses were performed according to methods described in [9] and they included: COD in the influent and the effluent and SS, VSS in mixed liquor.

2.2 Measurement of the oxygen uptake rate

The OUR was measured with a YSI oxygen meter, equipped with an appropriate probe providing an airtight seal with a 300 ml BOD bottle in a constant 23 ^{0}C temperature stirred water bath. Duplicate samples were saturated with air with the aid of an air pump and sealed with the probe; the drop of dissolved oxygen was recorded every minute for 15 minutes. The slope of oxygen drop with time gives the OUR in mg/L* min O_2.

2.3 Determination of the bacterial numbers

2.3.1 Direct Bacterial Count with epifluorescence microscopy

The method was first proposed in 1980 [10], and unlike the heterotrophic plate count methods, it precludes errors caused by viability-related phenomena such as selectivity of growth media, cell clumping and slow growth rates [9]. According to the DTC method bacterial cells are stained with 4', 6-diamidino-2-phenylindole (DAPI) a DNA-specific dye and illuminated with UV light that causes the DAPI-DNA complex to fluoresce at about 390 nm. In this way, bacteria cells are easily distinguished and may be directly counted with minimal error within 30 minutes after sampling.

The method was applied as follows: 500 ml of mixed liquor duplicate samples were homogenized for 5 min; addition of 1-2 drops of Tween 80 and shaking in a minishaker facilitated the homogeneous dispersion of bacteria. Samples were then diluted with phosphate buffer in order to maintain constant pH and avoid shock that may cause bacterial death. 20 ml of the diluted samples were then fixed with 1 ml 37% formalin.

For the staining and collection of bacterial cells, a Millipore glass apparatus and adjustable air pump were used. The apparatus consisted of a 25 ml glass tower, fitted with a 25 mm diameter glass funnel and a stopper fitted in a vacuum flask connected to the air pump. Black, 25 mm diameter polycarbonate filters of 0.22 μm porosity were used for the collection of bacterial cells. 2 ml of the diluted sample were placed in the tower, stained with DAPI for 5 minutes and filtered at reduced vacuum (<13 cm Hg) in order to avoid cell damage. The wet filter was then mounted with non-fluorescent oil on a glass slide and examined under 500 X and 1250X magnifications with oil-immersion objectives. Sterilized glassware and dilution water were always used.

An Olympus BH2 microscope equipped with fluorescence attachment, suitable for UV excitation, was used. Light, produced by a high pressure mercury burner, passes through (1) a UG exciter filter that allows only light of wavelength from 300 to 400 nm to pass through, (2) a dichroic mirror (DM 400) to reflect light and (3) an appropriate L-420 barrier filter to give optimal fluorescence. When excited with UV light at a wavelength of 365 nm the DAPI-DNA complex fluoresces at 390 nm or higher. As a result, against the dark background of the filter, sludge flocs and debris stained with DAPI seem yellow and are easily distinguished from bacteria which fluoresce a bright blue color. Bacteria are directly counted, at 1250X, in about fifteen optical fields or until a total of 600 cells per examined filter is reached. For statistical purposes, the original sample must be diluted properly so that no more than 40 bacterial cells appear per optical field.

2.3.2 Bacterial Membrane Filter count

For the determination of active heterotrophs in mixed liquor the method proposed by Hoffman and Atlas [9] has been followed. Both R2 agar and Plate Count agar were used. The addition of 1% TTC (1ml/100ml culture medium) facilitated counting by dying the colonies red. Properly diluted 100 ml samples were filtered through a sterile cellulose membrane filter of 0.45 μm porosity. The filter was then placed on a petri dish and incubated at 35 ^{0}C for 48 h. A colony counter was used to

count colonies; samples that produced more than 300 colonies were ignored. Since the method is suitable for samples with low bacteria counts, various sample dilutions were tested and the results were compared with DTC results.

3. RESULTS AND DISCUSSION

3.1 Comparisons of measures of bacteria biomass

The sampling period started *one month after* the beginning of the pilot plant operation and it was divided into two phases: During the first phase there was no sludge waste; this phase lasted for about one month, corresponds to samples 1 to 12 (see Figure 2). Therefore, the twelfth sample corresponds to a total sludge age of about 60 days, which coincides with the acclimation time of the sludge. The second phase started with a sludge waste of about 50% of the clarifier volume and lasted, also, for about one month (samples 13 to 18).

Various factors (raw waste characteristics, sludge age, temperature e.t.c.) can cause the ratio of active to inactive solids (MLVSS / MLSS) to change appreciably [2]. However, in our case, this ratio remained almost constant. The regression of MLVSS on MLSS was linear (r^2 = 88.9%,) with a slope of 0.58, which corresponds to the above mentioned ratio; this ratio value is rather low compared to typical values of 65-75% [4,11], maybe due to the old age of the sludge.

During the first phase of the plant operation, bacterial population measured by DTC follows an almost ideal exponential growth curve, (Figure 2). The sludge waste in the second phase is reflected by a sharp decline of the DTC. However, the corresponding MLVSS values fluctuate much less both during the first and the second phase. No linearity between MLVSS and DTC was found to exist either in the first or the second phase of plant operation. Even though the first seven values of MLVSS and DTC shown in Fig. 2, just before the upward leap of bacteria growth curve, seem to overlap and a linear relationship may be suspected, plotting the data in a different scale (Fig. 3) reveals clearly that MLVSS and DTC fluctuate quite independently.

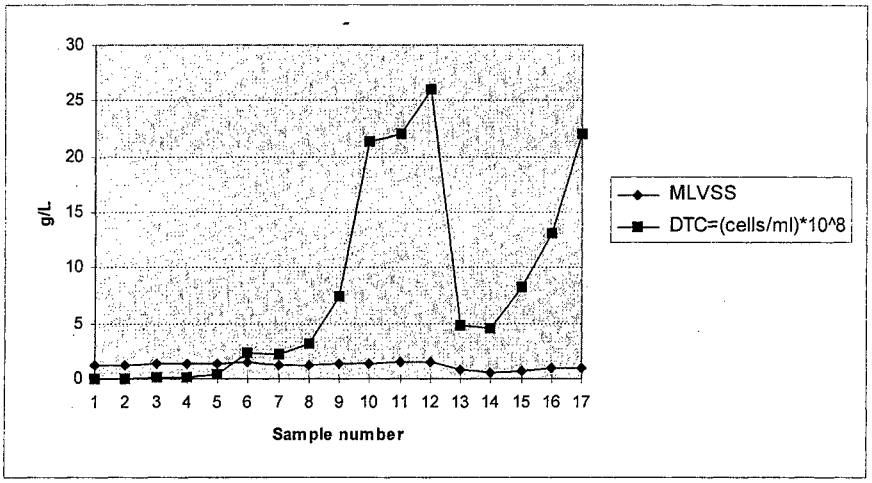


Figure 2. MLVSS and bacterial cells/ml * 10^8 counted by the Direct Total Count (DTC) method of epifluorescence in an aerobic pilot plant fed with synthetic wastewater during a three-month period of operation

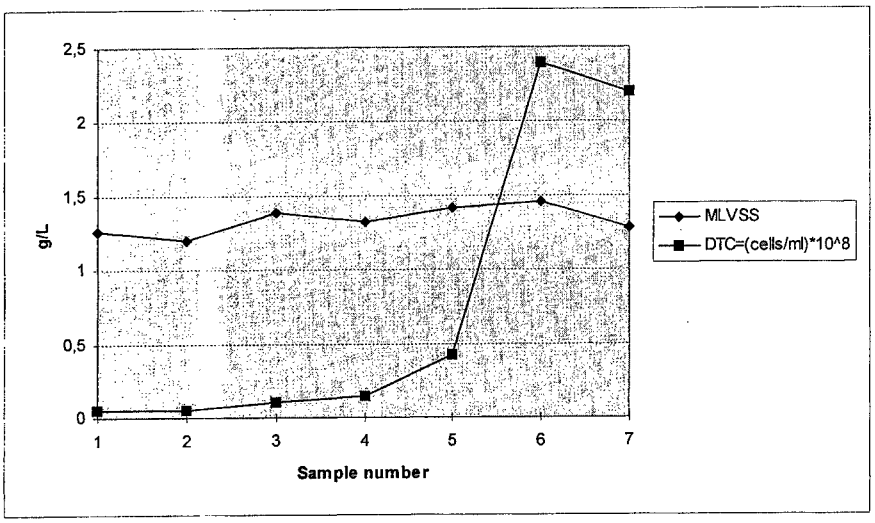


Figure 3. MLVSS and bacteria cells/ml* 10^8 counted by the Direct Total Count method of epifluorescence in an aerobic pilot plant fed with synthetic wastewater at the first stages of the bacteria growth

In order to damp the strong DTC fluctuations, the log(DTC) was plotted against MLVSS (Fig.4). During the first phase, the discrepancy between log(DTC) and MLVSS gradually becomes smaller and towards the end of the phase (samples 10,11, and 12) the two values almost overlap. During the second phase, values of log(DTC) and MLVSS show a much better correspondence. For sample numbers 11 to 18, corresponding to a sludge acclimation time of over 50 days, the linear regression of log(DTC) on MLVSS takes the form of $\log(DTC) = 0.385 + 0.697(MLVSS)$, ($r^2$ =63.5%).

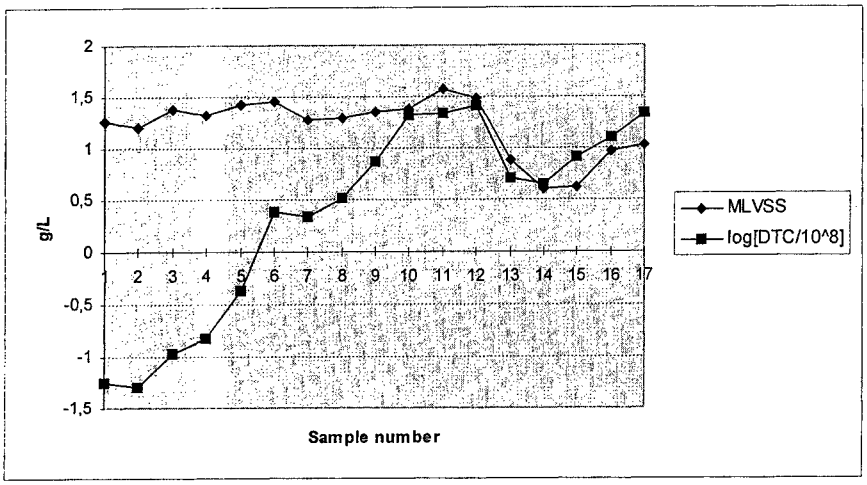


Figure 4. MLVSS and log10 cells/ml*10^8 in an aerobic pilot plant fed with synthetic wastewater during a three-month period of operation

In summary, within the experimental frame of this work, MLVSS *do not represent an accurate measure* of active bacteria biomass. MLVSS seems to be related, at least to some extent and after a prolonged period of sludge acclimation, to the log of bacteria cells per ml. More experimental work is needed to better establish the relation between the number of bacteria cells and MLVSS, especially under various conditions of sludge age and waste water characteristics.

As mentioned earlier, the MFC method is suitable for samples with low bacteria number. In this work, an effort has been made to investigate the possibility of using FMC method and getting results comparable with the DTC method. This is quite crucial, since the FMC is much more cheaper, especially regarding the initial cost of the purchase of an epifluorescence microscope. Bacteria numbers determined by the FMC method produced results up to four orders of magnitude lower than the bacteria numbers determined by the DTC method. However, when the original wastewater sample was diluted to a rate of 10^{-8}, FMC counts approached those of DTC method.

More experimental work is currently under way to establish the proper dilution rates and detailed experimental protocol for the application of FMC method in wastewater, in order to produce bacteria counts comparable with the DTC method.

3.2 SPOUR estimation

Relatively low and constant MVLSS and low OUR values indicate the presence of a bacterial community in equilibrium [2]. Measurements of the OUR began at the 10^{th} sampling, when the sludge was about 50 days old and the log of bacteria cells/ml and MLVSS seemed to converge (Fig. 4). The presence of an old bacteria population in equilibrium is reflected clearly in the almost constant values of MLVSS (samples 9,10 and 11), Fig. 2, and the corresponding low OUR values in Figure 5. The sludge waste, which was induced after the 12^{th} sampling, resulted, after three days (13^{th} sampling) in a younger, more active bacteria population, with an OUR value five times higher. The {OUR / log(DTC)} calculation of SPOUR seems to be more sensitive than {OUR / MLVSS} in reflecting this perturbation of the system.

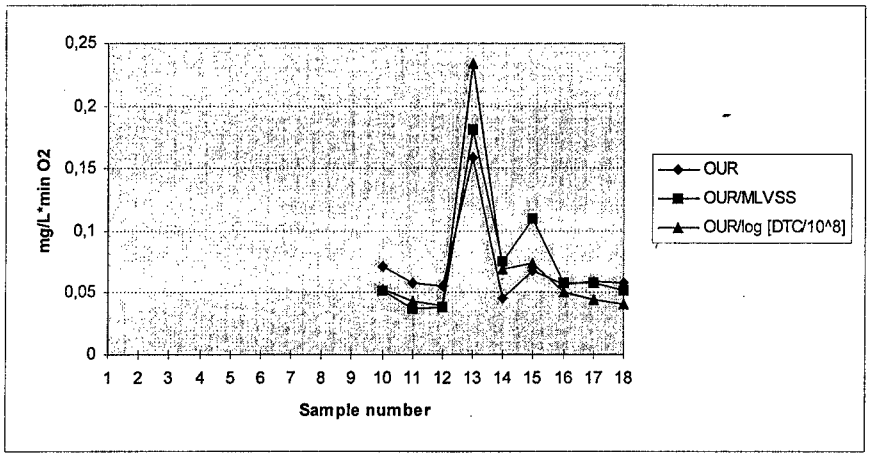


Figure 5. Oxygen Uptake Rate and Specific Oxygen Uptake Rate calculated using two different sludge biomass measures in an aerobic pilot plant.

The relationship of the two independent SPOUR estimations that resulted by the division of OUR by MLVSS and by the log(DTC), respectively, was found to be strongly linear (r^2 = 89.6%) and has the form: {OUR / log(DTC)} = -0.022+1.28 {OUR / MLVSS}.

Definite conclusions about the degree of sensitivity of {OUR/ log(DTC)} versus the sensitivity of {OUR/MLVSS} cannot be drawn at this moment. However, more experimental work is under way to reveal the true limits of MLVSS measure of bacteria biomass and its impact on the estimation of the sludge viability and activity.

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LEACHABILITY OF HEAVY METALS IN GREEK FLY ASH FROM COAL COMBUSTION

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ABSTRACT

A laboratory leaching test was used to determine the potential mobility of Pb, Cd, Cr, Cu, Zn, Ca and Mn in fly ash samples, originated from four locations in Northern Greece, in order to assess their leachability when these wastes are disposed of. The cascade leaching test was used at liquid to solid ratios (L/S) ranging between 5 and 100.

All fly ash samples exhibited strong alkaline reaction, as indicated by pH values > 11,75 at L/S = 10 and contact time of 10 min. In general, Ca showed the highest leachability and Mn the lowest in all samples. The percentage of leached amounts follows the trend Ca > Cd > Cr > Pb > Zn > Cu > Mn for samples from Kardia and Agios Dimitrios, Ca > Pb > Cd > Cr > Cu > Zn > Mn for the sample from Ptolemais, and Ca > Cu > Cd > Pb > Cr > Zn > Cu > Mn for the sample from Amideo.

ΕΚΠΛΥΣΗ ΒΑΡΕΩΝ ΜΕΤΑΛΛΩΝ ΑΠΟ ΙΠΤΑΜΕΝΕΣ ΤΕΦΡΕΣ ΤΗΣ ΕΛΛΑΔΟΣ

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ΠΕΡΙΛΗΨΗ

Στην εργασία αυτή χρησιμοποιήθηκε ένα τέστ έκπλυσης σε εργαστηριακές συνθήκες, προκειμένου να προσδιορισθεί η δυνατότητα έκπλυσης διαφόρων μετάλλων (Pb, Cd, Cr, Cu, Zn, Ca και Mn) από τέσσερα διαφορετικά δείγματα ιπτάμενης τέφρας από τη Βόρεια Ελλάδα, όταν η τέφρα αυτή εναποτίθεται. Στο διαδοχικό τέστ έκπλυσης χρησιμοποιήθηκε μια αναλογία υγρού-στερεού (L/S) από 5 έως 100.

Τα δεδομένα των πειραμάτων χρησιμοποιήθηκαν επίσης προκειμένου να εκτιμηθεί η έκπλυση της ιπτάμενης τέφρας από το νερό (L/S=10). Παρατηρήθηκε μια εξάρτηση της ικανότητας έκπλυσης σε συνάρτηση με το pH.

1. INTRODUCTION

Combustion of coal in power generating plants produces a number of residues (bottom ash, boiler slag, fly ash, flue gas desulfurization sludge, and noncaptured particulates). The relative amount of each residue depends on the power plant configuration and on the emission control devices available [1].

Trace metals, though present as relatively small fraction in fly ash, are of special interest, due to their cumulative build up and high toxicity to man, plants and animals through air, water and soil intake. Since many trace elements existing in fly ash, can leach out and contaminate soils as well as surface water and groundwater resources, the study of them has been regarded in recent years as very important in connection with protection of the environment. The discussion about test methods to assess the leaching behaviour of waste materials has entered a new phase as the urge to recycle and re-use waste materials has been increasing. This policy of recycling and re-use of waste materials requires a better control over the undesired release of contaminants into the environment.

The extent to which contaminants can be released by fly ash into the environment has been studied aggressively within the last decade. These studies have been driven by the necessity to find a more economical alternative to the storage or disposal of fly ash in landfill systems [2, 3]. Therefore, the estimation of the leaching potential for such toxic elements is important in assessing the possible environmental impacts associated with fly ash reuse and disposal [4, 5]. With this intention, regulatory agencies and technical institutions have developed standard laboratory extraction procedures to simulate natural leaching conditions in the absence of field data on leachate composition [6-10].

Worldwide, many different leaching tests have been developed to assess the release from waste materials under a variety of conditions. The same type of judgement (e.g. disposal conditions) is passed on the same type of materials using widely different leaching tests. In recent studies, the leaching data of different tests carried out on the same material have been compared.

The objective of this work was to assess the elemental leaching behaviour of fly ash by means of a standardized procedure [11]. The fly ash was produced by coal-fired electric power plants in Ptolemais Basin in Northern Greece. The Pliocene lingite deposits of the Ptolemais Basin are under intensive exploitation by opencast mining, and are used mainly for electric power generation. Although disposal of fly ash constitutes a serious environmental problem in Greece, there are no studies dealing with the leaching behaviour of greek fly ash. Knowledge of the leaching behaviour may be important for several reasons:

- To assess the elemental leaching behavior of fly ash - amended soil to devise environmentally and agronomically sound management practice.
- What proportion of the elements present in the residue can be removed by leaching.
- What will be the behaviour of a dump of this material when exposed to external influences and how will this affect the environment in Northern Greece.

2. MATERIALS AND METHODS

2.1. Fly Ash

Fly ash samples used for the leaching experiments were collected from four different thermal power plants located in Northern Greece: Sample 1 (Kardia), Sample 2 (Ptolemais), Sample 3 (Amideo)

and Sample 4 (Agios Dimitrios). Every fly ash sample examined was a composite sample of four different subsamples from each station.

Fly ash samples were dried at 105°C for 48 hours. All glassware, plasticware and teflonware were soaked in 20% nitric acid for 24 h and rinsed with deionized water prior to use.

2.2. Acid - base behaviour

The acid-base behaviour of the material was determined by the initial and the stabilized pH value of the contact liquid, measured after 1 and 10 minutes. Under these conditions, the system was not yet seriously affected by solubility limitations.

- If the pH (10 min) < 7, the material is said to be "acidic".
- If the pH (1 min) > 10, the material is said to be "alkaline". Otherwise, the material is said to be "neutral".

2.3. Standard leaching test

The leaching test developed by H. A. van der Sloot et al. (1984) was used in the present study. Unlike existing methods [12], the present test aims at a close approximation of field conditions, so as to improve the prediction of possible environmental effects.

Our objective was to study the long-term leaching behaviour and determine the maximum quantity of the material leached out of the fly ash. Therefore, the cascade rather than the column leaching test was used.

In the cascade test, the same quantity of solid residue is extracted a number of times with fresh leaching agent. An advantage over the column test is that in special cases the test may be performed on unbroken material and that high L/S ratios are reached in much shorter times. The test utilises a liquid to solid ratio from L/S = 5 to L/S = 100.

All the leachates were separated from the fly ash by vacuum filtration using a 0.45 μm Millipore filter. The filtered leachates were transferred to glass flasks, acidified with nitric acid to pH < 2 and stored prior to analysis. For the measurements a Perkin-Elmer Model 2380 AAS equipped with a graphite furnace HGA 400 was used. The heavy metals determined were lead, cadmium, zinc, copper, manganese, chromium and calcium.

2.4. pH effect

To assess the effect of pH on heavy metals leaching from fly ash, experiments were conducted at pH values 4, 6 and 8. Fifty g of fly ash was contacted with 500 mL of deionized water adjusted to the appropriate pH value with HCl and NaOH solutions. Liquid samples were withdrawn at selected times and analyzed by A/A.

3. Results and Discussion

3.1. Fly ash composition

The results of the quantitative analysis of the used fly ash samples are shown in Tables 1 and 2. Table 1 presents the major components and Table 2 presents some of the minor components contained in the ash.

Calcium oxide is the most abundant component in 2 of the 4 samples (1 and 4) followed by SiO_2 and Al_2O_3. In samples 2 and 3, SiO_2 is most abundant, followed by CaO and Al_2O_3.The least abundant major components in all samples are TiO_2, Na_2O and K_2O. In all samples, Mn was the most abundant trace element, whereas Cd was the least abundant. Cr was the second most abundant element in samples 1 and 2 followed by Pb. In samples 3 and 4 the order between Cr and Pb was reversed (Table 2).

TABLE 1: Bulk chemical composition of fly ash

Oxide	g/kg			
	Sample 1	Sample 2	Sample 3	Sample 4
Si as SiO_2	247.9	366.5	393.9	340.5
Fe as Fe_2O_3	44.1	54.6	37.3	66.8
Al as Al_2O_3	128.8	153.2	186.6	108.6
Ti as TiO_2	2.4	3.4	10.5	2.5
Ca as CaO	483.8	322.5	247.9	372.5
Mg as MgO	42.6	34.7	39.0	44.1
S as SO_3	44.3	72.6	72.5	49.0
Na as Na_2O	3.1	11.3	7.5	4.6
K as K_2O	6.4	12.1	9.2	8.0

TABLE 2: Total concentration of minor components in fly ash samples (mg/kg)

Element	Sample 1	Sample 2	Sample 3	Sample 4
Cd	13.2	11.7	11.6	14.4
Pb	143	123	139	131
Zn	59.6	86.9	78.0	63.7
Cu	31.8	62.8	63.3	32.4
Cr	151	160	110	119
Mn	280	275	330	213

3.2. Acid base behaviour

The acid-base behaviour of fly ash indicates to what extent the pH of the contact liquid was affected by the acidic and alkaline components in the ash. This was determined for the 4 fly ash samples generated from coals of different origin by measuring the pH of the contact liquid at an L/S ratio of 100 after 1 and 10 minutes contact time. All the examined samples were alkaline (Table 3). This can be explained on the basis of the large percentage of CaO in all fly ash samples.

3.3. Leaching test

Cumulative percentages for a number of elements leached out of a fly ash sample (Kardia) as a function of the liquid to solid ratio (L/S) used in the cascade test, are presented in Figure 1.

TABLE 3: Acid-base behaviour of the examined fly ash samples

	pH (1 min)	pH (10 min)	Characterisation
Sample 1	12.00	12.02	alkaline
Sample 2	11.73	11.75	alkaline
Sample 3	11.80	11.93	alkaline
Sample 4	12.02	12.12	alkaline

The leaching order for some elements (e.g. Mn, Cu and Zn) was independent of L/S. For others, the leaching order was a function of L/S. For example, the leaching order for Ca was third from the top after Cr and Pb for L/S < 40 and first from the top for L/S > 40 (Figure 1).

In general, Ca showed the highest leachability and Mn the lowest in all samples. The percentage of leached amounts for the different metals follow the trend Ca > Cd > Cr > Pb > Zn > Cu > Mn for samples 1 and 4 Ca > Pb > Cd > Cr > Cu > Zn > Mn for Samples 2 and Ca > Cu > Cd > Pb > Cr > Zn > Cu > Mn for sample 3.

Figure 2 presents the variation of pH as a function of L/S for the four fly ash samples. The decrease in pH was attributed to the depletion of materials controlling these parameters as the L/S ratio was increased.

Figure 1 permits a translation into practice, using the appropriate L/S ratio, for the disposal scenario of interest. For example, the quantity of heavy metals leached into fly ash transport water (L/S approximately 10) was calculated for all fly ash samples (Table 4). Thus, at an initial chromium content of 160 ppm (Sample 2) a concentration of 12 ppm may be expected in the transport water.

TABLE 4: Expected quantities (%) of heavy metals leached into fly ash transport water (L/S = 10)

L/S = 10	Ca	Cd	Cr	Cu	Mn	Pb	Zn
Sample 1	6.6	5	14.7	0.7	0.2	10.6	1.7
Sample 2	11.9	4.8	7.5	0.9	0.2	12.9	1.1
Sample 3	10.6	8.3	5.3	0.9	0.17	11.3	1.5
Sample 4	6.3	5.9	17.8	1.8	0.3	7.2	2.5

3.4. The pH effect on leaching of fly ash

The effect of pH on leaching is presented in Figure 3 for Sample 3. The six metals studied (Cd, Cr, Zn, Pb, Mn and Cu) exhibited an increase in the leachate concentration as the leachant pH was reduced from 8 to 4. It is evident from these figures that Pb followed by Cd exhibit the maximum % extractability in all pH values. The least leachable components were Cu and Mn.

The increase in the leachability of all metals at lower pH levels can be attributed to an increase in the intensity of attack on the ash mineral phases that contain these elements [13-15].

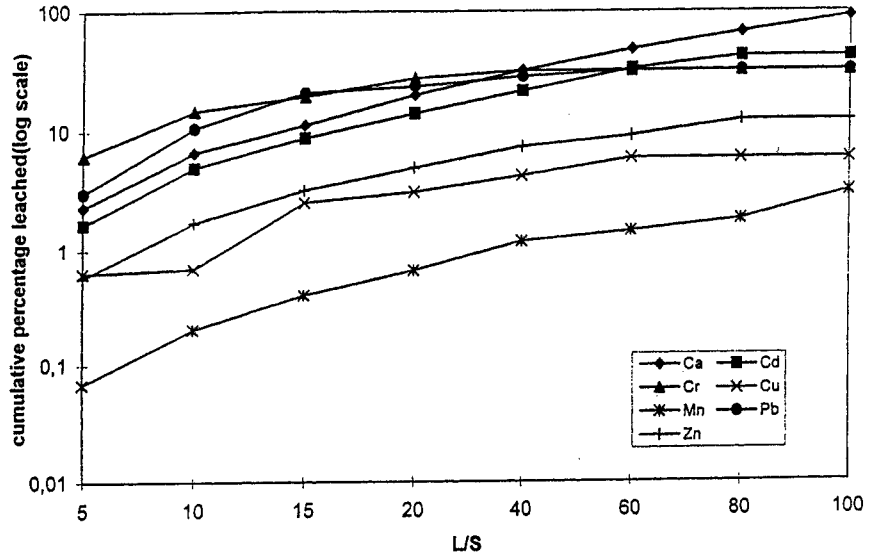


Figure 1: Cumulative percentages leached from fly ash sample 1 (Kardia) as a function of liquid to solid ratio (L/S).

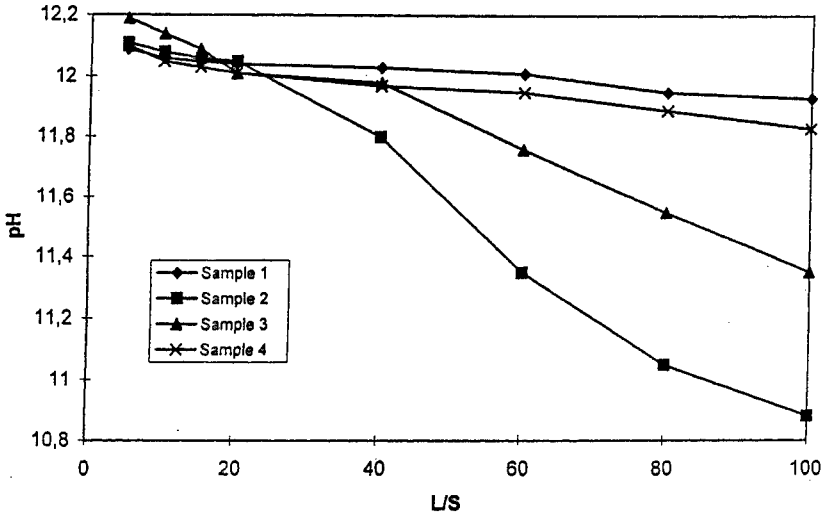


Figure 2: Variation of pH as a function of L/S.

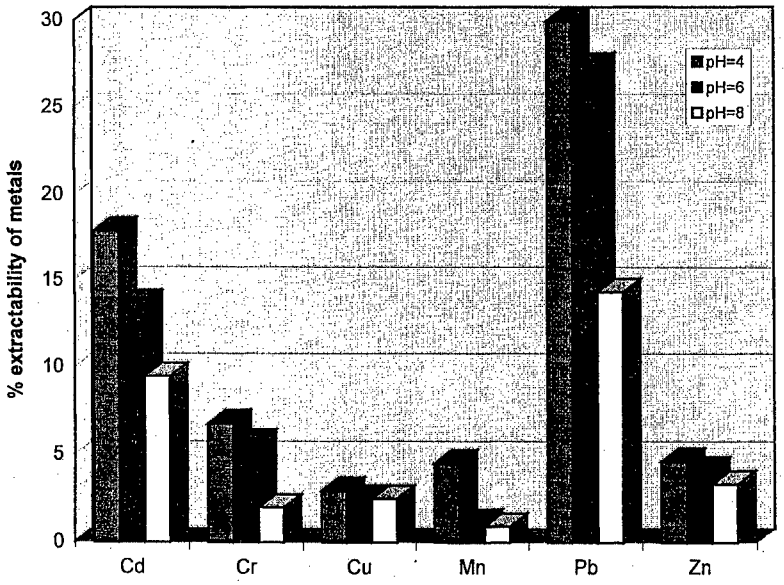


Figure 3: Effect of pH in heavy metal leaching from fly ash (Sample 3). Leaching time 48 hrs.

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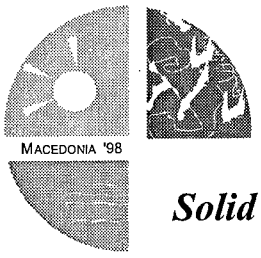
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Solid waste management

MODELLING AND FORECASTING OF MUNICIPAL SOLID WASTE GENERATION RATES

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ABSTRACT

A methodology dealing with the stochastic and deterministic modelling of daily and monthly municipal solid waste production rates is presented. Each sequence of values was modelled by a range of different deterministic models, as well Box-Jenkins stochastic models consisting of autoregressive, moving average and seasonal terms. Generally, deterministic models and time series models demonstrated statistical fit. Finally, modelling of the trends and forecasting ability was quite satisfactory in most cases.

ΜΟΝΤΕΛΟΠΟΙΗΣΗ ΚΑΙ ΠΡΟΒΛΕΨΗ ΤΗΣ ΕΞΕΛΙΞΗΣ ΤΩΝ ΠΟΣΟΤΗΤΩΝ ΑΣΤΙΚΩΝ ΑΠΟΡΡΙΜΜΑΤΩΝ

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ΠΕΡΙΛΗΨΗ

Στη συγκεκριμένη εργασία παρουσιάζεται μια μεθοδολογία μοντελοποίησης και πρόβλεψης ποσοτήτων στερεών αποβλήτων χρησιμοποιώντας στοχαστικά και αιτιοκρατικά μοντέλα. Για καθεμιά από τις χρονοσειρές που μελετήθηκαν (χρονοσειρές συνεχόμενων ημερήσιων τιμών και χρονοσειρές μηνιαίων ποσοτήτων) χρησιμοποιήθηκαν μια σειρά από ντετερμινιστικά μοντέλα και μοντέλα χρονοσειρών Box - Jenkins που περιείχαν όρους αυτοπαλινδρούμενους ή/και όρους κινητού μέσου ή/και εποχικούς όρους. Γενικά πάντως σε κάθε περίπτωση τα μοντέλα που επιλέχθηκαν είχαν άλλα λιγότερο και άλλα περισσότερο ικανοποιητική στατιστική προσαρμογή της κάθε χρονοσειράς, μοντελοποίηση των τάσεων και προβλεπτική ικανότητα.

1. INTRODUCTION

The issue of determining a suitable procedure of analysis for municipal solid waste (MSW) quantities has been dealt with by various investigators in many countries. The main objective in most cases is to simulate the multivariate problem of MSW (socioeconomic aspects, population, the contents of wastes) in a mathematical form by using deterministic models and trend analysis. Their application, in most cases, is related to the estimation of the forecasting ability of solid waste quantities. DeGeare *et al.*, (1971), performed a multiple stepwise regression analysis trying to predict, from the existing data sets, the weekly quantities of collected wastes [1]. Rhyner (1992) analyzed the monthly quantities of residential, commercial, industrial and other wastes generated between 1985-1989 in Winsconsin by using mean values and standard deviations for both winter-time and summer-time [2]. Matsuto and Tanaka (1993), in order to understand the mechanism of waste generation, normalized values of waste amounts and subsequently estimated moving averages [3]. The advantage of this analysis was that the moving average curve showed seasonal variations due, in most cases, to residents' behavior. In these cases statistical analysis and modelling proved to be quite effective tools in the examination of municipal solid wastes. However, analysis based solely on statistical indicators does not provide us with information regarding the time evolution of MSW production rates, while deterministic models give good results only for long-term analysis and forecasting. If we want a complete analysis and forecasting values of MSW quantities we should be based on techniques which identify trends and seasonality. An effective approach in analyzing time series is the Box-Jenkins models (Box and Jenkins, 1976) [4]. Such a methodology has been successfully applied in various environmental applications ([5], [6], [7]), yet limited use of time series models has been made in solid waste management [8].

The objectives of the present work are to analyze daily and monthly generation rates of municipal solid wastes by means of Box-Jenkins parametric modelling and deterministic models in order to identify seasonality effects and develop models for trend analysis and forecasting. This procedure can be used for long-term forecasting (useful for the scheduling of a complete plan of management, proper manipulation and develop ways to reduce MSW quantities) and for short-term forecasting (useful for the daily scheduling of collection vehicles and routes). The analysis was applied to MSW from the Thessaloniki Greater Area in Northern Greece (population 1 million).

2. METHOD OF ANALYSIS

In the first stage of the analysis performed we used 8 deterministic models and we checked both their modelling and their forecasting ability in the time series of daily MSW quantities and their modelling ability in the time series of monthly quantities (we did not have enough values to check their forecasting ability). The implementation of deterministic models in all cases was made by using regression analysis and the criterion was the minimization of Residual Sum of Squares (RSS). The deterministic models used were:

1 *Polynomial Models*

Linear regression	$y = \alpha + bt$
Quadratic regression	$y = \alpha + bt + ct^2$
Cubic regression	$y = \alpha + bt + ct^2 + dt^3$

2 *Exponential Models*

Exponential function	$y = \alpha e^{bt}$
Modified exponential - S model	$y = e^{\alpha + \frac{b}{t}}$
Logarithmic fit	$y = \alpha + b \ln(t)$
Power equation	$y = \alpha t^b$

3. **Hyperbolic fit - Inverse model** $$y = \alpha + \frac{b}{t}$$

In the second stage of analysis we performed the same analysis by means of Box-Jenkins models. Box-Jenkins time series techniques analyze discrete time series measured at equal time intervals, and give us a basic understanding of the system response to transfer changes of waste quantities as well as they help us to build function models for control strategies. One can then analyze model trends and seasonality in the examined series caused by periodicities in the exogenous variables. Although Box-Jenkins models follow a black-box approach, the system characteristics are intrinsically represented by the data themselves, provided that a relatively large number of data points are included in the time series. The methodology is particularly effective for temporally correlated data, such those often encountered in environmental engineering problems.

The selection of the most appropriate model is a step-by-step procedure. The first step involves the selection of a general class of models through the calculation of the autocorrelation function (ACF) and the partial autocorrelation function (PACF). The ACF measures the amount of linear dependence between observations in a time series that are separated by lag k. The PACF plot helps us determine how many autoregressive terms are necessary for the model or for the identification of seasonal models. Visual inspection of the functions may reveal one or more of the following characteristics: time lags where high correlations appear, seasonality, trends either in the mean level or in the variance of the series, and persistence. The definitions and the interpretation of the ACF and PACF and other indicators, useful in time series analysis, can be found in Box-Jenkins (1976), [4].

Based on the shape of the ACF and PACF and a set of rules, one may specify a model tentatively entertained (second step). For selecting a model, the concept of model parsimony is followed (i.e., a model with the smallest possible number of parameters is preferable). The general form of a univariate Box-Jenkins stochastic model, denoted as ARMA (p,q)×(P,Q), describing the current value x_t of a time series by its own past is:

$$\varphi_\rho(B)\,\Phi_P(B^s)\,x_t = \theta_q(B)\,\Theta_Q(B^s)\,\alpha_t + c \qquad \text{where,}$$

$\varphi_\rho(B)=1 - \varphi_1 B - \varphi_2 B^2 - \ldots - \varphi_\rho B^\rho$	is the autoregressive (AR) operator of order ρ
$\Phi_P(B^s)=1 - \Phi_1 B^s - \Phi_2 B^{2s} - \ldots - \Phi_P B^{Ps}$	is the seasonal autoregressive (SAR) operator of order P with seasonality s
B	is the backward shift operator ($Bx_t=x_{t-1}$ and $B^s x_t=x_{t-s}$)
x_t	is the current value of the time series examined
$\theta_q(B)=1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q$	is the moving average (MA) operator of order q
$\Theta_Q(B^s)=1 - \Theta_1 B^s - \Theta_2 B^{2s} - \ldots - \Theta_Q B^{sQ}$	is the seasonal moving average (SMA) operator of order Q with seasonality s
α_t	is the Gaussian white noise
c	is a constant term

The third step involves the estimation of the model parameters. This can take place by means of an iterative non-linear least square algorithm. The optimization criterion is based on the minimization of RSS between the real data and the estimated values. The stopping criteria are:

- the parameter estimation procedure stops when the RSS between iterations reaches a minimal change (in this study this change was 0.0001).
- the estimation procedure stops when the change in all parameter estimates between iterations reaches a minimal change (in this study this was 0.001).

Diagnostic checking is necessary to verify the statistical adequacy of the model (fourth step). This is usually done by two criteria: a chi-square statistic test based on the first 20 lagged residual

autocorrelations (portmanteau goodness of fit test), and the examination of the residual series for interdependence. The latter is accomplished by correlation analysis through the residual ACF plots. If the residuals are not correlated, then they should be white noise. If any of these two criteria is not valid, the model should be refined (step 2) and re-estimation of the parameters (step 3) should take place ([4], [9], [10]). After this procedure has been applied for a given time series, a calibrated model is obtained which has encoded the basic statistical properties of the time series into some model parameters. Therefore, we are able to use the time series not only for modeling, but also for forecasting. By taking conditional expectations at time t of each term of the ARMA model in equation (1), the minimum mean square error forecasts are:

$$[x_{t+k}] = \varphi_1[x_{t+k-1}]+\varphi_2[x_{t+k-2}]+\ldots+\varphi_p[x_{t+k-p}]+[\alpha_{t+k}]-\theta_1[\alpha_{t+k-1}]-\theta_2[\alpha_{t+k-2}]-\ldots-\theta_q[\alpha_{t+k-q}]+c$$

and the forecasts for a seasonal ARMA model are:

$$[x_{t+k}] = \varphi'_1[x_{t+k-1}]+\varphi'_2[x_{t+k-2}]+\ldots+\varphi'_{P+sP}[x_{t+k-p-sP}]+[\alpha_{t+k}]-\theta'_1[\alpha_{t+k-1}]-\theta'_2[\alpha_{t+k-2}]-\ldots-$$
$$-\theta_{q+sQ}[\alpha_{t+k-q-sQ}]+c$$

where k=1, 2, ... is the lead time for the forecasts x_{t+k}, φ'_1, φ'_2, ... are the generalized AR parameters defined by $\varphi'(B)=\varphi(B)\Phi(B^s)$ and θ'_1, θ'_2, ... are the generalized MA parameters defined by $\theta'(B)=\theta(B)\Theta(B^s)$.

3. RESULTS

3.1 Data manipulation

Due to the collection scheme, there were no data for Saturdays and Sundays (no MSW collection of these days). These days were excluded from the statistical analysis. The MSW time series had 11 missing values out of a total number of data equal to 260 (corresponding to five day per week collection for the period 3rd of January to 31st of December 1994). The missing values existed because no collection took place on these days due to holidays or strikes. This irregular behavior affected the value of the day following this missing value which showed a much higher than usual collected amount. These high-value data were named outliers. In the subsequent analysis we substituted the missing value with the mean value of this day throughout the period and, at the same time replaced the outlier value with the mean value of that day. After the proper construction of the time series the number of the daily collection tonnage data was 260. For the monthly quantities no problems appeared and the modelling procedure was applied to the initial time series.

3.2 Analysis and forecasting of daily quantities

For the formulation of the Box-Jenkins model a step-by-step procedure was followed. The first step involved the calculation of the ACF and PACF plots (Figure 1). The continuous lines in the graphs represent the confidence limits. Values of ACF and PACF within these limits are not significantly different from zero. The ACF plot shows that the data are seasonal due to the peaks of the ACF at lags that are multiples of 5. Because the ACF attenuates very slowly, this indicates the need for seasonal or non-seasonal differencing and / or seasonal term (or terms) of seasonality 5 to be included in the final proposed model. The PACF graph of the overall time series possesses a high value at lag 5 (approximately equal to 1) and significant values at lags 1, 2, 3, 4 and 10. After lag 5 it tails off. Therefore, a mixed process with seasonal terms of seasonality 5 is proposed. Simulation of the time series with ARMA models taking into consideration the existence of seasonality showed that the best model was the ARMA $(1,0)\times(1,1)_5$ model, a seasonal model that includes one autoregressive term and two seasonal terms (one autoregressive and one moving average of order 5).

The final step of the analysis performed included the examination of residuals for interdependence. The autocorrelation plots of the residual series (see Figure 1) signified that dependence between the residuals did not exist, since all values lay between the confidence limits. Therefore, no search for better models was required.

Figure 2 shows the results of MSW quantities simulation (during December of 1994) and prediction (during January of 1995) by using the $(1,0)\times(1,1)_5$ model. As we can see the Box-Jenkins approach was quite successful in simulating and predicting the trends of MSW quantities, demonstrating remarkable fit, even in the peak values (on Mondays). Yet, the prediction capability was not always satisfactory for the extreme high values. Further elaboration of the model may be required, such us development of transfer functions or multivariate models, which will include additional variables (population data, socioeconomic aspects, etc.).

After the Box-Jenkins approach we applied the 8 deterministic models to the time series. The results of this analysis were obviously not as good as the results of the implementation of Box-Jenkins model (Figure 3 presents the results of the simulation of the 8 deterministic models for the time period January 1994 - December 1994). The deterministic models do not have the ability to follow the extreme variations observed mainly on Mondays.

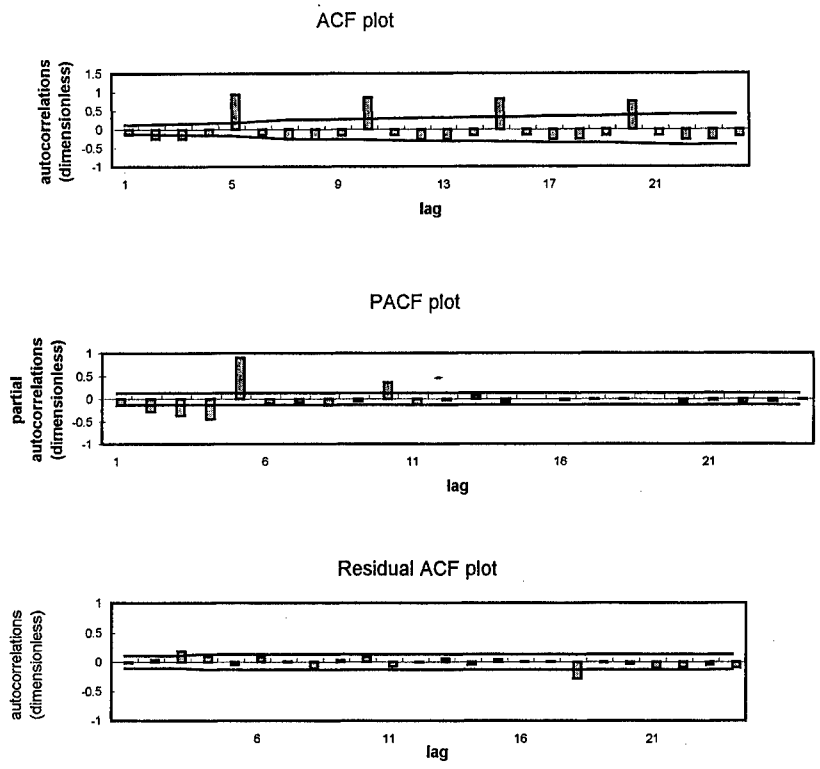


Figure 1. Autocorrelation Plot, Partial Autocorrelation Plot and Residual Autocorrelation Plot of the Daily MSW Quanitities

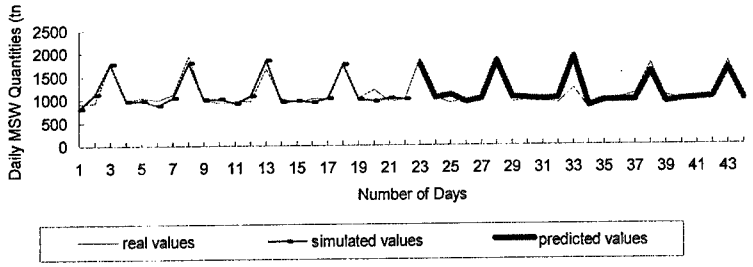


Figure 2. Real, Simulated and Predicted Daily MSW Quantities for the Time Period Dec. '94 - Jan. '95

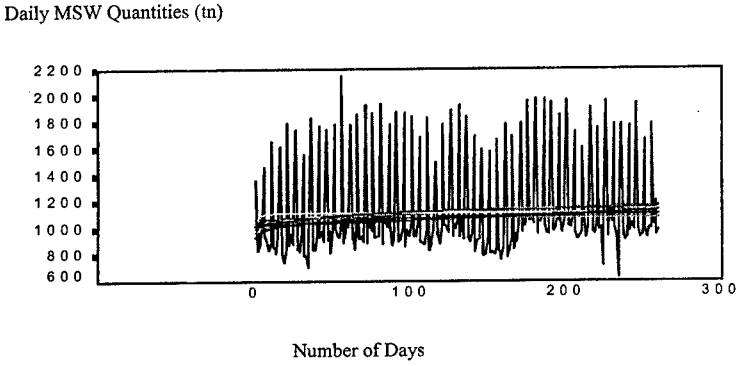


Figure 3. Real and Simulated Daily MSW Quantities by using Deterministic Models

TABLE 1. Analytical equation forms and Residual Sum of Squares (RSS) of all models used in the time series of daily MSW quantities

Model	Analytical Form of the Equation	RSS
Linear	$y = 1071.07 + 0.41t$	31.3×10^6
Quadratic	$y = 1041.72 + 1.08t - 0.003t^2$	31.3×10^6
Cubic	$y = 1022.96 + 1.94t - 0.01t^2 + 2.1 \times 10^{-5}t^3$	31.3×10^6
Exponential	$y = 1027.05 \times e^{0.0004t}$	31.8×10^6
S	$y = e^{6.99 - (0.08 / t)}$	32.1×10^6
Logarithmic	$y = 967.91 + 34.21 \times \ln(t)$	31.3×10^6
Power	$y = 937.74 \times t^{0.031}$	31.8×10^6
Inverse	$y = 1127.08 - (113.56 / t)$	31.6×10^6
Box - Jenkins	$\mathbf{(1 - 0.166B)(1 - 0.99B^5)\, x_t = (1 - 0.46B^5)\, \alpha\alpha_t + 2.26}$	$\mathbf{2.7 \times 10^{6*}}$

(*) is the minimum RSS value

Finally, Table 1 presents the analytical equations and the Residual Sum of Squares (RSS) after the implementation of the deterministic and the Box-Jenkins models in the daily time series. Table 1 verifies the result that the Box-Jenkins approach gives much better results.

3.3 Analysis of monthly quantities

Table 2 presents the analytical equation forms and the Residual Sum of Squares (RSS) for the monthly MSW quantities for the deterministic models and the Box-Jenkins models.

TABLE 2. Analytical equation form and RSS of all models used in the time series of monthly MSW quantities

Model	Analytical Form of the Equation	RSS
Linear	$y = 22792.27 + 178.33t$	114.9×10^6
Quadratic	$y = 21.441.46 + 391.62t - 5.76t^2$	103.8×10^6
Cubic	$\mathbf{y = 20610.56 + 643.97t - 22.58t^2 + 0.31t^3}$	$\mathbf{101.2 \times 10^6}$ *
Exponential	$y = 22834.26 \times e^{0.007t}$	117.5×10^6
S	$y = e^{10.21 - (0.35 / t)}$	148.4×10^6
Logarithmic	$y = 20080.05 + 2260.84 \times \ln(t)$	104.5×10^6
Power	$y = 20463.09 \times t^{0.09}$	103.4×10^6
Inverse	$y = 27095.85 - (8662.41 / t)$	153.4×10^6
Box - Jenkins	$(1 - 0.45B)\, x_t = \alpha_t + 14216.12$	190.5×10^6

(*) is the minimum RSS value

Although the Box-Jenkins model found (the autoregressive model AR(1)) was statistically adequate, yet it was worse than the deterministic approach and specially the cubic model which gave the best fit. Figure 4 presents the real and the model simulated values of the monthly quantities of MSW for the deterministic models only. As we already mentioned the deterministic models and specially the cubic model demonstrated reasonable fit regarding the trends, yet they were not very successful in simulating the extreme values of the original time series.

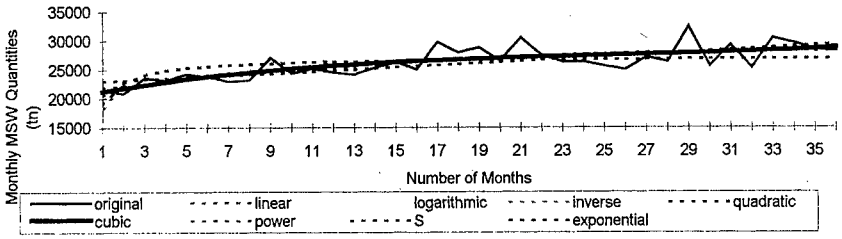


Figure 4. Real and Simulated Monthly MSW Quantities by using Deterministic Models

4. CONCLUSIONS

This work addressed an application of modelling and forecasting on daily and monthly quantities of MSW and the following conclusions were drawn: For the daily quantities time series a Box-Jenkins model with seasonality of length 5 due to MSW collection pattern was found to be the best model.

This model seems to be quite effective in providing good short-term analysis and forecasting, a fact which can be very helpful in scheduling MSW collection, the design and operation of transfer station, and the optimal queuing of collection trucks at the landfill. On the contrary, for the monthly quantities time series, deterministic models were found to give better results. Deterministc models can be very helpful in long-range planning and analysis, such as in the case of designing of sanitary landfills.

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SPREADSHEET MODELING OF SOLID WASTE MANAGEMENT

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ABSTRACT

This paper presents a decision support system (based on a recently developed and published modeling framework), capable of spreadsheet-simulating regional solid waste management (SWM) systems and providing elaborated solutions in locational issues for related facilities (i.e. landfills, incinerators, material recovery facilities and transfer stations of various evaluation typologies). A data bank for quantitative and qualitative analysis is incorporated in the system and the performances of various evaluation criteria of a compilied knowledge base are calculated, allowing the multicriterial evaluation and ranking of various alternative regional locating scenarios. A conducted application for the Region of Central Macedonia, Greece provides useful suggestions for the improvement and optimization of the Region's municipal SWM.

Keywords. Integrated Solid Waste Management, spreadsheet, Central Macedonia.

ΜΟΝΤΕΛΑ ΛΟΓΙΣΤΙΚΩΝ ΦΥΛΛΩΝ ΣΤΗ ΔΙΑΧΕΙΡΙΣΗ ΑΠΟΡΡΙΜΜΑΤΩΝ

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ΠΕΡΙΛΗΨΗ

Στην εργασία αυτή παρουσιάζεται σύστημα λήψης απόφασης τύπου λογιστικού φύλλου, βασισμένο σε πρόσφατα δημοσιευμένο θεωρητικό μοντέλο, με το οποίο προσομοιώνονται συστήματα διαχείρισης απορριμμάτων περιφερειακής κλίμακας, συγκρίνονται βέλτιστες εναλλακτικές λύσεις και αξιολογούνται υπάρχουσες ή προτεινόμενες εγκαταστάσεις (χώροι υγειονομικής ταφής, μονάδες θερμικής επεξεργασίας, σταθμοί μεταφόρτωσης διαφόρων τυπολογιών). Στο μοντέλο είναι ενσωματωμένη τράπεζα δεδομένων ποσοτικής και ποιοτικής ανάλυσης και λαμβάνονται υπόψη κριτήρια αξιολόγησης από την τράπεζα γνώσης μέσω των οποίων ιεραρχούνται σενάρια χωροθέτησης. Τέλος, παρουσιάζεται μια εφαρμογή για την Περιφέρεια Κεντρικής Μακεδονίας και προκύπτουν χρήσιμα συμπεράσματα για τη βελτιστοποίηση του συστήματος διαχείρισης απορριμμάτων στην περιοχή αυτή.

Λέξεις-κλειδιά. Ολοκληρωμένη διαχείριση απορριμμάτων, Λογιστικό φύλλο, Κεντρ. Μακεδονία.

1. INTRODUCTION

Addressed is the hierarchical, *post*-consumer, regional facility system for solid waste management (SWM) consisting of four levels [1]: Transfer stations (TS), material recovery facilities (MRF), anaerobic digestion facilities (ADF), and landfills (LF). This hierarchy is augmented by political and social tensions (NIMBY syndrom) that often result in the shipment of solid waste (SW) over long distances, as well as by recent legislative and institutional trends that put material recycling before thermal treatment (even) with energy recovery, in the context of an integrated approach towards SW diversion from landfills [2]. This approach begins at source reduction, therefore expanding in *pre*-consumer waste management, but this part is not addressed here. Thermal treatment plants (TTP) were not considered in this work, in accordance with expressed political positions [3]

Location-allocation network models, solvable by exact (e.g. branch and bound) or approximate (heuristic) algorithms, are a common operations-research approach often used for regional SWM [4-7]. Adopted and used here is a recently introduced modelling framework for regional SWM [8, 9] that facilitates formulation of linear 0-1 network models for locating SWM facilities and allocating SW to them.

2. MODELLING APPROACH

The following model was implemented in a spreadsheet environment, due to the offered flexibility and interactiveness [10], whereas the Solver of LINDO (What's Best) was used, due to the great number of variables [11]. Objective is set to be the location of the new facilities in such a way that SW treatment is satisfied and overall operating costs are minimized, whereas the constraints of facilities' upper limit (capacity) and mass preservation are satisfied. The objective function to be minimized consists by transportation, operational and investment costs for existing and/or candidate SWM facilities: min(CT+FT)

where:

CT: Transportation cost rate (GDR/day)

FT: the rhythm of investment and operational cost (GDR/day).

Transportation cost is the overall shipping cost to the treatment or disposal facility from all Waste Producers (WP) and is provided by a 'DISTANCES' worksheet. The rate of this cost results as the product of each corresponding element of waste mass of a 'CONSTRAINTS' worksheet and the corresponding cost-cell (GDR/ton) of the 'DISTANCES' worksheet. Transportation cost from producers to facilities is calculated, taking into account constrained situations as truck capacity, maximum allowed gross truck weight, and speed limits; it is given by the following equation [8]:

$$CT = \sum_{\mu}\sum_{i}\sum_{\pi} CT_{i\pi}\cdot\alpha_{i\pi}^{\mu} + \sum_{\nu}\sum_{i}\sum_{\rho} CT_{i\rho}\cdot\varepsilon_{i\rho}^{\nu} + \sum_{\xi}\sum_{i}\sum_{\sigma} CT_{i\sigma}\cdot\zeta_{i\sigma}^{\xi} + \sum_{o}\sum_{i}\sum_{\tau} CT_{i\tau}\cdot\eta_{i\tau}^{o} +$$
$$+\sum_{\mu}\sum_{\xi}\sum_{\pi}\sum_{\sigma} CT_{\pi\sigma}\cdot\vartheta_{\pi\sigma}^{\mu\xi} + \sum_{\mu}\sum_{o}\sum_{\pi}\sum_{\tau} CT_{\pi\tau}\cdot\iota_{\pi\tau}^{\mu o} + \sum_{\nu}\sum_{\xi}\sum_{\rho}\sum_{\sigma} CT_{\rho\sigma}\cdot\gamma_{\rho\sigma}^{\nu\xi} +$$
$$+\sum_{\nu}\sum_{o}\sum_{\rho}\sum_{\tau} CT_{\rho\tau}\cdot\kappa_{\rho\tau}^{\nu o} + \sum_{\xi}\sum_{o}\sum_{\sigma}\sum_{\tau} CT_{\sigma\tau}\cdot\delta_{\sigma\tau}^{\xi o}$$

where CT_{ij} the transportation cost from WP/facility i to treatment/final disposal facility j, and α, ε, ζ, η, θ, ι, γ, κ, and δ are waste flows from WP to TS, from WP to MRF, from WP to ADF, from WP to LF, from TS to ADF, from TS to LF, from MRF to LF, and from ADF to LF respectively. In our problem, $\mu=\nu=\xi=o=1$, as no sub-typology is assumed (i.e. one kind of e.g. TS is considered). A twenty year facility life time is assumed. The overall investment and operational cost is given by the following equation [8]:

$$FT = \sum_{\mu}\sum_{\pi}\left[CFF_{\varphi}^{\mu}\cdot\varphi_{\pi}^{\mu} + CFV_{\varphi}^{\mu}\cdot b_{\pi}^{\mu}\right] + \sum_{\nu}\sum_{\rho}\left[CFF_{\chi}^{\nu}\cdot\chi_{\rho}^{\nu} + CFV_{\chi}^{\nu}\cdot c_{\rho}^{\nu}\right] +$$
$$+\sum_{\xi}\sum_{\sigma}\left[CFF_{\psi}^{\xi}\cdot\psi_{\sigma}^{\xi} + CFV_{\psi}^{\xi}\cdot d_{\sigma}^{\xi}\right] + \sum_{o}\sum_{\tau}\left[CFF_{\omega}^{o}\cdot\omega_{\tau}^{o} + CFV_{\omega}^{o}\cdot e_{\tau}^{o}\right]$$

where CFF_i^j represents the investment flow of facility i of typology j, whereas φ, χ, ψ, and ω are binary variables, and b, c, d, and e are the arriving amount of wastes at TS, MRF, ADF and LF.

Service demand. These constraints ensure that waste produced by every WP is transferred to a SWM facility for treatment or disposal. The same is enforced for any SW leaving a facility for another. The service demand constraint is given by the following equation [8]:

$$a_i = \sum_{\mu}\sum_{\pi}\alpha_{i\pi}^{\mu} + \sum_{\nu}\sum_{\rho}\varepsilon_{i\rho}^{\nu} + \sum_{\xi}\sum_{\sigma}\zeta_{i\sigma}^{\xi} + \sum_{o}\sum_{\omega}\eta_{i\omega}^{o}, \quad i = 1,\ldots,|I|$$

Facility capacity. For existing facilities, this constraint equals actual capacity. In the case of candidate facility, its capacity is calculated from the ratio of waste produced by the note, and the operational time of facilities, whereas a library of facilities provides relavant data. These constrains are given by following equations [8] (k, g, h, and u are capacities of TS, MRF, ADF and LF):

$$b_{\pi}^{\mu} \le k_{\pi}^{\mu} \cdot \varphi_{\pi}^{\mu}, \quad \mu = 1,\ldots,|GAST_{\mu}|, \quad \pi = 1,\ldots,|I \cup J \cup K|$$
$$c_{\rho}^{\nu} \le g_{\rho}^{\nu} \cdot \chi_{\rho}^{\nu}, \quad \nu = 1,\ldots,|GAST_{\nu}|, \quad \rho = 1,\ldots,|I \cup J \cup K|$$
$$d_{\sigma}^{\xi} \le h_{\sigma}^{\xi} \cdot \psi_{\sigma}^{\xi}, \quad \xi = 1,\ldots,|GAST_{o}|, \quad \sigma = 1,\ldots,|I \cup J \cup K|$$
$$e_{\tau}^{o} \le \upsilon_{\tau}^{o} \cdot \omega_{\tau}^{o}, \quad o = 1,\ldots,|GAST_{o}|, \quad \tau = 1,\ldots,|I \cup J \cup K|$$

Mass preservation at facilities. A matrix of the 'CONSTRAINTS' worksheet represents the mass preservation constraints. Variables are the mass flows from each treatment facility to another (e.g. from TS to LF). The following equations express the constraints of mass prevention for any facility:

$$b_{\pi}^{\mu} = t_{\pi}^{\mu}, \quad \mu = 1,\ldots,|GAST_{\mu}|, \quad \pi = 1,\ldots,|I \cup J \cup K|$$
$$f^{\nu} c_{\rho}^{\nu} = s_{\rho}^{\nu}, \quad \nu = 1,\ldots,|GAST_{\nu}|, \quad \rho = 1,\ldots,|I \cup J \cup K|$$
$$f^{\xi} d_{\sigma}^{\xi} = q_{\sigma}^{\xi}, \quad \xi = 1,\ldots,|GAST_{\xi}|, \quad \sigma = 1,\ldots,|I \cup J \cup K|$$

3. CASE-STUDY

The presented system was applied for the Region of Central Macedonia (RCM); this area of Northern Greece consists of seven Prefectures, yielding an overall population of just over 1 million being served by the municipal SWM system considered. WPs, production rates and composition were incorporated in a spreadsheet database (fig. 1). Considered WP were major RCM municipalities; a recent survey revealed all sites of interest (fig. 2).

Waste Producers at Region of Central Macedonia		
Authority	Producer	Waste production (t/d)
Pieria	Aiginio	4553
Pieria	Katerini	43613
Pieria	Kolindros	3732
Pieria	Litochoro	6656
Imathia	Alexandria	12109
Imathia	Veroia	37858
Imathia	Agelochori	2635
Imathia	Naoussa	19794
Pella	Aridaia	4455
Pella	Giannitsa	22504
Pella	Kria Vrissi	5767
Pella	Pella	2374
Pella	Edessa	17128
Pella	Skydra	4562
Kilkis	Kilkis	12139
Kilkis	Polycastro	5.260
Kilkis	Axioupoli	2.981

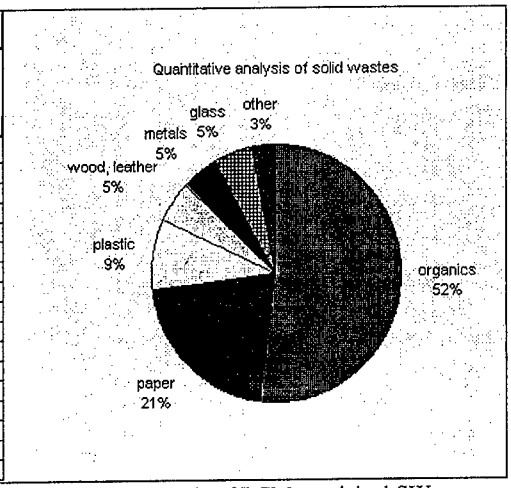


Figure 1. Quantitative and qualitative analysis of RCM municipal SW.

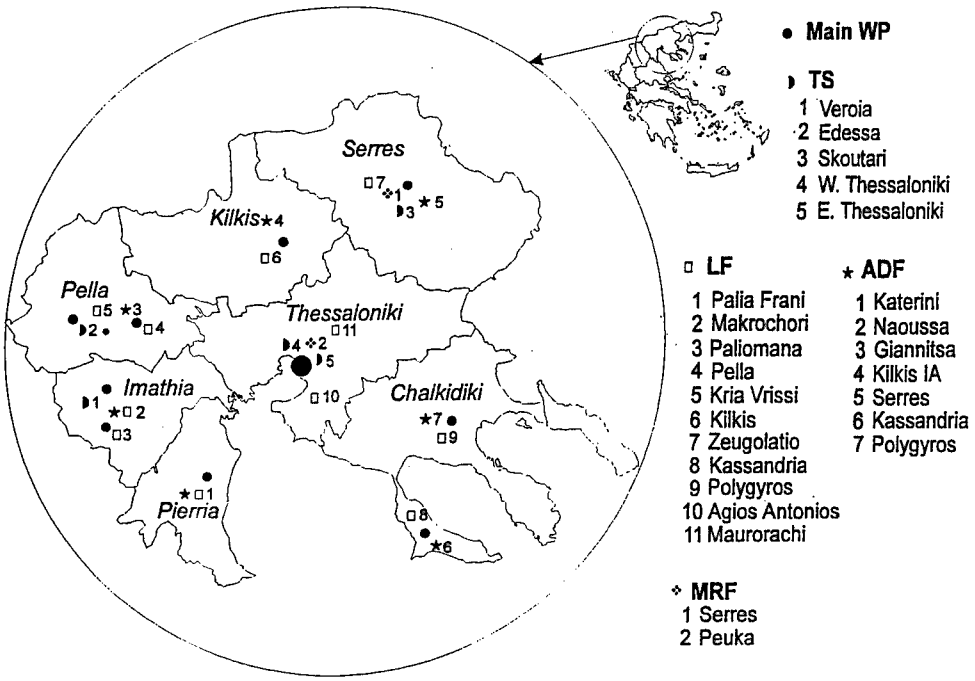


Figure 2. Hellenic case-study area; WP and sites of interest are given.

Daily production of municipal SW in RCM is estimated 1,800-2,000 t exceeding the 2,000-ton threshold in summer (peak period). Overall SWM scheme is given in Table 1. RCM's Local Authorities dispose of the aforementioned SW quantities at areas not fullfilling appropriate specifications according to current lagislative frame and EU Directives. An extreme example is the uncontrolled landfill of Skydra Municipality nearby Edessaios river. Site restoration has never been an issue. Individual Prefectures (e.g. Imathia, Serres) have conducted studies in the past for SWM at prefecture level. Furthermore, Region Committees and Municipalities pursued the same way, promoting pre-approval procedures for new facilities with the appropriate Environmental Studies. The Association of Local Authorities of the Greater Thessaloniki Area is planning actions as construction of material recovery facilities, a transfer station and landfill facilities (cf. [13] for an extensive study of the Thessaloniki SWM system).

TABLE 1. Available data concerning case-study area [12].

Prefecture	Amount of wastes (kt/a)	NR of semi-controlled landfills	NR of un-controlled landfills	Related problems
Thessaloniki	270.5	56	37	Leachates from landfills to Thermaikos Gulf. Pollution of Gallikos, Axios, and Loudias rivers, Koronia and Volvi lakes.
Imathia	41.5	3	60	Pollution of Aliakmonas river.
Kilkis	25.0	67	13	Pollution of Axios, and Gallikos rivers.
Serres	61.0	59	39	Pollution of Strimonas river.
Pella	41.0	29	many	Pollution of Edessaios river.
Pieria	33.0	22	21	Pollution of surface and underground water.
Chalkidiki	24.5			Sea and underground water pollution.

In 1990, the Prefecture Authority of Serres decided for one LF, while its local authorities planned four TS and proposed the construction of a MRF and a LF. Kilkis Prefecture evaluated a biomass incineration plant with energy recovery and electricity production. Finally, the Hellenic Ministry of Environment suggested a number of pre-approved areas for landfill location within RCM [14-18].

4. SCENARIOS

In order to enhance the analysis' completeness, it was decided to investigate different sets of initial boundary conditions, comparatively evaluating scenarios that illustrate both (a) the decision-makers' expressed (and, to some extent, pursued) locational preferences (cf. section 3) and (b) the optimization results from the model application (cf. section 2); in the latter case, locational preferences serve as a means to generate candidate sites where the facility typology may or may not be a variable. Thus, three scenarios were formulated regarding initial boundary conditions:

- Scenario 1 (closed scenario): Self-administration and -service is promoted at Prefecture level and is incorporated in the model as explicit constraint; furthermore, collected locational preferences are closely followed. This assumption is in agreement with expressed political preferences regarding self-disposal of SW and the avoidance of SW tourism. One LF is the maximum that may be constructed at each of the seven Prefectures. Beside the optimum location of 0 or 1 LF per Prefecture, the model performs no further optimization.
- Scenario 2 (intermediate scenario): Self-administration at Prefecture level is not considered as explicit constraint in the model; however, it is not excluded from the model's results. This tolerance means that SW of one Prefecture is allowed to eventually be disposed of in some other of the considered Prefectures. Binary variables are associated with every facility proposed from expressed locational preferences of competent local authorities and the model performes a subsequent single-objective optimization.
- Scenario 3 (open scenario): A great number of facilities is taken in account. 48 sites are considered, each associated with binary variables regarding every possible facility typology. Thus, the full extent of the used modelling framework is utilized.

Each scenario constitutes of worksheets: (a) distances, (b) transportation cost, (c) constraints, (d) solution, (e) financial criteria, (f) environmental criteria, and (g) chart. LINDO's solver WHAT'S BEST is applied to each and results are discussed in the following chapter.

5. RESULTS AND DISCUSSION

The three optimum location-allocation solutions are shown in Tables 2-4. Also, the comparison between scenarios for greenhouse effect, final disposal, energy and material recovery, and total cost is presented in Figure 3. Scenario 1 consists of 18 facilities (i.e. 3 TS, 2 MRF, 2 ADF, 11 LF), whereas scenario 2 has an optimal solution comprising of 13 facilities (i.e. 2 TS, 2 ADF, 2 MRF and 7 LF - cf tables 2, 3). Thus, 23495 GDR/t are scenario-1's total cost, whereas scenario 2 yields an optinmal-solution cost of 16926 GDR/t, a result clearly demonstrating the sparing effect of scale economics that result from lifting the Prefecture barrier to SWM. Scenarios 1 and 2 each have 18 binary decision variables, whereas scenario 3 has 46; this analogy demonstrates the difference between them regarding completeness and problem size. The optimal solution of scenario 3 consists of 21 facilities (i.e. 7 TS , 6 ADF, 1 MRF and 7 LF), yielding a total cost of 16652 GDR/t..

In order to enhance the evaluation of the scenarios, other criteria were also considered and the performances of each scenario's optimal solutions were calculated as well (cf. Fig. 3). These criteria were selected from a recently compiled knowledge base [19] and were the following:

- Greenhouse effect (kt/year of CO2 equivalent - to be minimized).
- SW quantity finally landfilled (kt/year of SW - to be minimized).

- Energy recovery (GWh/year - to be maximized).
- Material recovery (kt/year - to be maximized).

TABLE 2. SW allocation of scenario-1's optimum solution.

Area	Katerini	Veroia	Naoussa	Alexandria	Edessa	Giannitsa	Kilkis	Ampelokipoi	Polichni	Neapoli	Peuka	Pulaia	Kalamaria	Serres	Sidirokastro	Nigrita	ADF Kilkis IA	TS E. Thessaloniki	TS W. Thessaloniki	MRF Peuka	MRF Serres	ADF Serres	Capacity being used (t/d)
LF Palia Frani	43,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43,6
LF Makrochori	-	37,9	-	12,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50,0
LF Paliomana	-	-	19,8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19,8
LF Pella	-	-	-	-	-	22,5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22,5
LF Kria Vrissi	-	-	-	-	17,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17,1
ADF Kilkis IA	-	-	-	-	-	-	12,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,1
LF S. Kilkis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,9	-	-	-	-	-	2,9
TS E. Thessaloniki	-	-	-	-	-	-	-	-	-	-	-	26,4	109,0	-	-	-	-	-	-	-	-	-	506,6
TS W. Thessaloniki	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33,4
LF Agios Antonios	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	506,6	-	97,1	-	-	603,7
LF Maurorachi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33,4	-	-	-	33,4
MRF Peuka	-	-	-	-	-	-	-	51,4	45,0	35,0	2,3	-	-	-	-	-	-	-	-	-	-	-	404,5
LF Kassandria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,5
LF Polygyros	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,4
TS Skoutari	-	-	-	-	-	-	-	-	-	-	-	-	-	30,0	-	-	-	-	-	-	-	-	30,0
MRF Serres	-	-	-	-	-	-	-	-	-	-	-	-	-	20,4	-	6,2	-	-	-	-	-	-	26,6
ADF Serres IA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,3	-	-	-	-	-	-	-	5,3
LF Zeugolatio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13,6	1,3	14,9
Waste production (t/d)	43,6	37,9	19,8	12,1	17,1	22,5	12,1	51,4	45,0	35,0	2,3	26,4	109,0	50,4	5,3	6,2	2,91	506,6	39,4	97,1	6,4	1,3	

TABLE 3. SW allocation of scenario-2's optimum solution.

Area	Katerini	Veroia	Alexandria	Edessa	Giannitsa	Kilkis	Ampelokipoi	Agios Paulos	Triandria	Pulaia	Kalamaria	Sindos	Chalastra	Polygyros	Sidirokastro	Nigrita	ADF Kilkis IA	TS E. Thessaloniki	TS W. Thessaloniki	MRF Peuka	ADF Serres	Capacity being used (t/d)
LF Palia Frani	43,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43,6
LF Makrochori	-	37,9	12,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	69,8
LF Prodromos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0
LF Pella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0
LF Kria Vrissi	-	-	-	17,1	22,5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39,6
ADF Kilkis IA	-	-	-	-	-	12,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,1
LF S. Kilkis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,9	-	-	-	-	2,9
TS E. Thessaloniki	-	-	-	-	-	-	-	-	13,6	26,4	3,8	-	-	-	-	-	-	-	-	-	-	506,6
TS W. Thessaloniki	-	-	-	-	-	-	-	-	-	-	-	-	7,1	-	-	-	-	-	-	-	-	33,4
LF Agios Antonios	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0
LF Maurorachi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	506,6	33,4	97,1	-	643,1
MRF Peuka	-	-	-	-	-	-	51,4	9,0	-	-	105,2	6,0	-	-	-	-	-	-	-	-	-	404,5
LF Kassandria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0
LF Polygyros	-	-	-	-	-	-	-	-	-	-	-	-	-	4,5	-	-	-	-	-	-	-	9,9
TS Skoutari	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30,1
MRF Serres	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,2	-	-	-	-	-	26,4
ADF Serres IA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5,3	-	-	-	-	-	-	5,3
LF Zeugolatio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,3	7,6
Waste production (t/d)	43,6	37,9	12,1	17,1	22,5	12,1	51,4	9,0	13,6	26,4	109,0	6,0	7,1	4,5	5,3	6,2	2,9	506,6	39,4	97,1	1,3	

TABLE 4. SW allocation of scenario-3's optimum solution.

Area	Katerini	Veroia	Naoussa	Alexandria	Edessa	Giannitsa	Kilkis	Ampelokipoi	Menemeni	Euosmos	Stavroupoli	Polichni	Neapoli	Pavlos	Sykies	Agios Paulos	Triandria	Lagadas	Koufalia	Polygyros	Kassandria	Alexandria	TS Edessa	Capacity being used (t/d)
ADF Katerini	43,6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43,6
LF Palia Frani	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,4
TS Veroia	-	37,9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37,9
ADF Naoussa	-	-	19,8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,1	-	69,8
TS Alexandria	-	-	-	12,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,1
LF Makrochori	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,0
TS Edessa	-	-	-	-	17,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17,1
ADF Edessa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17,1	39,6
TS Giannitsa	-	-	-	-	-	22,5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22,5
MRF Giannitsa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0
LF Kria Vrissi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,3
ADF Kilkis IA	-	-	-	-	-	-	12,1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,1
LF S. Kilkis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,2
TS E. Thessaloniki	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	571,9
TS W. Thessaloniki	-	-	-	-	-	-	-	-	30,0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48,6
LF Agios Antonios	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0
LF Mavrorachi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32,3
ADF Peuka	-	-	-	-	-	-	-	51,4	-	46,3	47,1	45,0	35,0	2,3	27,1	9,0	13,6	6,1	-	-	-	-	-	929,8
ADF Sindos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13,1
TS Koufalia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,6	-	-	-	-	7,6
ADF Kassandria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,0	2,5	-	-	2,5
Waste production (t/d)	43,6	37,9	19,8	12,1	17,1	22,5	12,1	51,4	30,0	46,3	47,1	45,0	35,0	2,3	27,1	9,0	13,6	6,1	7,6	4,5	2,5	12,1	17,1	

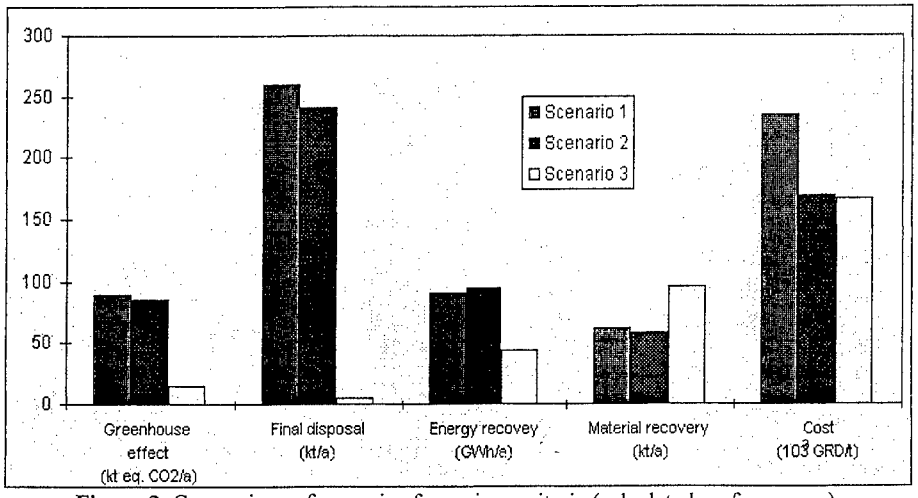


Figure 3. Comparison of scenarios for various criteria (calculated performances).

Scenario 3, due to its greater allowance for optimization yielded improved performances for three out of four additional criteria, being inferior than the other two only in terms of energy recovery due to the reduced SW amount landfilled and the subsequent lower quantities of produced and utilized biogas. The performances of scenarios 1 and 2 were of the same order of magnitude (cf. Fig. 3),

scenario 2 appearing slightly superior that 1 in terms of final disposal, greenhouse effect and energy recovery.

Thus, the optimum solution of scenario 3 (cf. Table 4) is finally proposed for SWM in RCM. As a concluding remark, it must be noted that scenario-3's optimal solution is only slightly better that scenario-2's in terms of the optimization criterion (total cost, cf. Fig. 3). This points out that the expressed locational properties of the local authorities are generally correct and towards the direction of reduced cost. In this context, it is suggested that RCM's seven Prefectures should work together and in a regional scale, lifting eventual prefectual barriers regarding SW transportation.

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MATHEMATICAL MODELING OF SANITARY LANDFILL CAPACITY AS A FUNCTION OF DESIGN PARAMETERS

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ABSTRACT

In designing a landfill (LF) or landraise (LR) for solid waste disposal, specific choices are made regarding the size of several design parameters (d.p.) such as: *side slopes, lift height, bench width between lift and cell cover thicknes* which affect its capacity V. In the literature review conducted, no functional relationships between V and d.p. were found. In this work, such relationships are developed for a LF/LR of specific morphology, relating capacity V with: (1) the LF/LR base area size and (2) each of the above d.p. It is found that V is a multiplicative function of base size and a linear function of every d.p. The implications to LF/LR planning and design are significant, as the designer can assess the impact of his choices for d.p. sizes and make the necessary trade-off analyses.

ΣΥΝΑΡΤΗΣΙΑΚΕΣ ΣΧΕΣΕΙΣ ΧΩΡΗΤΙΚΟΤΗΤΑΣ ΧΥΤΑ ΜΕ ΠΑΡΑΜΕΤΡΟΥΣ ΣΧΕΔΙΑΣΗΣ ΚΑΙ ΛΕΙΤΟΥΡΓΙΑΣ

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ΠΕΡΙΛΗΨΗ

Ο σχεδιασμός ενός Χώρου Υγειονομικής Ταφής Αποβλήτων (ΧΥΤΑ) δεν έχει μελετηθεί σε ικανοποιητικό βαθμό, όσον αφορά την εξάρτηση της χωρητικότητας από παραμέτρους σχεδίασης όπως: *κλίση πρανών, ύψος ταμπανιών, πλάτος ζώνης μεταξύ ταμπανιών, πάχος επικάλυψης για την ημερήσια στρώση, κλπ.* Ο μηχανικός επιλέγει τιμές των παραμέτρων αυτών χωρίς άμεση αντίληψη των επιπτώσεων στη χωρητικότητα του ΧΥΤΑ. Στην παρούσα εργασία, η χωρητικότητα ΧΥΤΑ συγκεκριμένης μορφολογίας εκφράζεται ως συνάρτηση του μεγέθους της βάσης και ως γραμμική συνάρτηση κάθε μιας από τις παραπάνω παραμέτρους.

1. THE PROBLEM ENVIRONMENT

In designing a sanitary landfill (LF), or a landraise (LR), the engineer/analyst wishes to maximize the space that will be made available for wastes, subject to specific constraints on: (1) the external morphology of the LF or the LR in its final covered state, (2) environmental impact (e.g. leachate and gas outflows), (3) expenditures, and (4) other concerns or impacts. In doing so, the designer is faced with choices on the values of several geometric and operation parameters, like lift height, cover thickness, side slopes, etc.

To be more specific, in the process of planning a LF/LR and for a given base area shape, specific choices need to be made regarding the values of design parameters such as: *side slopes, lift height, bench width between lifts, daily cell cover thickness (top, side, front), and final cover thickness.* These values affect the capacity **V** of the LF/LR (m^3 of waste placed), the physical life of the LF, and/or the construction and operation cost.

In the literature review conducted, no functional relationships between V and the above parameters were found. The relevant literature suggests ranges of values for such design parameters [6, 9, 10], letting the designer pick the exact size. It turns out, however, that the LF/LR capacity is often quite sensitive even to small variations in the values of some of the design parameters [3,7]. The engineer chooses parameter levels without the benefit of an analytical tool, which would allow him/her to study the trade-offs involved between capacity and parameter sizes, or among the design parameters themselves.

In cases of other large engineering systems (bridges, roads, buildings, liquid waste treatment plants etc.), the effects of variations in the values of design parameters to the performance measures of the system have been studied in considerable depth, over many decades. This is not the case (yet) for sanitary landfills. A LF/LR is a complex engineering system in terms of planning, designing, constructing and operating it; no mathematical models have been reported describing its capacity as a function of various design and operation parameters. One could of course simulate such relationships. It would be even better, however, if a simple mathematical model were formulated. This paper attempts to formulate such mathematical models, on the basics of simulated results.

The first two authors have been studying this problem over a number of years, having faced real-world situations as consultants, where choices on design parameter values had to be made [3,7]. The first author has further explored the issue in his doctoral dissertation [2]. The work presented herein is a refinement of the work in [3] and [7], mainly in terms of the simulation model used and the functions derived. A computer simulation model was developed for a typical LF/LR shown in Figure 1 and Table 1. Essentially, LF/LR capacity was expressed as a function of several parameters, nine of which are shown in Table 1; four of them define the geometry of the morphology while the other five can be set and re-adjusted during operation. The ranges of values for the parameters as well as the typical values come from standard textbooks [6,8,9].

The LF of Figure1 is naturally an idealized case which, however, can serve as a starting point of the analysis. (Work is currently going on for more complex cases: multi-faced sloping base, allowance for settlement, excavation and filling). The main contribution here is not some conclusion that capacity is an increasing or decreasing function of a specific parameter, but the estimation of the sensitivity of capacity size to small variations in that parameter's value. The target user is the design or operation engineer who considers the importance of such small variations in design and operation parameters.

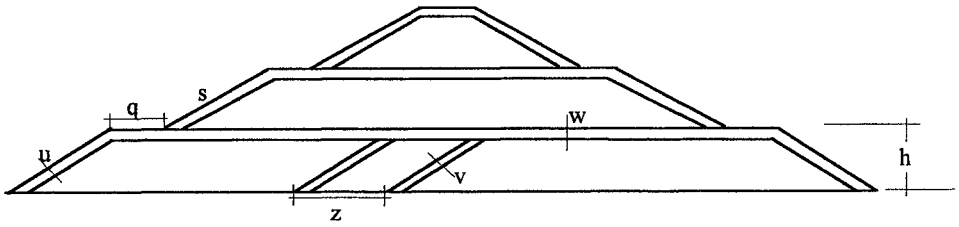


Figure 1: Landraise cross-section (symbols explained in Table 1)

TABLE 1: Landraise Design Parameters and their Values (see Figure 1)

Design Parameters				Range of Values (Min-Max)	Step in value change[1]	Typical (standard) value
	Description	Symbol	Units			
1	Base Area	E	10^3 m^2	50 - 1000	50	-
2	Lift Height	h	m	2.00 - 6.75	0.25	2.50
3	Side Slope	s	m/m	0.21 - 0.59	0.02	0.33
4	Daily working length	z	m	3.00 - 12.50	-[2]	6.00
5	Width of strips between lifts	q	m	0.00 - 1.90	0.10	0.50
6	Horizontal cell cover thickness	w	m	0.15 - 0.72	0.03	0.30
7	Side cell cover thickness	v	m	0.15 - 0.34	-	0.15
8	Front cell cover thickness	y	m	0.000 - 0.285	-	0.15
9	Final cover thickness	u	m	0.60 - 3.45	-	1.50

[1] Successive increment for getting the 20 values of the algorithm of §3.1 and 3.2
[2] Not investigated in this paper

2. FUNCTIONAL RELATIONSHIPS OF LF/LR CAPACITY

Let us refer to the LR morphology of Figure 1 and Table 1. The final height of the LR and the total number of lifts are determined by the base geometry and size as well as the specific values assigned to the design parameters. The capacity V (in $m^3 * 10^3$ of space available for placing waste) is a function of: a. the base area size E (in 10^3 m^2), b. the geometry of the base and c. a number of geometric and operation parameters, as follows:

$$V = f(E_\gamma, x_1, x_2, \ldots, x_p, \ldots, x_N) \quad (1)$$

where

- γ is a geometry index for the base area, as follows:
  γ=1: circle; γ=2: square; γ=3: rectangle with sides ratio=2; γ=4: rectangle with sides ratio=5
- E_γ is the size of the base area, whose geometric shape corresponds to index γ
- x_p is the value of the p^{th} parameter
- N is the set of all geometric and operation parameters affecting the value of V.

For selected t*ypical* values of the parameters in N, one could examine the effect of area size E on the capacity V:

$$V_\gamma = f(E), \quad \text{for specific values of all } x_i \in N, \text{ for } \gamma = 1 \text{ to } 4. \quad (2)$$

Similarly, capacity V can be expressed as a function of each parameter x_p, for selected values of E and x_i, $i \in \{N\text{-}p\}$, and for a specific base geometry:

$$V_{\gamma,E} = f(x_p) \mid \text{all other quantities in Relation (1) are fixed and } \gamma=1 \text{ to } 4. \quad (3)$$

It would be even more useful to express capacity as a single function of both x_p and E:

$$V_\gamma = f(x_p, E) \mid \text{all other quantities in Relation (1) are fixed and } \gamma=1 \text{ to } 4. \quad (4)$$

The objective of the analyst is to choose technologically acceptable values for each and every parameter p, so as to maximize LF/LR capacity over a specific base area. This could be easily accomplished if the capacity function of Relation (1) were available. It is not.

The present work is an attempt to generate the function of Relation (2) and the functions of Relations (3) and (4) corresponding to four of the design parameters of Table 1: *lift height h, side slope s, width q of strips between lifts, and horizontal cell cover thickness w.*

3. THE MATHEMATICAL MODELING PROCEDURE

The heart of the computational procedure is a stereometric model of the capacity of a LF/LR with the specific shape of Figure 1 [3,4]. A computer program was developed for computing the capacity for: given values of the base area size (E), given values for all the relevant parameters (x_p), and given geometric shape of the base. Allowing one of the variables to assume different values over a technologically acceptable range (Table 1), a set of pairs $\{V_\gamma, E\}$ or $\{V_\gamma, x_p\}$ is obtained through this computer program. These values of V_γ can be considered as the actual 'experimentally established' values. Essentially, it is these capacity values on which LF/LR planning, design, construction and operation decisions are based, anyway.

The above derived pairs are then 'fitted' into specific functional forms, through another specially developed program [4,5] which examines a large number of alternative functional forms in searching for the 'best fit' (a least-squares-based algorithm). A functional form is acceptable if the difference between the "experimental" value of V_γ and its function-based value is less than 5% of V_γ (i.e error-vector values are less than 5%), throughout the corresponding range for the values of E or x_p. If a linear function meets the acceptability criterion, it is chosen (for simplicity and uniformity reasons), even if another functional form might offer a better fit.

3.1 Generation of the Function $V_\gamma = f(E)$

Given:

- LF/LR morphology (as in Figure 1)
- Range of values for all parameters (Table 1)
- Computer program VOL for computing the capacity of the LF/LR of Figure1
- Computer program FIT for best-fitting a set of pairs to various functional forms (it computes the function's parameters which offer the best fit to the data)
- Computer program NORM for computing the *error vector* between VOL values and the function's values
- Four different possible geometric shapes for the base area (circle, square, rectangular 1:2, rectangular 1:5).

Step 1: 1.1 Choose a geometric shape for the base area
1.2 Through program VOL, and for each of the 20 values of E (Table 1), compute the corresponding value of V using the *typical* values for all parameters p from Table 1. Obtain a set of 20 pairs $\{V_i,E_i\}$.
Step 2: 2.1. Through program FIT, find the best fit of the above pairs to a number of alternative functional forms.
2.2. Through program NORM, check the acceptability of each of the above functions
2.3. Choose the function with the least *error-vector* unless there is a linear function among the acceptable forms, whereupon the linear form is chosen.
Step 3: If all geometric shapes have been examined, STOP. Otherwise, return to Step 1.

3.2 Generation of the Function $V_\gamma = f(x_p)$

Given: (As in § 3.1)
Step 1: 1.1 Choose a geometric shape for a base area
1.2 Choose one of the following four values for E: 50, 100, 500, 1000 (10^3 m^2)
1.3 Through program VOL, and for each of the 20 values of p (Table 1), the corresponding value of V is computed. For all other parameters, the *typical* values of Table 1 are used. Obtain a set of 20 pairs $\{V_i, x_i\}$.
Step 2: (As in § 3.1)
Step3 : 3.1. Return to Step 1.2 to choose another value for E.
3.2 If all E values have been examined, return to Step1.1 to choose another shape. If all shapes have been examined, STOP.

4. COMPUTATIONAL RESULTS

4.1 Capacity as a Function of Base Area Size

Following the procedure in §3.1 above, the 'best' mathematical model generated for Relation (2) is

$$V_\gamma = k_\gamma * E^{\wedge}\beta_\gamma \qquad (\text{for } 50 \le E \le 1000) \tag{5}$$

where the coefficients k_γ and β_γ have the values shown in Table 2.

TABLE 2: Values of Coefficients k and β in Relation (5)

Geometric Shape		Coefficient k	Coefficient β	Relation (5) (50≤E≤1000)
Circle,	γ=1	1.17	1.53	V=1.17*E^1.53
Square,	γ=2	1.01	1.53	V=1.01*E^1.53
rectangle 1:2,	γ=3	0.87	1.53	V=0.87*E^1.53
rectangle 1:5,	γ=4	0.55	1.55	V=0.55*E^1.55

It is observed that the exponent coefficient β is practically insensitive to base geometry variations, while coefficient k decreases drastically, as one moves from the circle to 1:5 rectangle. For the same size of base area E, a move from square to 1:2 rectangle results in a capacity decrease of 14%; if the move is to a 1:5 rectangle, the capacity decrease is about 45%. These decrease percentages remain the same for any value of the base area E [3].

4.2 Capacity as a Function of LF/LR Parameters

Following the procedure in §3.2, a single functional form was generated relating capacity V with each of the four design variables indicated earlier. Relation (3), for any of these four parameters, is now specified as follows:

$$V_{\gamma,E} = \alpha_{\gamma,E} + \delta_{\gamma,E} * x_p \quad (6)$$

where: $V_{\gamma,E}$ is the capacity corresponding to base shape γ and base size E, while all design parameters, except p, assume their *typical* values (Table 1); and $\alpha_{\gamma,E}$ and $\delta_{\gamma,E}$ are constants corresponding to specific base shape γ and size E. The values of coefficients $\alpha_{\gamma,E}$ and $\delta_{\gamma,E}$ are shown in Table 3. For all shapes and base areas, the maximum error for the parameters h, s, q and w, respectively was 4.02%, 1.62%, 1.45% and 0.28%.

TABLE 3: Values of Constants α (in $m^3 \cdot 10^3$) and δ (in $m^3 \cdot 10^3$ per unit of the parameter) in Relation (6) for the Four Design Parameters

Design Parameter	Circular Base		Square Base		Rectangular Base (1:2)		Rectangular Base (1:5)	
	α	δ	α	δ	α	δ	α	δ
Base Area Size, $E=50x10^3$ m^2								
h	444.2	4.0	387.6	3.6	339.0	2.3	227.3	0.9
s	-60.2	1541.2	-58.7	1364.8	-56.9	1203.4	-53.1	845.8
q	473.9	-45.4	413.6	-39.2	358.8	-33.3	237.6	-20.5
w	508.8	-195.0	444.7	-171.0	386.0	-148.0	256.5	-99.1
Base Area Size, $E=100x10^3$ m^2								
h	1297.5	11.9	1138.5	10.4	994.9	8.7	679.2	4.4
s	-135.6	4381.2	-129.8	3877.0	-125.9	3423.0	-114.4	2410.6
q	1387.0	-137.3	1216.5	-119.4	1061.4	-103.0	717.6	-66.3
w	1487.1	-570.7	1304.6	-500.2	1138.9	-436.5	773.2	-296.8
Base Area Size, $E=500x10^3$ m^2								
h	15139.6	140.3	13357.8	123.8	11753.9	105.9	8180.1	71.3
s	-953.8	49220.5	-898.1	43599.6	-850.6	38519.2	-739.6	27232.9
q	16223.8	-1668.2	14311.1	-1465.9	12579.7	-1282.2	8739.8	-877.0
w	17355.8	-6659.0	15313.2	-5875.6	13462.0	-5165.1	9364.0	-3592.5
Base Area Size, $E=1000x10^3$ m^2								
h	43255.2	401.1	38214.7	354.3	33663.8	308.6	23548.3	212.0
s	-2309.5	139367.7	-2154.4	123471.5	-2015.7	109095.7	-1706.4	77178.9
q	46376.2	-4810.2	40965.3	-4237.6	36069.9	-3719.2	25203.9	-2569.9
w	49587.8	-19025.9	43808.8	-16808.5	38580.9	-14802.4	26978.2	-10351.3

4.3 Capacity as a Function of both E and x_p

An attempt has been made to express coefficients a and δ in Relation (6), as functions of the base size E, so that Relation (4) would be specified. Some preliminary runs show that, for the four parameters considered here, both α and δ can be expressed as follows:

$$\alpha_\gamma = A_\gamma * E\hat{}t_\gamma \quad (7)$$

$$\delta_\gamma = D_\gamma * E\hat{}r_\gamma \quad (8)$$

where γ indicates the base area shape and A_γ, D_γ, t_γ, r_γ are constants specific for each design parameter and base area geometry. (Work is currently under way specifying the functional form and the parameter values at a statistically more acceptable level). Therefore, for these four parameters, Relation (4) becomes:

$$V_\gamma = A_\gamma * E\hat{}t_\gamma + D_\gamma * E\hat{}\, r_\gamma * x_p \quad (9)$$

For example, regarding lift height h, we have the following:

For circular base: $V = 1.13 * E^{1.53} + 0.01 * E^{1.54} * h$ (10)

For square base: $V = 0.97 * E^{1.53} + 0.009 * E^{1.53} * h$ (11)

Letting h = 2.50 m (which is its *typical* value, Table 1) in Relations (10) and (11), one gets almost identical values with those computed from Relation (5) (see Table 2). Functional relationships of the form (10) and (11) allow the analyst to easily investigate the effect of slight changes of h on LF/LR capacity.

The preliminarily computed specific values of coefficients α and δ in Relation (9), for the other three parameters are shown in Table 4.

TABLE 4: Values of Coefficients A_γ, t_γ, D_γ and r_γ in Relation (9)

Parameter	Coefficient	circular base	square base	rectangular base (1:2)	rectangular base (1:5)
width of strips between lifts (q)	A_γ	1.20	1.03	0.88	0.55
	t_γ	1.53	1.53	1.54	1.56
	D_γ	-0.105	-0.088	-0.072	-0.039
	r_γ	1.56	1.56	1.57	1.61
horizontal cell cover thickness (w)	A_γ	1.30	1.12	0.95	0.60
	t_γ	1.53	1.53	1.54	1.55
	D_γ	-0.50	-0.43	-0.37	-0.23
	r_γ	1.53	1.53	1.54	1.55
side slope (s)	A_γ	-0.51	-0.52	-0.53	-0.56
	t_γ	1.22	1.20	1.19	1.16
	D_γ	4.30	3.81	3.35	2.33
	r_γ	1.50	1.50	1.50	1.51

5. A FINAL COMMENT

Many sanitary landfills or landraises are expected to be built and put into operation over the next ten years (probably more than 50 in Greece alone). Thus, there is a growing need to develop basic design rules and guides, like those already existing for other civil engineering works. Although the literature on sanitary landfills grows rapidly, very little seems to have been paid to the issues raised in this paper. The design engineer needs guidance, not only on 'traditional' issues like leachate treatment, hydraulic design, or types of liners, but also on seemingly 'easier' issues like the ones mentioned in this paper, which have substantial impact on LF/LR performance. Through models like those presented here, non-specialist decision-makers can enter effectively into the planning game, evaluating the importance of design and operation parameters under an integrated systems approach where capacity could be related to the life of the LF/LR, the cost, the recycling levels, etc.

Although the generated capacity functions correspond to a specific LF/LR morphology, they can be quite effective. Analogous functions can be developed for other LF/LR morphologies. The engineer, using the relations (essentially coefficients α and δ) of Table 3, can employ these mathematical models for investigating trade-offs between pairs of parameters in cases of small changes in their values. For major changes in the d.p. values, multi-parameter functions would have to be developed. Similarly, through functions of the form developed here, the differential costs for changing the value of a design parameter can be weighted against the differential benefits from the changes in the capacity (e.g. cost of constructing a steeper slope vs extra volume).

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A PROCEDURE FOR GENERATING LANDFILL COST FUNCTIONS AND ESTIMATING THE DEGREE OF ECONOMIES OF SCALE

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ABSTRACT

A general framework is presented for generating cost functions of the form Cost = K * T $^{\alpha}$ for landfills, where T is the landfill size (tons of wastes ultimately placed) and K and α are coefficients depending on base geometry and symmetry, on design requirements and on landfill morphology. The general approach involves the classification of all landfill system components into four categories, according to whether their cost is linearly depended on base area size, perimeter length, quantity of wastes, or other factors. An example landfill morphology is analyzed in depth. As expected, economies of scale are observed (α <1); the main contribution here is the exact estimation of the scale factor α which is almost independent of base geometry and of design requirements.

ΔΙΑΜΟΡΦΩΣΗ ΣΥΝΑΡΤΗΣΕΩΝ ΚΟΣΤΟΥΣ ΓΙΑ ΧΩΡΟΥΣ ΤΑΦΗΣ ΑΠΟΡΡΙΜΜΑΤΩΝ ΚΑΙ ΠΡΟΣΔΙΟΡΙΣΜΟΣ ΤΟΥ ΒΑΘΜΟΥ ΟΙΚΟΝΟΜΙΑΣ ΚΛΙΜΑΚΑΣ

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ΠΕΡΙΛΗΨΗ

Στην παρούσα εργασία αναπτύσσεται μία διαδικασία διαμόρφωσης συναρτήσεων κόστους της μορφής Cost = K * T $^{\alpha}$, για Χ.Υ.Τ.Α., όπου Τ η συνολική ποσότητα αποβλήτων που εισρέουν σε όλη τη διάρκεια ζωής του Χ.Υ.Τ.Α. και Κ, α συντελεστές εξαρτώμενοι από την γεωμετρία και τη συμμετρία της βάσης, τις προδιαγραφές και τη μορφολογία Χ.Υ.Τ.Α. Τα υποσυστήματα ενός Χ.Υ.Τ.Α ομαδοποιούνται αναλόγως της εξάρτησής του κόστους-των από το εμβαδόν της βάσης, την περίμετρο, την ποσότητα αποβλήτων ή άλλους παράγοντες. Αναλύεται Χ.Υ.Τ.Α συγκεκριμένης μορφολογίας. Διαπιστώνεται θετική οικονομία κλίμακας (α<1), ενώ ο εκθέτης α είναι ανεξάρτητος της γεωμετρίας της βάσης και των προδιαγραφών σχεδίασης.

1. THE PROBLEM ENVIRONMENT

Sanitary landfills for solid wastes have only recently appeared in the project management and project planning related literature, with many questions on costs, user tips, and operations management still not thoroughly understood and analyzed. The work here is an attempt to address a specific question, that of the economies of scale in landfill development and operation. A general analytical framework is outlined for investigating the degree of economies of scale. To this end, cost functions are developed for a specific, almost of typical morphology, landfill (actually, a landpile).

Exact landfill cost functions are of vital importance for the planning and development of integrated regional solid waste management alternatives, not only for establishing trade-offs among competing management plans, but also (and perhaps more importantly) for effective communication with the decision-makers. A basic question decision-makers face at the regional level, the answer to which requires the use of landfill cost functions, is the following: For given solid waste streams in the region, is it economically preferable to build a single large landfill taking advantage of the economies of scale but bearing the larger transportation costs, or to build several smaller landfills in order to have smaller overall transportation costs which might cover the extra landfill development costs?

Essentially, the objective in this paper is to specify the function Cost = f (size). The "*size*" might refer to population served, to the landfill base acreage, to inflow level (tons/year) or to tons eventually deposited. The measure of size most often used is *total quantity of wastes, in tons, placed in the landfill* throughout its life.

Scarce references in bibliography, based on limited available data concerning landfill cost functions ([1],[12][13]), tend to accept the form:

$$C = K * T^{\alpha} \qquad (1)$$

where C is the ***total*** cost, T is the size, and K, α are coefficients. A geometry-based proof for the general form of such cost function is given in [1]. A more elaborate and general justification is needed.

In Equation (1), it is the exponent α which determines the degree of economies of scale. Not many researchers have dealt with the estimation of this coefficient. In [1] it is concluded that $0.67 < \alpha < 1.0$. In [13], a value of 0.8 is suggested without detailed analysis and justification. In [12] a value of 0.655 is determined on the basis of cost data from EPA. Most of the relevant studies deal with management issues concerning optimum size and life span [10], capacity expansion strategies [4], modular construction of landfill [5] and strategies for consuming landfill space over time ([6],[9]). A first analysis of the problem raised here was presented in [8].

In general, and taking into consideration the special features of the landfill as a construction project, it is logical to expect the exact form and the coefficient values of the cost function in (1) to depend on: (i) Design Requirements (which could depend on size), (ii) Landfill Size (tons), (iii) Base area geometry and size, and (iv) Other site-specific factors, like the topography, the hydrogeological conditions, etc.

The total cost C for a landfill can be seen from various perspectives. One method for looking at it, is a chronological classification as follows [7,11] :

$$\text{Total Cost} = \text{Predevelopment Cost} + \text{Construction Cost} + \text{Operating Cost} + \text{+ Closure Cost + Post Closure Cost.} \quad (2)$$

Another way of looking at this total cost, is to consider it as the sum of all landfill *component* costs, as follows: From a project management perspective, a landfill can be seen as a *system* consisting of several *subsystems* ; the development, construction, operation and closure of a landfill can be depicted as sequences of activities, each activity corresponding to the planning, the construction, or the operation of a landfill subsystem. Such activities are, for example: site characterization, land clearing, leachate and gas management, waste compacting, surface water control, environmental monitoring, seeding, fencing, land service care, site inspections, etc. Each activity corresponds to a *component cost* which could refer to the planning, construction, or operation of a subsystem. Thus,

$$\text{Total Landfill System Cost} = \sum \text{Activity Costs} = \sum \text{Landfill Component Costs} \quad (3)$$

The following two observations are important for the analytical framework developed in this paper:
1. Some component costs would be proportional to the *base area size* (e.g. liner installation), some would be proportional to the length of the perimeter (e.g. fencing), and some proportional to the quantity of the wastes (e.g. gas management system).
2. Landfill configuration is not fixed. Different landfills might have different set of subsystems due to different design requirements; some subsystems, of course, are always mandatory. For example, all landfills will have bottom soil lining, but not all will have a gas collection system. Such differentiation could occur even within the same category of landfills, but for different size ranges.

If there were no changes in system configuration as the landfill system size changes, then the cost function of (1) would have the form of Figure 1.a. When changes occur (e.g. additional subsystems are added as the size range goes from *small* to *medium* or to *large)*, then the cost function might look like that of Figure 1.b.

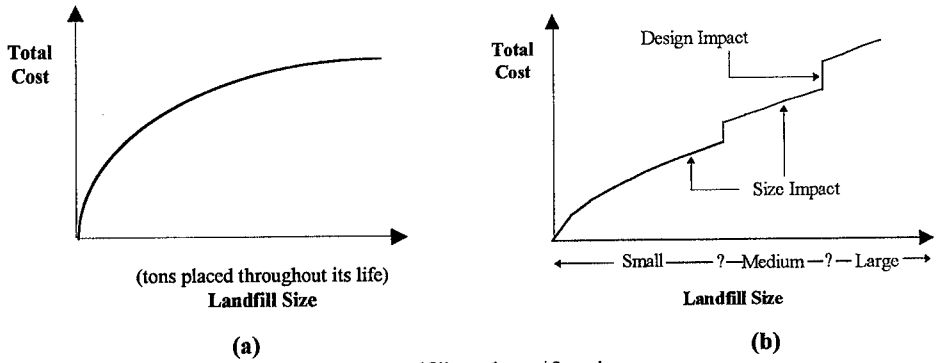


Figure 1. Landfill total cost function

2. THE ANALYSIS PROCEDURE

A procedure is now presented for generating the cost function of *any specific* landfill category (e.g. for municipal wastes, or for hazardous wastes). The landfill may have: *any* external morphology, *any* geometric shape of base area, and *any* set of design requirements which may be changing with

landfill size ranges. Other factors which are site-specific (e.g. hydrogeological characteristics, initial site morphology, availability of wastes cover material), will be considered as *fixed*; their cost impact will be added to the cost function derived. In other words, the cost functions generated here will take into consideration only *base area shape*, *design requirements*, and required *external morphology*. This is necessary in order to focus on comparable and controllable features.

The procedure is as follows:

1. Identify all landfill subsystems (and their corresponding activities) expected to be required for the specific category of landfill under consideration, in the specific region or country. (Actually, such a list may be a *subset* of a longer and permanent list available to the analyst).
2. Establish size ranges within which different subsystems or design requirements may apply (in Figure 1.b, for example, three different ranges have been identified).
3. For each size range, a list of the required subsystems and activities is established. (The expected new European Directive on landfills for municipal wastes, would probably have two ranges: one for landfills of size less then 10,000 tons serving small islands with *only one* landfill or isolated settlements with difficult access, and one for all other sizes, without exception as to the region of Europe or the composition of the municipal wastes).
4. Each component or activity cost is *characterized* and *classified* according to whether it is (or could be adjusted to be) directly proportional to:
   - the base area of the landfill
   - the perimeter length of the landfill.
   - the maximum quantity T of wastes eventually placed in the landfill

   Cost components not belonging to any of the above three groups, are grouped separately for special consideration at the end.
5. On the basis of the geometry and the morphology of the landfill:
   a. express the base area-related component costs as a function of the total quantity T
   b. express the perimeter-related component costs as a function of T
   c. express the quantity-related component costs as a function of T.

   These functional forms will be valid for any size range and any design requirements.
6. Add up the cost functions from step 5.

We define the following:

A	base area of the landfill, in $m^2 * 10^3$ (assumed flat, with known geometric shape). For a given morphology of the landfill, to which the corresponding capacity is T tons (in $m^3 * 10^3$), the base area A can be related to the quantity T through a specific function A(T)
M	the set of landfill components whose cost is (or could be transformed to be expressed as) proportional to the base area A.
M_i	the cost per unit area A of component i in set M; $\sum_M \mu_i = \mu$ (e.g. $\$ / 10^3 * m^2$)
P	the length of the perimeter of the landfill (in $m * 10^{3/2}$), along which some components of the landfill system will be set up. For a given morphology and base geometry of the landfill, to which the corresponding capacity is T tons, the perimeter P can be related to the quantity T through a specific function P(T)
L	the set of landfill components whose cost is (or could be transformed to be expressed as) proportional to the perimeter length P

λ_i	the cost per unit length of the perimeter P of component i in set L; $\sum_L \lambda_i = \lambda$ (e.g. $\$ / 10^{3/2} * m$)
N	the set of landfill components whose cost is (or could be transformed to be expressed as) proportional to the quantity T
v_i	the cost per unit of quantity T of component i in set N; $\sum_N v_i = v$
$C_A(T)$	Sum of all landfill component costs corresponding to the set M; $C_A(T) = \mu A(T) = \sum_M \mu_i A(T)$
$AC_A(T)$	Total Unit, or Average, cost for all components in M, i.e. cost per 10^3 tons; $AC_A(T) = C_A(T)/T = \mu^* A(T)/T$ (4)
$C_P(T)$	Sum of all landfill component costs corresponding to the set L; $C_P(T) = \lambda P(T) = \sum_L \lambda_i P(T)$
$AC_P(T)$	Total unit, or average, cost for all components in L; $AC_P(T) = C_P(T)/T = \lambda * P(T)/T$ (5)
$C_Q(T)$	Sum of all landfill component costs corresponding to the set N; $C_Q(T) = v * T = \sum_N v_i T$
$AC_Q(T)$	Total unit, or average, cost for all components in N; $AC_Q(T) = C_Q(T)/T = v$ (6)
G	Sum of all component costs which do not correspond to any of the sets M, L or N

(Note: All costs are expressed in terms of present values)

Then, the Total Average Cost AC(T) will be:

$$AC(T) = AC_A(T) + AC_P(T) + AC_Q(T) + G/T \quad (7)$$

or

$$AC(T) = \mu * A(T)/T + \lambda * P(T)/T + v + G/T \quad (8)$$

In order to generate the exact function for Relations (4) to (8), one has to refer to a landfill of specific morphology and characteristics. It is not possible to have a single cost function for every imaginable landfill shape or form. As already mentioned, this paper examines the effect of size on the average cost (degree of economies of scale) for a specific category of landfills.

3. AN EXAMPLE CASE

The example case of Figure 2 will now be used for the generation of the cost functions (4) to (8). It is a typical simple type of a landfill, built above ground (*area method*). Work is currently going on for generation of cost functions for different landfill morphologies. Note that the full height H and the total number of lifts depend on the geometry.

In [2] and [3], the capacity V of the landfill of Figure 2 (in terms of 10^3 m^3 available for placing wastes) is computer - simulated using the default set of values for the design parameters shown in Figure 2 and is expressed as a function of area A and as a function of each of the design parameters. The area-related capacity function assumed the form

$$V = k A^{\beta} \tag{9}$$

where k and β are coefficients depending on base area geometry (four shapes were considered: *circle, square, rectangle 1:2, and rectangle 1:5)* and the specific design parameters.

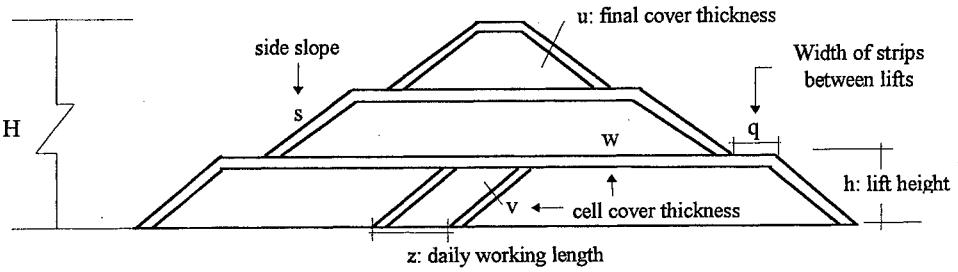


Figure 2. Cross-section view of the landfill for the Example Case

Letting b be the density of wastes in the landfill, we have V = T / b and, through this, (9) becomes

$$T / b = k A^{\beta} \tag{10}$$

or

$$A(T) = (kb)^{-1/\beta} T^{1/\beta} . \tag{11}$$

From (4) and (11),

$$AC_A(T) = \mu (kb)^{-1/\beta} T^{1/\beta - 1} \tag{12}$$

The perimeter P of each of the four shapes of the base can be related to the base area A through simple mathematical manipulations. For example, for *square shape base*, with radius R, we have: $P = 2\pi R$ and $A = \pi R^2$, thus $P = 2\pi^{1/2} A^{1/2}$. Then, through (11), we have $P(T) = 2\pi^{1/2} (kb)^{-1/2\beta} T^{(1-2\beta)/2\beta}$ and, from (5), we get:

$$AC_P(T) = \lambda \gamma (kb)^{-1/2\beta} T^{(1-2\beta)/2\beta} \tag{13}$$

where, coefficient $\gamma = 2\pi^{1/2}$ and it depends only on the base area shape (it would be different for other base area shapes).

The total average cost in (8) now becomes:

$$AC(T) = G T^{-1} + \lambda \gamma (k b)^{-1/2\beta} T^{(1-2\beta)/2\beta} + \mu (k b)^{-1/\beta} T^{(1/\beta - 1)} + v \tag{14}$$

The specific values of coefficients k, β for the four base area shapes, were estimated through curve fitting techniques and are given in [2]. In [2], the following values were assumed for the design parameters shown in Figure 2: h = 2.5 m; s = 0.33; z = 8.0 m; q = 0; w = 0.30 m; v = 0.15 m; u = 0.80 m.

The corresponding values of k, β along with coefficient γ are shown in Table 1.

Table 1: Values of Coefficients in Relation (14)

Base Geometry	**k**	**β**	**γ**
Circle	1.73	1.52	3.54
Square	1.50	1.52	4.00
Rectangle 1:2	1.30	1.53	4.24
Rectangle 1:5	0.85	1.54	5.37

Letting $b = 0.7$ tons / m^3, Relation (14) becomes:

circle: $$AC(T) = G\,T^{-1} + 3.324\,\lambda\,T^{(-0.671)} + 0.882\,\mu\,T^{(-0.342)} + \nu \quad (15)$$

square: $$AC(T) = G\,T^{-1} + 3.936\,\lambda\,T^{(-0.671)} + 0.968\,\mu\,T^{(-0.342)} + \nu \quad (16)$$

rectangle 1:2: $$AC(T) = G\,T^{-1} + 4.375\,\lambda\,T^{(-0.673)} + 1.064\,\mu\,T^{(-0.346)} + \nu \quad (17)$$

rectangle 1:5: $$AC(T) = G\,T^{-1} + 6.352\,\lambda\,T^{(-0.675)} + 1.401\,\mu\,T^{(-0.351)} + \nu \quad (18)$$

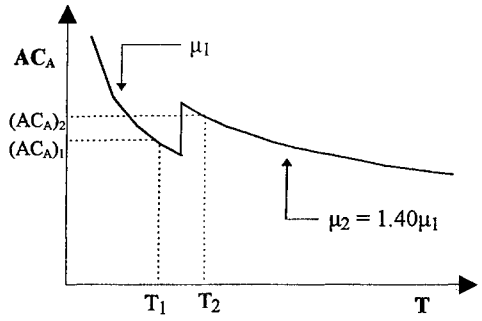
3. DISCUSSION

In (14), **ν**, **μ** and **λ** can be seen as the *design impact* coefficients; **γ** and **k** as the *geometry and symmetry impact* coefficients; **β** as the *morphology and size impact* coefficient and **b** as an *operation impact* coefficient.

It is observed that the scale factor **β** is almost constant for all base area geometries; it is coefficient **k** which sharply differentiates the impact of the different geometries on capacity levels and on costs. Thus, for example, for any given base area size, the area-related average cost $AC_A(T)$ for rectangle 1:2 base will be *20% larger* than $AC_A(T)$ for circular base area; similarly, for the perimeter-related cost $AC_P(T)$, this percentage increase in the cost would be 31%.

The essential feature of the analysis here is that the functional form of the cost remains unchanged when the value of μ, λ and/or ν change. A change in the value of μ, λ, and/or ν, could cause the "design impact" jump shown in Figure 1.b. Relations (8) and (14) are valid within ranges set by the values of μ, ν, and λ.

In Figure 3, the average cost $AC_A(T)$ is shown for the case of rectangle 1:2 base area and $b = 0.7$ tons/m^3. Here, it is observed that, at least theoretically, it is possible to have a design impact which could cancel the economies of scale. For example, if μ_1 and μ_2 correspond to different sets of design requirements, with $\mu_2 = 1.40\mu_1$, then, as one moves from an initial size level T_1 to a new level $T_2 = 1.5 \cdot T_1$, there is an increase (approximately 10%) in AC_A rather than a decrease. Clearly, it is not impossible for the economies of scale to be canceled by this increase in μ. Similar trade-off analyses can be performed for $AC_P(T)$ and $AC_Q(T)$.



$$AC_A(T)_1 = 1.064\ \mu_1\ T^{(-0.346)}$$
$$AC_A(T)_2 = 1.064\ \mu_2\ T^{(-0.346)}$$

Figure 3. Average cost function for the example case, for rectangle 1:2 base area and b = 0.7 tons/m^3

As already mentioned, the main contribution of this work is the presentation of an analytical procedure for generating the cost functions. Here, such a function has been generated for a specific type of landfill. Other types and morphologies of landfills can be analyzed through the same procedure producing similar cost functions.

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GREEK LANDFILL LEACHATE QUALITY AND MANAGEMENT OPTIONS

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ABSTRACT

Recently in Greece, great emphasis is placed on the development of landfill technology. Environmental concerns have led to demands for the increased and improved collection, treatment and disposal of leachate. Leachate composition and production vary widely. There are many processes that can be applied to the treatment of the leachate. Besides, the management of the leachate is a serious problem which has to be solved economically without adverse environmental effects. In this paper, leachate quality analyses of Greek landfills are given. Moreover, the options for leachate collection, treatment and disposal are presented and evaluated.

ΠΟΙΟΤΗΤΑ ΚΑΙ ΕΠΙΛΟΓΕΣ ΔΙΑΧΕΙΡΙΣΗΣ ΣΤΡΑΓΓΙΣΜΑΤΩΝ ΕΛΛΗΝΙΚΩΝ ΧΩΡΩΝ ΔΙΑΘΕΣΗΣ ΑΠΟΡΡΙΜΜΑΤΩΝ

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ΠΕΡΙΛΗΨΗ

Πρόσφατα στην Ελλάδα δίνεται μεγάλη έμφαση στην ανάπτυξη τεχνολογίας στους χώρους διάθεσης απορριμμάτων. Η μέριμνα για το περιβάλλον έχει οδηγήσει σε απαιτήσεις για αυξημένη και βελτιωμένη συλλογή, επεξεργασία και διάθεση των στραγγισμάτων των Χώρων Υγειονομικής Ταφής Απορριμμάτων (ΧΥΤΑ). Η σύνθεση και η παραγωγή των στραγγισμάτων παρουσιάζουν μεγάλη διακύμανση. Υπάρχουν πολλές διεργασίες που μπορούν να εφαρμοστούν για την επεξεργασία των στραγγισμάτων. Επιπροσθέτως, η διαχείρισή τους είναι σοβαρό πρόβλημα που πρέπει να επιλυθεί οικονομικά χωρίς δυσμενείς περιβαλλοντικές επιπτώσεις. Στην εργασία αυτή δίνονται ποιοτικές αναλύσεις στραγγισμάτων ελληνικών χώρων διάθεσης και παρουσιάζονται και αξιολογούνται οι επιλογές συλλογής, επεξεργασίας και διάθεσης των στραγγισμάτων.

1. INTRODUCTION

Leachate is produced as water percolates through the solid waste, leaching soluble components and degradation products from the refuse. The flowrate and composition of leachate vary both from site to site and seasonally at each site for a wide range of reasons, including the interactions between refuse composition, age of landfill, hydrogeology of the site, climate, pH, nutrients, toxins, particle size, oxidation-reduction potential, and moisture content through the fill. Leachate contains considerable amount of dissolved organics, heavy metals, in some cases adsorbable organic halogen or polyaromatic hydrocarbons, and has intense color. Leachate collection and treatment systems were not a concern until the late 1970s, and previously landfills were designed without liners. These old landfills, most of which are now closed, still generate leachate and may require remedial collection systems. Modern landfills can be quite sophisticated, employing leachate collection and detection systems with extensive field and laboratory testing on a routine basis.

The contamination of surface and groundwater by landfill leachates has been recognized by many researchers [1,2,3,4]. The major concern with the movement of leachate into the subsurface aquifer below unlined and lined landfills is the fate of the constituents found in leachate. Mechanisms that are operative in the attenuation of the constituents found in leachate as it migrates through the subsurface soil include mechanical filtration, precipitation and coprecipitation, sorption, gaseous exchange, dilution and dispersion, and microbial activity. Assessment of present and future solid waste landfill design requirements and contaminant impacts on adjacent surface and ground waters requires accurate characterization of the quality and quantity of leachate produced.

Because of the potential risk involved in allowing leachate to percolate to the groundwater, best practice calls for its elimination or containment. Although it is mostly the leachate quality that causes pollution, it is its quantity that is more easily controllable. Careful site management can reduce the amount and strength of leachate, however, some form of treatment is necessary to protect receiving waters. As a result of the variability in leachate characteristics, the design of leachate treatment systems is complicated. A wide range of treatment options have been utilized with varying degrees of success. Alternatives which have been used to manage the collected leachate include : leachate recycling, evaporation, treatment followed by disposal, and discharge to municipal wastewater collection systems [3]. Since landfill leachate is comparable to complex industrial waste streams [5], new regulations tend to limit the discharge to municipal sewers. On-site «high-tech» treatment systems are often avoided due to large construction and operation costs [6].

In this paper Greek landfill leachate quality data are reported. Moreover, options for leachate management are examined and their application to Greek landfills is evaluated.

2. LEACHATE CHARACTERISTICS

In designing of new sanitary landfills the construction of leachate collection systems , which will reduce the groundwater pollution, must be anticipated. For this reason an estimate of the leachate generation rate and volume is required. Several researchers [3,7,8,9,10] have suggested various techniques for estimating the leachate generation. These techniques use a water budget analysis. However, generally the determination of the water budget is not a simple task. The interactions among the climate, the cultivation and the soil characteristics and their effects on runoff, evaporotranspiration and the vertical drainage are complex and laborious. For this reason, many attempts for developing simulation models of leachate generation have been reported. Such kind of simulation models are the USDAHLL [11],

HSSWDS [12], HELP [13], etc. Research efforts have indicated that models like HELP may constitute useful tools for the design of sanitary landfills.

The characteristics of the leachate are highly variable depending on the composition of the solid wastes, rate of water application, refuse moisture content, landfill design, operation and age of the landfill, and events preceding the time of sampling. The biodegradability of the leachate varies with the time too. Leachates generated from recently emplaced wastes have high concentrations of organic compounds, low pH value and high ammonia concentrations. This organic material is readily biodegradable and as the leachate ages its concentration reduces. So, an older leachate has a relatively low, but non-biodegradable organic fraction with a high strength ammonia fraction [14]. These variabilities result in complications when designing leachate treatment systems. Representative data on the characteristics of leachate from : (1) Literature [3], (2) Attiki's landfill in Ano Liosia [15,16], and (3) Thessaloniki's Greater Area landfill in Tagarades [17,18,19] are reported in Table 1, as the minimum and maximum values of the parameters. The lake and the pond are located at the lowest side of the landfills and the leachate is stabilized. Fresh samples (of only few days) were collected directly from the deposition area.

Table 1. Characteristics of leachate composition

Parameter	Literature data		Attiki (Ano Liosia)		Thessaloniki (Tagarades)	
	New landfill	Mature	Gushing up	Lake	Fresh leachate	Pond
pH	4.5 - 7.5	6.6 - 7.5	8.1 - 8.5	8.0 - 8.5	4.9 - 6.7	7.2 - 7.9
BOD_5	2000 - 30000	100 - 200	650 -1150	440 - 880	9500 - 80800	50 - 2000
COD	3000 - 60000	100 - 500	4000 - 8810	3000 - 7000	44000 - 115000	685 - 11900
TS			9000 - 19600	7550 - 18600	3210 - 7710	3140 - 14000
TDS			8740 - 19250	7490 - 18450	3120 - 7620	3800 - 13000
TSS	200 - 2000	100 - 400	90 - 470	40 - 300	40 - 190	50 - 750
TKN					1560 - 2020	150 - 380
Org-N	10 - 800	80 - 120			135 - 1425	82 - 412
$N\text{-}NH_3$	10 - 800	20 - 40	1650 - 3870	912 - 2120	900 - 10250	39 - 720
$N\text{-}NO_3^-$	5 - 40	5 - 10	14 - 91	31.5 - 97	10 - 840	1.1 - 44
TP	5 - 100	5 - 10			14.6 - 23.8	0.14 - 0.39
$P\text{-}PO_4^=$	4 - 80	4 - 8	5 - 13.2	4.2 - 18	1.6 - 655	0.02 - 137.5
$SO_4^=$	50 - 1000	20 - 50	70 - 350	80 - 350	400 - 2500	2.6 - 500
Alkal. $CaCO_3$	1000 - 10000	200 - 1000	1100 - 3500	1000 - 4000	3540 - 26200	923 - 4692
Hard. $CaCO_3$	300 - 10000	200 - 500			570 - 855	87 - 122
Fe	50 - 1200	20 - 200	5 - 16.2	9.3 - 17.25	8.7 - 159.6	0.11 - 25
Mg	50 - 1500	50 - 200	85.2 - 140	80 - 124	147 - 443	0.02 - 337
Ni			0.67 - 1.35	0.68 - 1.13	0.2 - 7.8	0.08 - 5.08
Cu			0.09 - 0.28	0.09 - 0.25	0.01 - 4.8	0.02 - 4.54
Pb			< 0.1	<0.1	0.23 - 2.11	<0.5
Cd			<0.1	<0.1	0.02 - 6.51	<0.01 - 0.07
Cr			0.7 -1.91	0.27 - 1.05	0.01 - 3.66	0.15 - 0.45
Colour			4000 - 9375	4000 - 6800	6250 - 20000	955 - 8600
Chloride	200 - 3000	100 - 400	760 - 2350		3780 - 3820	3 - 5960

All the units are in mg/l, except the pH and colour

It is readily noticed from Table 1 that there is a wide variation of organic matter in Thessaloniki's data. Observations of Ano Liosia landfill leachate composition indicates that it has high pH, and low BOD/COD ratio values, which means that it is stabilized and the microbial action is already limited in the landfill. Consequently, this high organic load leachate must be treated, at least initially, by physicochemical processes instead of biological or a combination of both methods may be used [15,20]. Moreover, it must be noticed that in Ano Liosia the stabilization of the solid wastes and the start of the methane production phase was observed to take place in relatively short time (less than a year). This is probably due to the high moisture content (48%) of the solid wastes which combined with the high

temperatures favor the development of the wastes decomposing microorganisms [16]. Thessaloniki's leachates are high in organic material and low in contents of examined metals, especially the stabilized effluent of the pond. Moreover, the leachate of the pond is characterized by a very low BOD/COD ratio which excludes the possibility of treatment by biological processes only [17,18] unless it is combined with municipal sewage [21].

3. LEACHATE MANAGEMENT OPTIONS

To limit or eliminate the movement of leachate from the landfill site liners are now commonly used. There are a variety of liner systems, including clay liners and single- and double-composite liners. Composite liner design can include various combinations of geomembranes, geotextiles, and soil layers. A typical single composite liner will comprise a sand drainage layer, flexible geomembrane liner (with leachate collection system), and layer of compacted clay. Currently the composite liners for municipal solid waste landfills are usually double liner systems consisting of a leachate collection system embedded in geonet, a porous synthetic drainage layer, or gravel, followed by a geomembrane and a compacted clay or geosynthetic clay liner, typically made of sodium bentonite sandwiched between two sheets of geotextile. This composite top liner is then followed by a leak detection system consisting of a gravel or geonet layer and another geomembrane or composite liner.

By combining geomembranes and geosynthetic clay liners into one landfill liner system, capture rates for landfill leachate are better than 99%. Researchers monitored the hydraulic performance of municipal waste landfill cells with composite liners and found that the average rate of landfill leachate drainage into the leak detection layer was 0-4l/hectare/day [22].

Landfill liner performance depends on the materials selected for the liner, the quality of the liner construction and the operation of the landfill. Sometimes failures happen because of operator error, such as driving heavy equipment on the liner just after construction. In order to avoid leaks in geomembrane liners the following factors are considered most important : the professionalism and skill of the seaming-machine operator; environmental factors such as moisture, temperature and wind; the simplicity of the liner design; the thickness and weldability of the liner material; and the liner care and handling procedure. An electrical leak-location survey conducted after final construction, but prior to placing waste in the cell, is a cost-effective way for testing and locating leaks.

The leachate collection system usually consists of headers and laterals. The laterals are a series of parallel collection pipes that drain to the low end of the disposal area and connect to headers that pipe the liquid to a pump station. Then, the collected leachate is transported to a treatment facility, stored in a tank, or recirculated to the landfill.

The primary means of leachate disposal has been discharge to publicly owned treatment works, often by trucking. However, this discharge is becoming increasingly difficult because of requiring sewer connections (difficult for remote locations) and local political opposition, suggesting the need for more on-site treatment of leachate. Problems associated with traditional methods of leachate management, such as siting a conventional treatment plant or hauling to off-site treatment facilities, include the following : (1) On-site plant operation and maintenance is costly, (2) The addition of leachate to municipal sewage may disrupt the normal biological process upon which treatment depends, and (3) The municipal treatment facility can refuse to accept the waste stream at any point they deem the effluent inappropriate for the municipal treatment works.

One of the simplest leachate management systems involves the use of lined leachate evaporation ponds [3]. Leachate that is not evaporated is sprayed on the completed portions of the landfill. Depending upon the climate, it may be necessary the lined leachate storage facility to be covered with a geomembrane. During the summer when the pond is uncovered, surface aeration may be required to control odors.

Solar distillation offers an alternative for leachate treatment, which can be very efficient, at least in «solar-rich» countries. The main parts of this system is a sedimentation basin and the solar stills. The use of sloping-roof stills offers, in many cases, an attractive alternative, since cheap land is usually available in the vicinity of the landfills, and land requirements for the solar plant is a small percentage (e.g. 2%) of the solid waste disposal area [23]. The possibility of piecewise construction and the use of disposed wastes layers as leachate reservoirs add to the attractiveness of this leachate treatment method.

Several researchers have suggested that recirculation of leachate through solid wastes could result in accelerated decomposition of the wastes, assisted by their increased moisture content and indicated by a rapid decline in the strength of leachates produced. However, the hydrology of landfill sites where recirculation is planned should be carefully considered to prevent possible lateral movement of liquids into surrounding surface or groundwater. In order to gain the benefits of leachate recirculation, leachate/waste contact opportunity must be provided at a rate which does not cause leachate to accumulate excessively within the landfill, or emerge from landfill slopes and contaminate stormwater runoff. Proper management of leachate requires an understanding of a recirculating landfill water balance. In any case, ex situ liquid storage is vital to proper management of leachate during early phases of landfill operation, during peak storm events, and following closure of the cell. However, in some areas precipitation rates are so low that ensuring sufficient moisture to wet the waste adequately is more problematic than managing leachate.

The advantages of leachate recirculation include distribution of nutrients and enzymes, pH buffering, dilution of inhibitory compounds, recycling and distribution of methanogens, liquid storage and evaporation opportunities [24]. The frequency of recirculation can be employed as a new control measure to optimize landfill operations and alter leachate characteristics as desired. Small and less frequent rates of leachate recycling are often practiced during the acidogenic phase to avoid any potential inhibitory effects on the overall process. More aggressive recirculation may follow during the methanogenic phase [25]. Leachate recirculation has also important consequences with regard to metal contamination of leachate, eliminating effectively the majority of heavy metals. However, in order to avoid remobilization of precipitated metals, the inactivation of the landfill (removing all excess leachate) is suggested once the waste has been stabilized. Where leachate treatment is the primary objective, leachate recirculation may be confined to treatment zones located within the landfill where appropriate processes are optimized. Use of in situ nitrification, denitrification, anaerobic fermentation and methanogenesis have been proposed to treat leachate depending on the phase and age of the waste [26]. Although some organic materials can be removed from leachate during recirculation, concentrations of ammonia, chloride and COD may remain high. Recirculation of leachate can offer benefits in reducing the volume and strength of leachate, but cannot be considered to be a complete answer to surface leachate discharges [27]. At many sites a combination of recirculation through the landfill and aerobic treatment of the leachate may be the most effective option.

As experience is gained in the operation and design of full-scale leachate recirculation landfills, it is expected that advantages of leachate recirculation will become more evident, including economic benefits associated with increased gas utilization opportunities, reduced leachate treatment requirements, avoidance of long-term monitoring and liability, and the

potential for landfill mining and reuse. Moreover, the total investment in leachate recirculation with in situ treatment could be offset by savings consequenced by landfill space recovering. Therefore, leachate recirculation and rapid stabilization can be integrated into an effective landfill management program.

Where leachate recycling and evaporation is not used, and direct disposal of leachate to a treatment facility is not possible, some form of pretreatment or complete treatment will be required. Whereas biological processes are able to remove the readily biodegradable organic fraction, less biodegradable material passes through untreated. In addition, it is difficult to achieve biological nitrification due to the large amount of inhibitory material present in the leachate. By contrast physicochemical treatment options are able to strip ammonia from a leachate but do not achieve a significant degree of organic removal [28]. The treatment process or processes selected will depend to a large extent on the characteristics of the leachate and the contaminants to be removed and secondarily on the geographic and physical location of the landfill [3].

In Germany, several treatment plants for landfill leachate are being planned or under construction. So far, three main treatment schemes have been developed : (1) Biological treatment + activated carbon adsorption, (2) Biological treatment + oxidation by ozone/UV and (3) Reverse osmosis + ammonia recovery + drying solids. Although the feasibility of all of these treatment schemes has been demonstrated, the costs are significantly high. Therefore, new process combinations are studied now in order to find out whether there could be any cost benefits from synergistic effects [29].

In Norway [6] and the USA [30] integrated landfill leachate treatment systems were developed utilizing aerated lagoons followed by constructed wetlands. The overall removal for organic matter (COD, BOD, TOC), N, P, Fe and pathogens (E.Coli) was promising (60-99%). These data suggest various physical, microbiological and chemical processes occurring within the aerated lagoons and constructed wetlands can provide an effective alternative to standard techniques for leachate treatment and disposal.

For Greek landfills, containment and collection of leachates, in order to protect the surface and ground water from pollution, must be initially the major concern. The use of lined leachate evaporation ponds is favored by the Greek climatic conditions and may minimize substantially the volume of the leachate to be treated and disposed of. Moreover, these ponds may be used as leachate storage facilities and operate in conjunction either to leachate recycling in the landfill or its on-site treatment. Solar distillation offers a promising alternative too, because Greece is a «solar-rich» country. However, skilled personnel is required in order to avoid a failure, like the one that happened in the plant of the Greek island Patmos more than 25 years ago [23]. Leachate recycling is considered a desirable management option, simple enough in operation and cost effective. A method of on-site treatment that is inexpensive and requires little maintenance or power after landfill closure, like constructed wetlands, is extremely important. More sophisticated treatment processes, although may be necessary, must be limited to residual leachate quantities and only to major landfills, which will have available the necessary economic funds and adequately trained personnel to operate effectively these treatment facilities. The application of a single treatment method cannot efficiently reduce the organic load of leachate originating from stabilized landfills. The residual leachate, if accepted by municipal wastewater treatment plants, may be transferred and treated combined with municipal sewage.

4. CONCLUSIONS

Leachates are one of the most variable waste streams, and that makes them difficult to treat on-site, costly to treat off-site, and risky to transport. At all landfill sites leachate control and treatment should aim to make the optimum use of natural features of individual landfill settings, with the primary objective of reducing overall leachate management cost. New generation full-scale landfills are implementing recirculation as a leachate management tool with increasing frequency. Recirculation of leachate, while significantly increases the rate of waste stabilization, can help to reduce leachate disposal costs too. Generally, the treatment of leachate is difficult because of its continuous variation in flow and quality. The variability of leachate composition and complexity of leachate treatment makes it nearly impossible to formulate strict design guidelines of universal validity. Before treatment options are evaluated it must first considered the leachate composition, volume and susceptibility of treatment, but also the regulatory agencies receptiveness to permitting such systems as well as the economics of each treatment alternative. For Greek landfills containment and collection of leachates is the major concern. From the existing worldwide technologies and operational experience it must be selected the most appropriate for each landfill site, which will take under consideration not only the technical feasibility but mainly the available economic funds and properly trained personnel.

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LANDFILL LEACHATE AND UNDERGROUND IMPACT

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ABSTRACT

This study includes the determination of the pollution level of the groundwater as well as an evaluation of the hydrological balance of a landfill site situated in Athens area. The study concerns the area in which the major landfill site of Greece is situated. The hydrological balance was estimated by using the Hydrological Evaluation of Landfill Performance (HELP) model. Regarding the groundwater quality, the groundwater near the landfill site is characterized as not potable and not suitable for irrigation, since most of the physical and chemical parameters examined exceed the permissible limits.

ΠΑΡΑΓΩΓΗ ΣΤΡΑΓΓΙΣΜΑΤΩΝ ΣΤΟ ΧΩΡΟ ΔΙΑΘΕΣΗΣ ΑΠΟΡΡΙΜΜΑΤΩΝ ΑΝΩ ΛΙΟΣΙΩΝ ΚΑΙ ΕΠΙΔΡΑΣΗ ΣΤΟΝ ΥΔΡΟΦΟΡΟ ΟΡΙΖΟΝΤΑ

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ΠΕΡΙΛΗΨΗ

Στα πλαίσια της παρούσας εργασίας προσδιορίσθηκε ο βαθμός ρύπανσης των υπογείων υδάτων της περιοχής του χώρου διάθεσης απορριμμάτων Άνω Λιοσίων. Επίσης, εκτιμήθηκαν οι παράμετροι που συμμετέχουν στο υδρολογικό ισοζύγιο του χώρου διάθεσης μέσω εφαρμογής του μαθηματικού μοντέλου HELP. Τα αποτελέσματα του μοντέλου αυτού κυμαίνονται σε λογικά και αναμενόμενα επίπεδα. Όσον αφορά στην ποιότητα των υπογείων υδάτων, τα δείγματα που λήφθηκαν από σημεία πλησίον του χώρου διάθεσης χαρακτηρίζονται ως ακατάλληλα για πόση και άρδευση, λόγω του ότι οι περισσότερες από τις παραμέτρους που μετρήθηκαν παρουσιάζουν τιμές υψηλότερες από τις επιτρεπόμενες.

1. INTRODUCTION

A common problem of the storage of wastes in landfills, is potential contamination of soil, groundwater and surface waters that may occur as leachate (produced by water or liquid wastes moving into, through and out of the landfill) migrates into adjacent areas. The situation is more severe, when industrial wastes are involved, that contain substances quite resistant to biological or chemical degradation.

The quantity of leachate produced is affected to some extent by decomposition reactions and initial moisture content; however it is largely governed by the amount of external water entering the landfill, the climate and the geomorphology of the area.

The chemical quality of leachate varies as a function of a number of factors including the original nature of the buried waste materials and the various chemical and biochemical reactions that may occur as well as the conditions prevailing (T, pH, COD, etc) throughout the waste materials decomposition. In the absence of evidence to the contrary, most regulatory agencies based on previous experiences and the «present library principles» usually assume that any leachate produced will, potentially, contaminate either ground or surface waters, [1]. Leachate composition for a given landfill cannot be predicted from literature data since the parameters influencing its quality are not easy to justify. Research has shown that the composition of landfill leachate from the same source as well as from different sources is extremely variable, [1-3]. The composition of leachate from recent and aged areas within a municipal landfill has been studied and it was confirmed that leachate composition alters with time, [4].

Identification of groundwater contamination as a serious environmental problem is relatively recent. In a review of the scientific literature on groundwater pollution and sanitary landfills, Zanoni 1971, [6], identified only one citation on the topic prior to 1950, [7], and eight citations in the 1950s. In the 1960s the number increased to 47. The adverse impacts of landfill leachates on adjacent surface and groundwater have prompted a great number of studies after 1980. This includes researches on the constituents of leachate produced [8-11] as well as on the underground water quality [12-15].

2. METHODOLOGY

In order to assess the pollution of the groundwater, two general procedures can be followed, the experimental determination of the pollutants and the estimation through mathematical modeling. In this work the first procedure was chosen as a first step. In addition the Hydrologic Evaluation of Landfill Performance (HELP) Model was implemented for the estimation of the leachate quantity.

2.1 Area Description

The study concerns the area in which the major landfill site of Greece (Ano Liosia - Athens) is located.

The landfill has been in operation since 1973 and extents to an area of 173 ha, of which 45 ha are actually covered by deposited wastes. The average quantity of wastes deposited daily is 3500 tns, received from an urban population of nearly 3 500 000 inhabitants. The daily per capita production of wastes is estimated at approximately 0.875 kg/capita/day with an annual increase rate of the range of 1.5-2.5%, [16]. The composition of waste is 52% organics, 20% paper, 9% plastics, 4% metals, 4% glass, 3% textiles, wood and leather, 4% inert, 4% other.

The area in which the disposal site is located, is moderately steep, semi-arid, covered by wild vegetation consisting of low plants and grass. The prevailing geological formations are limestone (karst type) of the Triassic and Jurassic ages. These formations have a relatively dense network of fissures and fractures which are characterized as quite permeable, with an average percolation rate of 8-10 m/day.

The bottom of the landfill is not lined and there is no provision for the collection of leachate apart from a system of surface trenches dug along the bottom contours of the deposits that collect leachates mixed with surface runoff and divert it to a pond with a capacity of approximately 1000 m^3. The wastes are compacted on site mechanically, deposited in layers of 150-350 cm and covered by 50-200 cm of earth, sand gravel and clay materials. The depth of deposition in the center of landfill body exceeds the depth of 20 m, [17].

The groundwater of the greater area under study is mainly used for industrial and irrigation purposes. Its use as potable water is very limited since the area is covered by the central water supply system. Due to the shortage of rainfall during the past few years, the underground water might be used in the near future, for household needs if its quality permits such a use. The detailed examination of a large number of parameters will allow the characterization of water and consequently its suitable use.

2.2 Evaluation of the Water Balance

The Hydrologic Evaluation of Landfill Performance (HELP) computer program, developed by the U.S. EPA, [22], is a quasi-two-dimensional hydrologic model of water movement across, into, through and out of landfills. The model accepts weather, soil and design data and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled, [1]. The various layer characteristics data used in the present simulation are shown in Table 1.

TABLE 1: Landfill Layer Structure

No of Layer	Type of Layer	Layer Thickness (cm)	Hydraulic Conductivity (cm/sec)
1	Fine Sandy Loam	15	0.52 . 10E -03
2	Silty Clay	100	0.33 . 10E -04
3	waste	350	0.10 . 10E -02
4	Silty Clay	50	0.33 . 10E -04
5	waste	300	0.10 . 10E -02
6	Silty Clay	140	0.33 . 10E -04
7	waste	260	0.899.10E -03
8	Silty Clay	100	0.319 .10E -04
9	waste	150	0.899.10E -03
10	Silty Clay	50	0.319 .10E -04
11	waste	250	0.899.10E -03
12	Silty Clay	200	0.319 .10E -04
13	waste	300	0.899.10E -03

The weather data required in the HELP model are classified into four groups: evapotranspiration, precipitation, temperature and solar radiation. Meteorological data concerning years 1973-1995 were entered into the model. Therefore model output covers a period of 23 years by giving yearly values

for every parameter that is involved in the hydrologic balance. The program uses average quarterly relative humidity and average annual wind speed.

The SCS (Curve Number) method [1], based on daily amounts of rainfall and snowmelt, computes the runoff. An assumption of the program is that the areas adjacent to the landfill do not drain onto the landfill and the time distribution of rainfall intensity is not considered. Therefore the program cannot be expected to give accurate estimates of runoff volumes for individual storm events on the basis of daily rainfall data. However, because the SCS rainfall-runoff relationship is based on considerable daily field data, long-term estimates of runoff should be considered as reasonable.

The HELP program uses Darcian flow for vertical drainage through homogeneous, temporally uniform soil and waste layers and for leakage through barrier soil liners. Leakage is assumed to occur only as long as there is head on the surface of the liner. Explicitly preferential flow through channels such as cracks, root holes or animal burrows are not considered, but vertical drainage through the evaporative zone at moisture contents below field capacity is allowed. As such, the program will tend to overestimate the storage of water during the early part of the simulation and the time required for leachate to be generated. The effects of these limitations are minimized since the program increases the effective saturated hydraulic conductivity and decreases the field capacity.

The model also assumes that the soil moisture retention properties and unsaturated hydraulic conductivity can be calculated from the saturated hydraulic conductivity and limited soil moisture retention parameters (porosity, field capacity and wilting point).

The vegetative growth and decay can be characterized by a vegetative growth model development for crops and perennial grasses. An energy-based Penman method is used for modeling the potential evapotranspiration.

As mentioned before, the landfill under study is not lined. For this simulation, twelve layers were taken into account. The structure of twelve layers, an alternation of soil liners and waste material accounting for a depth of 22.5 m, is in accordance with what Stournas *et al,* [17] report in respect with the landfill structure.

2.3 Experimental Analysis

In order to assess the state of quality of the groundwater in the vicinity of the landfill, six testing wells were chosen. The wells' locations and depths are given in Table 2.

TABLE 2: Characteristics of the Wells

Well No	Location (m)	Depth (m)
well 1	40 at the entrance of the disposal site	100
well 2	100 East of the landfill	120
well 3	400 Southeast of the landfill	100
well 4	1000 South of the landfill	85
well 5	2000 Southwest of the landfill	67
well 6	3000 Southwest of the landfill	80

The sampling covered the period February - March 1997. Samples were taken on weekly basis. The samples were collected in 1L high density polyethylene (HDPE) bottles and they were usually analyzed immediately, since changes in the various parameters could occur, [3]. When this was not possible, they were preserved accordingly, refrigerated and analyzed within 24 hours.

The parameters measured were pH, colour, total solids, suspended solids, dissolved solids, conductivity, hardness, alkalinity, BOD_5, COD, phosphates (PO_4^{3-}), sulphates (SO_4^{2-}), ammonia (NH_3-N), nitrates (NO_3-N), nitrites (NO_2-N), chlorides (Cl^-), sodium (Na), potassium (K), calcium (Ca), and trace metals (Cd, Cr, Cu, Fe, Ni, Pb, Zn). All parameters were measured using analytical methods based on Standard Methods, [APHA, AWWA, WPCF, 1989], [18]. The determination of trace metals was performed by Atomic Absorption Spectroscopy using Perkin-Elmer 2380 and ICP (AES, Jobin Yvon).

3. RESULTS AND DISCUSSION

3.1 Hydrologic Evaluation of Landfill Performance (HELP Model)

The results from the model simulation are given in the table below:

TABLE 3:Average Annual Totals and SD for years 1-23

	%	mm	m^3	sd
Precipitation	100	390.54	175743	109.9
Surface Runoff	1.1	4.4	1977	7.7
Evapotranspiration	55.6	217.1	97709	56.4
Percolation/Leakage through the base of the landfill	42.8	167.0	75154	65.3

Taking into consideration other researches, [18-20], in other disposal sites in Europe, reporting that the yearly leakage from the base of the site, after the final capping, fluctuates between 70-400 mm, it can be concluded from the present study, that the results (leakage 167 mm), are at normal and expected levels.

3.2 Groundwater Quality

The mean values of the results obtained are shown in Table 4. The limits for the various parameters in drinking water, according to EC Directive 80/778, [21] and EPA, [22] were taken into account. The pH for all sampling sites was about neutral, 6.92-7.31. The range is acceptable according to the EC suggested level (6.5-8.5).

The colour value of the water samples at wells 1 (1092 Pt units) , 3 (55 Pt units) and 4 (50 Pt units) is above the recommended EC limit (15-20 standard Pt units). In the other wells the colour is below the limit.

For all wells under investigation, except from well 5 (320mg/l), the range of dissolved solids is 1250-2200 mg/l. This range is above the EPA, recommended limit for drinking waters (500 mg/l). The concentrations of suspended solids were also found to be in high levels, (130- 280 mg/l).

At wells 1, 2 and 4 BOD_5 values were relatively low. BOD_5 ranged at these sites between 2-12 mg/l, while at wells 3, 5 and 6 was not detected. According to the Greek legislation waters are suitable for irrigation, when the BOD_5 values are below the suggested limit of 40 mg/l. COD values ranged between n.d (well 5) and 115 mg/l (well 1). COD concentration were not detected at well 5. It is quite evident that the groundwater is affected by the landfill leachates.

The hardness is very high (560-8100 ppm) compared with the EC limit which is 120 ppm $CaCO_3$.

The range of conductivity is between 750-3730 μiS/cm. Conductivity was found to be high, especially at wells 1, 3, 4 and 6. These high conductivity values measured for the groundwater near the landfill is an indication of its effect on water quality. At all wells, conductivity values were above the EC suggested level (400 μS/cm at 20 °C). Nevertheless, at well 5, water is suitable for irrigation according to the Greek legislation for irrigation waters (conductivity < 1000 μiS/cm at 20 °C).

High chloride concentrations are observed in particular at wells 1, 3 and 4 (1180-1010 mg/l). The range at wells 2 and 6 was 520-630 mg/l. All the wells, except well 5 (50 mg/l) demostrate much higher chloride concentrations than the recommended EC limit (250 mg/l). Usually chlorides are considered as tracers but in this case it is difficult to assess the effect of the landfill since these high concentrations could be also attributed to the intrusion of seawater since the area is located in the vicinity of the Saronic Gulf. This phenomenon could possibly explain the fact that the most remoted site (well 6) gives higher concentrations than well 5.

Generally, phosphate concentrations measured were below the EC level of 400 mg/l. The highest concentrations were found at well 1 (170 mg/l) while at well 6 phosphates were not detected.

At all wells ammonia concentrations were above the EC limit (0.5 mg/l) with the highest concentration at well 1 (70 mg/l). The nitrate and nitrite concentrations fluctuate around relatively normal levels ($N\text{-}NO_3$: 128 - 933 mg/l, $N\text{-}NO_2$: n.d - 333mg/l).

All wells show relatively low concentrations of sulphates (4-115mg/l) which are below the EC limit (maximum allowable level 250 mg/l).

TABLE 4: Groundwater Characteristics for Sampling Wells 1, 2, 3, 4, 5, 6 - (Mean values)

	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Parameter						
pH - value	7.20	7.10	6.92	7.18	7.38	7.31
Colour (Pt units)	1091.8	16.2	56.0	50.6	6.2	13.4
Total Solids (mg l^{-1})	2500	1450	2500	2225	452	1475
Suspended Solids (mg l^{-1})	280	213.8	162.5	178.4	132.6	147.5
Dissolved Solids (mg l^{-1})	1981.2	1273.3	2170.3	1809.1	319.4	1341.2
BOD_5 (mg l^{-1})	11.3	2.6	nd	7.5	nd	nd
COD (mg l^{-1})	114.9	35.6	54.5	61.3	nd	10.2
Hardness (mg l^{-1})	806.7	727	785.5	807.2	617.7	560
Conductivity (μiS cm^{-1})	3727.5	1786.5	3162.5	30025	756.4	2041.5
Alkalinity (as $CaCO_3$) (mg l	216.3	134.7	141.7	160	49.4	44.7
Sulphate (SO_4^{2-}) (mg l^{-1})	65.2	88.7	112	96	4.2	15
Phosphate (PO_4 - P) (mg l^{-1})	171.3	76.2	86.8	102.5	102.5	11.3
Ammonia (NH_3 - N) (mg l^{-1})	67.8	6.4	18.2	22.3	0.9	3.6
Nitrate (mg l^{-1})	211.2	884.8	395	229.2	714.8	702.5
Nitrite (mg l^{-1})	26.7	295.8	7.8	0.8	20.1	298.7
Chlorides (mg l^{-1})	1174.5	522.2	1082	1006.4	50.2	625.6
Potassium (mg l^{-1})	87.3	20.0	34.4	42.1	3.2	3.8
Sodium (mg l^{-1})	447.5	234.2	376.3	425.8	50.8	271.3
Calcium (mg l^{-1})	126.0	176.7	139.9	160.9	93.2	259.6
Iron (mg l^{-1})	1.9	0.6	0.9	0.5	0.5	nd
Zinc (mg l^{-1})	0.1	0.1	0.2	0.2	0.2	0.1
Lead (mg l^{-1})	0.3	nd	0.3	nd	nd	nd
Nickel (mg l^{-1})	0.1	nd	0.1	0.1	nd	nd

Potassium was found in high concentrations at wells 1, 2, 3 and 4 (9.8-115 mg/l) while at wells 5 and 6 ranged between 1.6-6 mg/l; a fact which confirms once again the leachate effect. Sodium concentrations are also very high (30-590 mg/l). Calcium was found to be very high (79-283 mg/l) at all sampling sites and this can be attributed to the geological background of the area that consists of limestone.
The metals, copper and zinc are characterized as undesirable substances (80/778/EE). Copper tracers were not detected while zinc concentrations (0.02-0.32 mg/l) were found to be below the EC limit (0.1 mg/l) at sites 1 and 6, (0.02-0.09 mg/l) and above the limit at all other sites (0.1-0.32 mg/l). Iron concentrations were above the limit (0.05 mg/l) at all sites.

The metals lead, cadmium, chromium and nickel are characterized as toxic according to 80/778/EE. Lead concentrations are quite high at sites 1 and 3 (0.21-0.39 mg/l) and exceed the limiting EC value (0.05 mg/l). Cadmium and chromium were not detected. Nickel has higher concentrations than the limiting value of 0.05 mg/l in sampling sites (sites 1, 3 and 4), located closer to the landfill.

4. CONCLUSIONS

The average per year leakage that was estimated, using the Hydrologic Evaluation of Landfill Performance (HELP) model, is 167 mm and it is considered to be at normal and expected levels.

As a result, site 1 is characterized as the most polluted. This was expected since it is the closest one to the landfill. Sampling wells 3 and 4, though more remote, are more polluted than well 2 which is closer to the landfill. This is an indication of the leachate movement and the pollution transfer. Well 6 is more contamined than well 5. This most probably, must be attributed to a local pollution source, or to the geological and hydrological characteristics of the area under study.

The groundwaters near the landfill (sites 1, 2, 3, 4) are characterized as:

- Non potable, since almost all of the physical, chemical parameters examined exceed the permissible limits.
- Not suitable for irrigation, since the conductivity is high and in addition increased concentrations for chlorides, sodium and calcium were observed. These ions affect greatly the soil alkalinity and salinity. The waters at sites 2, 3 and 4 are used for cement production. The intense pumping rates, accelerate the pollution of the aquifer caused by the leachates.

Sites 5 and 6 show a better quality of groundwater, although the water is not suitable for drinking purposes but it can be used for irrigation.

Finally, the present work showed that within the study period there are indication that the pollution moves towards the southwestern side of the disposal site. Furthermore, the study confirmed the fact that the landfill leachates constitute a serious threat to the local aquifer.

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CHARACTERISTICS AND TREATABILITY OF THE LEACHATE FROM THE MUNICIPAL LANDFILL OF THE CITY OF PATRAS

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ABSTRACT

The main characteristics and the treatability of the leachate originating from the solid waste landfill of the city of Patras are presented in this study. COD values for the weak leachate were in the range 3900-5600 mg/l and for the strong leachate (young cells) in the range 12000-23000 mg/l. The ratio COD/TKN/TP was in the range 100/(7.8-48.4)/(0.06-0.48) and the sum for six heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) was below 1.5 mg/l. Anaerobic treatment at ambient temperatures succeeded limited COD removals and at elevated temperatures (28-34 °C) and hydraulic retention time of 5d resulted in mean COD removals 20% for the weak and 43% for the strong leachate. Aerobic treatment of anaerobically pretreated leachate effected COD removals in the range 20-40%.

ΧΑΡΑΚΤΗΡΙΣΙΚΑ ΚΑΙ ΕΠΕΞΕΡΓΑΣΙΜΟΤΗΤΑ ΤΩΝ ΣΤΡΑΓΓΙΣΜΑΤΩΝ ΑΠΟ ΤΟΝ ΧΩΡΟ ΥΓΕΙΟΝΟΜΙΚΗΣ ΤΑΦΗΣ ΑΠΟΡΡΙΜΜΑΤΩΝ ΤΗΣ ΠΑΤΡΑΣ

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ΠΕΡΙΛΗΨΗ

Τα κυριότερα χαρακτηριστικά και η επεξεργασιμότητα για τα στραγγίσματα που προέρχονται από τον χώρο υγειονομικής ταφής των απορριμμάτων της Πάτρας παρουσιάζονται στην εργασία αυτή. Οι τιμές ΧΑΟ για τα ασθενή στραγγίσματα ήταν στην περιοχή 3900-5600 mg/l και για τα ισχυρά σταγγίσματα (από πρόσφατα κύτταρα) στην περιοχή 12000-23000 mg/l. Ο λόγος ΧΑΟ/ΤΚΝ/Ολικός Ρ βρέθηκε στην περιοχή 100/(7.8-48.4)/(0.06-0.48) και το άθροισμα των συγκεντρώσεων για έξι βαρέα μέταλλα (Cd, Cr, Cu, Ni, Pb και Zn) μικρότερο από 1.5 mg/l. Αναερόβια επεξεργασία σε θερμοκρασίες περιβάλλοντος έδωσε περιορισμένη αφαίρεση ΧΑΟ ενώ σε υψηλότερες θερμοκρασίες (28-34 °C) και υδραυλικό χρόνο παραμονής 5 d πέτυχε μέση αφαίρεση ΧΑΟ 20% για τα ασθενή και 43% για τα ισχυρά στραγγίσματα. Αερόβια επεξεργασία αναερόβια προεπεξεργασμένων στραγγισμάτων πέτυχε αφαίρεση ΧΑΟ 20-40%.

1. INTRODUCTION

Leachates from municipal solid waste landfills contain high concentrations of organic matter and inorganic compounds. Appropriate management of this type of wastewater is therefore required in order to reduce the environmental threat to the nearby groundwater and surface water. The quality and quantity of landfill leachates fluctuate so seriously that they require special attention in the design stage of treatment systems. The amount of leachate produced in a landfill depends on its water balance. The parameters of this balance are the precipitation, the surface runoff, the surface runto (landfills should be designed so that water outside the site should not enter the site), the evapotranspiration, and the change in water storage. It is the objective of the design of landfill sites to minimize the quantities of leachate and this requires specific attention to top covers, bottom liners and leachate collection systems.

Solid waste with a relatively high content of organic matter is deposited in most landfills. The main types of this solid waste are household refuse (containing waste food, paper, etc.), industrial organic waste, garden waste and, on some sites, sewage sludge as well. Soon after deposition, organic compounds start to decompose and landfills become large-scale reactors, producing biogas by means of methane bacteria. The total amount of methane extracted per tone of waste landfilled depends largely on the type of waste and is estimated at approximately 200-250 m^3/1000 kg of waste. The mean annual production of methane for the first ten years of landfill operation is about 10-15 m^3 /1000 kg of waste (1). In the early stages of landfill operation the concentration of organic matter in the liquid phase is higher than in subsequent time. In the stabilized anaerobic environment inside the landfill most of the heavy metals released in the liquid phase form insoluble sulfides. The concentration of heavy metals in the leachate produced depends not only on the solid waste deposited but also on the operational conditions established in the landfill.

The polluting load of a leachate from a young site is usually much higher than that from mature landfills. The nature of landfill from which the leachate is produced dictates its characteristics and the required pretreatment before being allowed to be treated at an adjacent wastewater treatment plant or received by a municipal wastewater treatment plant in the proximity of the landfill site. The sanitary landfill of the city of Patras is located at Xerolakka, approximately 10 km southeast of the city. The total available area is 400000 m^2 , of which 70000 m^2 are developed as landfill area. The landfill serves an equivalent population of 150000 inhabitants, accepts 70000 Mg of municipal solid waste per annum and its design period was 18 yr. The operation of the landfill started during 1993. Biogas is extracted from gas wells by induced vacuum and is consequently flared in appropriate equipment. The leachate is collected in a system of holding wells and its treatment is effected by the recirculation through the landfill cells. The objective of this work was to define the main characteristics of the leachate originating from the municipal solid waste landfill of the city of Patras as well as to study the anaerobic and aerobic treatment of this wastewater.

2. LEACHATE CHARACTERIZATION

The leachate was taken from the exit pipe of the collection system of the municipal solid waste landfill of the city of Patras. Septage hauling trucks (capacity 13-15 m^3) were used for the transportation of leachate to the wastewater treatment plant of the Patras University Campus. In the period from May 1997 until September 1997, two to three loads of leachate were received every week in order to feed the experimental systems. A representative sample was taken from each truck

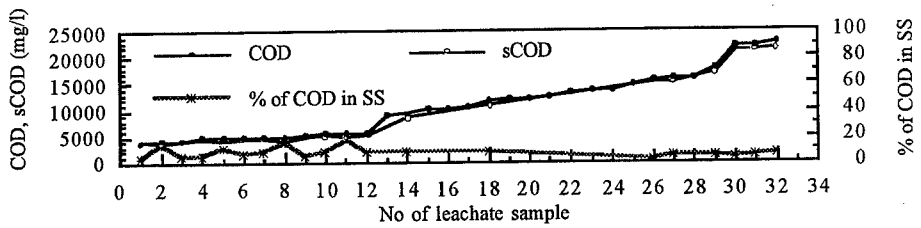


Figure 1. COD and sCOD data for the leachate

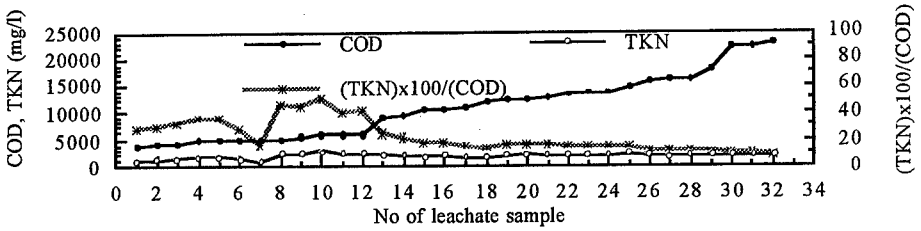


Figure 2. COD and TKN data for the leachate

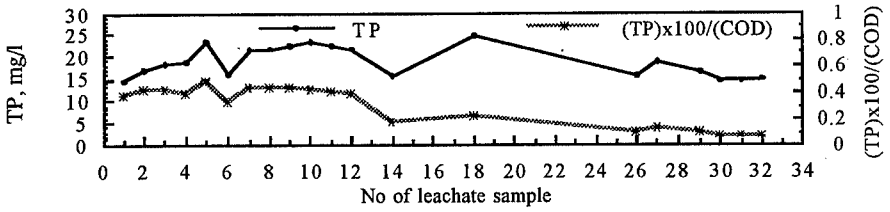


Figure 3. Total Phosphorous data for the leachate

as the leachate was transferred to a 20 m^3 storage tank. The parameters measured were COD, soluble COD, TKN, soluble TKN, TP, soluble TP and six heavy metals (Cd, Cr, Cu, Ni, Pb, Zn). These heavy metals are among the more frequently reported in wastewater characterization studies All analytical determinations were made according to the Standard Methods for the Examination of Water and Wastewater (2). The Heavy Metals were analyzed by using a GBC 906 Atomic Absorption Spectrophotometer equipped with a GBC 3000 Graphite Furnace.

The leachate samples were analyzed and after all the analysis have been completed over the whole study period new numbers were given to the different day samples in a way that the sample with the lower COD value was named sample No 1 and increasing sample numbers corresponded to increasing COD values.

COD and sCOD values for the different leachate samples are given in Figure 1. The COD values of the leachate SS as a percentage of the total COD are also given in Figure 1. Statistical values for the parameters presented in Figure 1 as well as for the SS concentration in the leachate samples are given in the following tabulation:

Parameter	Samples	Mean value	Range	Standard deviation
COD, mg/l	32	10802	3940-22930	5659
sCOD, mg/l	20	9344	3700-21740	6687
SS, mg/l	20	720	105-1220	465
COD in SS, % of COD	20	6.67	1.97-17.54	3.93

COD and TKN values as well as the ratio (TKN)x100/(COD) for the different leachate samples are given in Figure 2. Figure 3 displays the TP concentration in the different leachate samples and the ratio (TP)x100/(COD). Each number in the x axis in Figures 1, 2 and 3 refers to a particular leachate sample and so all the characteristics (COD, sCOD, TKN and TP) for each sample are given with the help of these three figures. Statistical values for the parameters presented in Figure 2 and 3 are given in the following tabulation:

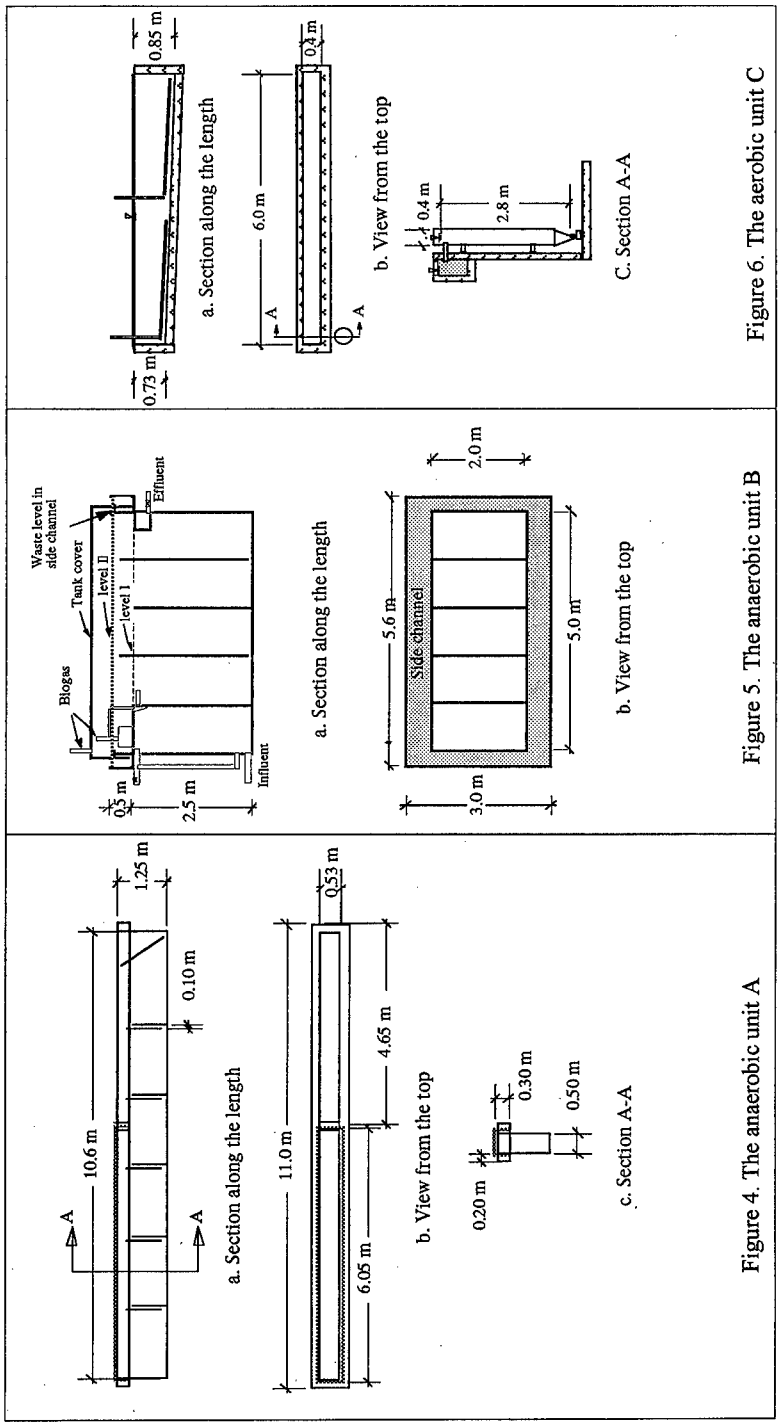
Parameter	Samples	Mean value	Range	Standard deviation
COD, mg/l	32	10802	3940-22930	5659
TKN, mg/l	32	1794	784-2744	395
(TKN)x100/COD	32	21.3	7.8-48.4	11.7
TP, mg/l	20	18.9	14.4-24.9	3.5
(TP)x100(COD)	20	0.27	0.06-0.48	0.15
COD/TKN/TP	20	100/21.3/0.27		

Statistical values for the concentration of each of the six heavy metals measured in the leachate samples are given below.

Heavy metal	Samples	Mean value	Range	Standard deviation
Cd, μg/l	32	45	15-79	20.3
Cr, μg/l	32	135	45-235	49.8
Cu, μg/l	32	224	98-356	70.2
Ni, μg/l	32	163	56-903	142.4
Pb, μg/l	32	278	98-467	95.2
Zn, μg/l	32	59	12-145	28.3

3. TREATMENT OF THE LEACHATE

Three large-scale experimental systems were used in this study (Figures 4, 5 and 6). The first (Unit A, Figure 4) was a long narrow baffled anaerobic steel tank (total volume 5.5 m^3) and was placed in the open air in the wastewater treatment plant of the Patras University Campus. The second system (Unit B, Figure 5) was a baffled anaerobic steel tank (total volume 25 m^3) which was placed in a greenhouse construction located also in the wastewater treatment plant of the Patras University Campus. The temperature of the anaerobic mixed liquor of unit B was higher than the corresponding temperature in unit A during all the study period. A perimetrical side channel was incorporated in the upper part of units A and B. In this channel, which was filled with water, the top covers of the tanks were supported in a way securing a permanent water seal between the atmosphere and the tanks content. The third unit (Unit C, Figure 6) was an aerobic system with a long narrow cement channel as aerobic tank (active volume 1900 l) and a cylindrical steel tank (active volume 350 l) used as a secondary sedimentation tank.


1.25 m
0.10 m
10.6 m
A
A
a. Section along the length
0.53 m
11.0 m
4.65 m
6.05 m
b. View from the top
0.20 m
0.30 m
0.50 m
c. Section A-A
Figure 4. The anaerobic unit A
Waste level in side channel
Tank cover
level II
level I
Biogas
Effluent
Influent
0.5 m
2.5 m
a. Section along the length
2.0 m
5.6 m
Side channel
5.0 m
3.0 m
b. View from the top
Figure 5. The anaerobic unit B
0.85 m
0.73 m
a. Section along the length
0.4 m
6.0 m
A
A
b. View from the top
0.4 m
2.8 m
C. Section A-A
Figure 6. The aerobic unit C

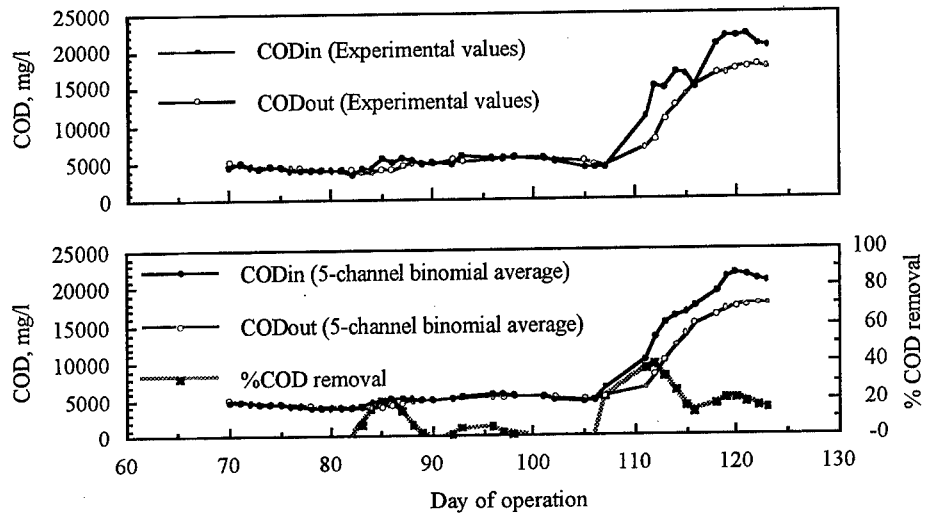


Figure 7. Data from the operation of the anaerobic unit A

3.1. Anaerobic Treatment of Leachate in the Experimental Unit A

The feeding of unit A (Figure 4) with leachate was started on April 21, 1997 (day of operation 28). From March 25, 1997 (day of operation 1) until day of operation 28, the unit was fed a mixture of municipal type wastewater and landfill leachate with stepwise increasing leachate percentages. Until March 25, 1997 (day of operation 1) unit A was used as an anaerobic reactor treating municipal wastewater for over one year period. The leachate was fed from a plastic tank (capacity 1200 l) which was filled each day from the 20 m^3 holding tank (in which the leachate was stored as it was received from the landfill of the city of Patras). The leachate was fed continuously at a flow rate 40-45 l/h and the anaerobic reactor was operated with a hydraulic retention time well near of 5 d. The unit was operated at ambient temperatures and the temperature of the anaerobic mixed liquor was in the range 23-28 °C.

COD data for the operation of the anaerobic unit A are given in Figure 7. The influent COD (CODin) and effluent COD (CODout) values in the upper part of Figure 7 stand for the values measured whereas the corresponding data in the lower part of the figure are smoothed values (5-channel binomial averages). The 5-channel binomial algorithm (3) was used in order to estimate a more representative COD removal based on data for COD values measured in the same day for the leachate fed to the anaerobic unit and for the treated effluent.

The COD values of the leachate received in the period from June 3, 1997 until July 11, 1997 (days of operation 70 until 107) were in the range 3530-5580 mg/l (leachate from old landfill cells operating for over a 4 years period) and the COD values of the leachate received from day of operation 107 until 125 were in the range 10700-21800 mg/l (leachate from landfill cells operating less than 2 years). The COD removal from the first type of leachate was quite low (below 10% with unstable performance) and the COD removal from the stronger leachate was in the range 12-38% (mean value 22%).

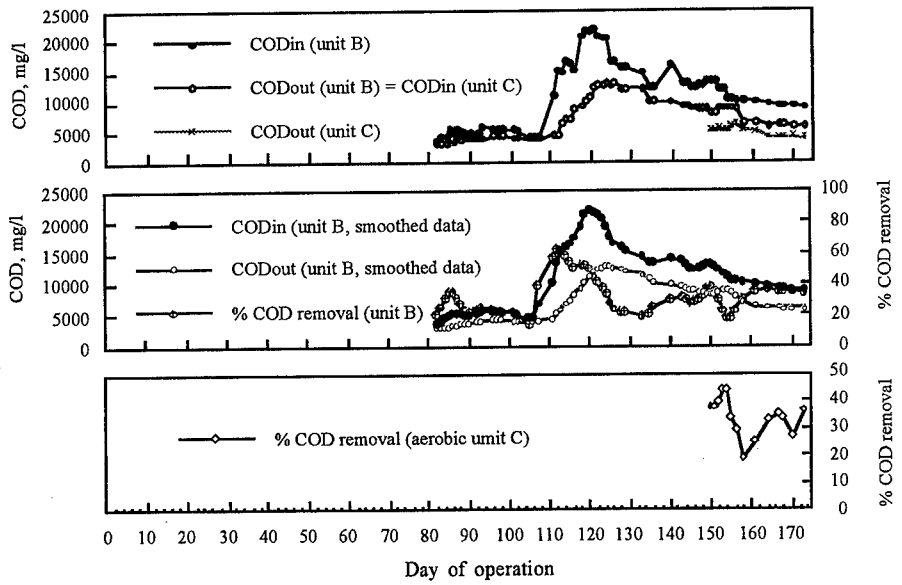


Figure 8. Data from the operation of the anaerobic unit B and the aerobic unit C

3.2. Anaerobic Treatment of Leachate in the Experimental Unit B

Unit B (Figure 5) was an active anaerobic digestor treating olive oil mill wastewater and from March 25, 1997 it was fed with a mixture of municipal wastewater and leachate (10% leachate) at hydraulic retention time of 5 d. Feeding of the unit B with leachate only started on June 1. Unit B was inside a glass greenhouse and the temperature of the anaerobic mixed liquor was in the range 28-34 °C. The hydraulic retention time was about 5 d. COD data from the operation of unit B are given in the upper part of Figure 8. Smoothed COD data (5-channel binomial averages) as well as the % COD removals effected are presented in the middle part of Figure 8. Three leachate types were fed to unit B. In the period before day of operation 107 the leachate was weak (from old cells), in the period between day of operation 107 and 125 the leachate was strong (from young cells) and finally in the period after day 125 it was of middle strength (mixed leachate from old and young cells). The COD removals effected for the three types of leachate fed are given in the following tabulation:

Leachate type	Lechate COD range	% COD removal (range)	% COD removal (mean)
Weak (old cells)	3500-5600	15-38	20
Middle (old + new cells)	6000-12000	18-39	29
Strong (new cells)	12000-23000	22-62	43

3.3. Aerobic Treatment of Anaerobically Pretreated Leachate

The aerobic unit C was fed with the effluent from the anaerobic unit B. From day of operation 100 until day 140 unit C was fed with a mixture of municipal wastewater and effluent from unit B (municipal wastewater 85-95%). From day of operation 141 the aerobic unit was fed with anaerobic effluent only at hydraulic retention times in the range 3.9-4.3 d. After day of operation 150 the concentration of MLSS in the aeration tank was in the range 4.9-5.5 g/l. The sludge recycle from the sedimentation tank to the aeration tank was in the range 80-120%. COD data for the influent to the

aerobic unit and for its effluent are given in the upper part of Figure 8. The COD removals effected in the aerobic unit are given in the lower part of Figure 8 and are in the range 20-40%.

3.4. Determination of the non degradable COD in the leachate

Determination of the final non biodegradable concentration of the leachate under anaerobic and aerobic conditions was made by running two appropriate experimental units. the first was an expanded volume well mixed anaerobic reactor operating at hydraulic detention time of 60 days (initial volume of anaerobic liquid 5 l and final volume 26 l after 100 d of operation). The second was an expanded volume aerated reactor operating at hydraulic detention time of 40 d. The anaerobic and aerobic units operated for a 100 d period. The anaerobic unit was fed with anaerobic effluent from the experimental unit B taken at day of operation 170 and stored in a deep freeze chamber and the aerobic unit was fed with effluent from the aerobic unit C taken at day of operation 170 and stored in deep freeze. The initial concentration of MLSS in the anaerobic unit was 1100 mg/l and in the aerobic unit 970 mg/l. The non anaerobically degradable COD concentration was found 2600 mg/l and the non aerobically degradable COD concentration was found 2850 mg/l.

4. CONCLUSIONS

Based on the findings of this study concerning the characterization and the anaerobic and aerobic treatability of the leachate originating from the solid waste landfill of the city of Patras the following conclusions may be drawn:

1. The COD concentration of the leachate originating from new cells was in the range 12000-23000 mg/l and the COD concentration of the leachate originating from mature cells (filled with solid waste more than 4 years before) was in the range 3900-5600 mg/l.
2. The concentration of TKN in the leachate was very high whereas the concentration of TP was very low. The ratio COD/TKN/TP was in the range 100/(7.8-48.4)/(0.06-0.48) with the higher percentages of TKN corresponding to leachate from mature cells.
3. The sum of the six heavy metals (Cd, Cr, Cu, Ni, Pb, Zn) concentrations was below 1.5 mg/l with the higher mean value corresponding to Pb (278 μg /l) and the lower mean value corresponding to Cd (42 μg /l).
5. Anaerobic treatment of the leachate at ambient temperatures and hydraulic retention time of 5 d resulted at limited COD removals (less than 25%) and anaerobic treatment at elevated temperatures (28-34 °C) effected mean COD removals 20% for the case of the weak leachate and 43% for the case of the strong leachate.
6. Aerobic digestion of anaerobically pretreated leachate at ambient temperatures with hydraulic retention times about 4d resulted in limited organics removal (20-40% in terms of COD)
7. The non degradable COD concentration in the leachate was 2600 mg/l under anaerobic conditions and 2850 mg/l under aerobic conditions.

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EXPERIMENTAL AND THEORETICAL STUDY OF FLOW OVER LANDFILL BOTTOM LINERS

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ABSTRACT

A Hele-Shaw model is used to study leachate flow over inclined bottom landfill liners. The model simulates flows over impermeable inclined surfaces, which result from the impingement of fluid on the inclined surface. The features of the model and the methodology for data collection are presented. The theoretical analysis of the same flow is accomplished through a one-dimensional flow equation, which utilizes the extended Dupuit-Forchheimer assumptions. The steady state form of this equation is solved numerically and the results are compared with the experimental data. The discrepancies between experimental and theoretical results are attributed to the definition of the downstream boundary condition in the theoretical model and to possible two dimensional behavior of the flow over the liner.

ΠΕΙΡΑΜΑΤΙΚΗ ΚΑΙ ΘΕΩΡΗΤΙΚΗ ΜΕΛΕΤΗ ΡΟΗΣ ΥΠΕΡΑΝΩ ΣΤΡΩΜΑΤΩΝ ΠΥΘΜΕΝΙΚΗΣ ΣΤΕΓΑΝΟΠΟΙΗΣΕΩΣ Χ.Υ.Τ.Α.

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ΠΕΡΙΛΗΨΗ

Ενα μοντέλο Hele Shaw χρησιμοποιείται για την μελέτη ροής υπεράνω κεκλιμένων στρωμάτων πυθμενικής στεγανοποιήσεως ΧΥΤΑ. Το μοντέλο προσομοιώνει ροή η οποία προκύπτει από την προσκρουση υγρού στην κεκλιμένη επιφάνεια. Τα χαρακτηριστικά του μοντέλου και η μεθοδολογία συλλογής δεδομένων παρουσιάζονται εδώ. Η θεωρητική ανάλυση της ροής επιτυγχάνεται μέσω μιας μονοδιάστατης εξισώσεως ροής που αξιοποιεί τις υποθέσεις των Dupuit-Forchheimer και η οποία επιλύεται αριθμητικώς για μόνιμη ροή. Οι διαφορές μεταξύ θεωρητικών και πειραματικών αποτελεσμάτων αποδίδονται στον ορισμό της κατάντη συνοριακής συνθήκης για το θεωρητικό μοντέλο και σε πιθανή δισδιάστατη συμπεριφορά της ροής υπεράνω της κεκλιμένης επιφάνειας.

1. INTRODUCTION

The potential for groundwater contamination by leachates produced in solid waste landfills has led to new engineering standards for the design and construction of landfill bottom liners and leachate collection systems ("Minimum technology", EPA 1985). A typical liner consists of a series of contiguous, alternating-direction sloping layers constructed from material of low permeability (compacted clay) in conjunction with sheets of a prefabricated synthetic material. The liner is equipped with perforated collection pipes, which are installed along lines of low elevation and a highly permeable drainage layer which is placed over the liner. Leachate draining into the perforated pipes, is pumped out and directed to a treatment facility.

An understanding of the hydraulics of liners is essential in the proper design and operation of such systems. It is apparent that several hydraulic and geometric parameters are of importance in liner performance. Thus, liner slopes vary from 0% to as high as 30% or more, with 2% being a practical minimum ("Minimum technology", 1985). Saturated hydraulic conductivity of the drainage layer typically ranges from 10^{-1} cm/s for coarse sands to 10^{-3} cm/s for a very fine or loamy sand, while clay liners have hydraulic conductivity in the range 10^{-6} to 10^{-9} cm/s (McEnroe and Schroeder, 1988). The EPA recommends a minimum value of 10^{-2} for the drainage layer and a maximum value of 10^{-7} for the clay liner ("Minimum technology", 1985).

In addition, the EPA recommends a minimum thickness of 90 cm for clay liners and a sloping-layer length of 15 - 60 m. McEnroe (1989b) reports that EPA regulations, for hazardous waste landfills, limit the leachate depth over the liner to 30 cm. Leachate impingement rates may vary from essentially zero for capped landfills to maximum values dictated by local climatic conditions.

The systematic investigation of liner hydraulics commenced about twenty years ago. Wong (1977) was the first to present an approximate solution for unsteady drainage resulting from a uniform buildup of head over a sloping low-conductivity liner. His solution was extended by Kmet et al. (1981), while Demetracopoulos et al. (1984) and McEnroe (1989a) used the extended Wong solution to explore sensitivity of various factors on collection system performance.

A steady state, one dimensional equation describing flow over and leakage through an inclined liner was presented and solved analytically by Demetracopoulos and Korfiatis (1984). Their solution was extended to a more general form by McEnroe (1989b). The unsteady state form of the equation was solved numerically by Korfiatis and Demetracopoulos (1986); their formulation was employed by McEnroe (1989a) to extend the solution for the period after cessation of the impingement rate, when the leachate in the drainage layer recedes towards the collection pipe. Studies of flow over inclined, impermeable layers have also been conducted in the context of hill slope hydrology (e.g. Childs, 1971; Chapman, 1980).

In the vast majority of the aforementioned studies there exists a lack of validation of one dimensional flow models, through comparison with laboratory or field data. A notable exception is the laboratory data of Korfiatis et al. (1986), which were also utilized by Demetracopoulos (1988).

The present study is a contribution in model validation. A vertical Hele-Shaw model of flow through porous media was used for simulation of leachate impingement rates and flow over sloping, impermeable liners. The experimental data are compared with a numerical solution of the one dimensional flow model and conclusions are drawn with regard to model validity. The aforementioned work is described in the sections that follow.

2. ONE DIMENSIONAL FLOW EQUATION

Leachate flow over an inclined, impermeable liner is shown schematically in Fig. 1. For such a flow, the extended Dupuit-Forchheimer assumption is utilized, i.e. the streamlines corresponding to steady state flow are approximately parallel to the liner and lines normal to the liner are equipotentials. Hence, the piezometric head at any point of a vertical section A-A is

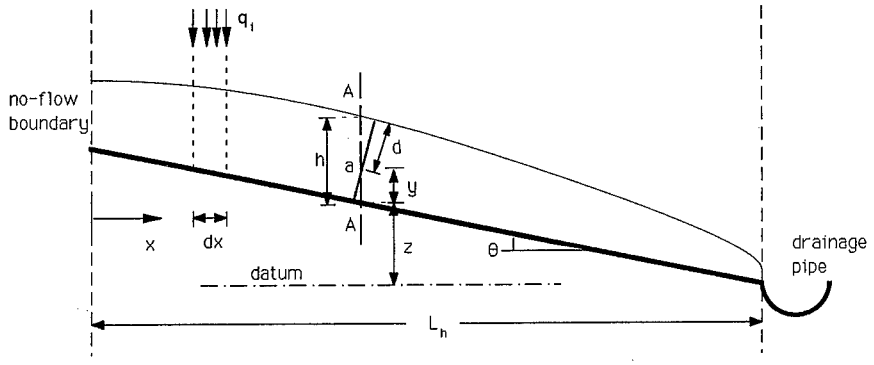


Figure 1. Flow over an impermeable liner

$$\phi = z + y + d\cos\theta = z + y + (h - y)\cos^2\theta \tag{1}$$

and the corresponding Darcy velocity is

$$q_x = -K\frac{\partial\phi}{\partial x} \tag{2}$$

with K the hydraulic conductivity of the drainage layer. Integration of eq. (2) over the vertical section A-A yields the discharge:

$$Q_x = -Kh\left(\frac{\partial h}{\partial x} - \tan\theta\right) \tag{3}$$

Application of liquid mass balance on a control volume of height h and length dx and use of eq. (3) yields the general flow equation over the liner

$$K\frac{\partial}{\partial x}\left[h\left(\frac{\partial h}{\partial x} - \tan\theta\right)\right] + q_i = n_e\frac{\partial h}{\partial t} \tag{4}$$

where n_e is the effective porosity of the drainage layer and q_i the impingement rate.

For steady state conditions, eq. (4), after integration, yields

$$Kh\left(\frac{\partial h}{\partial x} - \tan\theta\right) = -q_i x \tag{5}$$

where $0 \leq x \leq L_h$. Equation (5) automatically satisfies the upstream b.c. of the problem under consideration. Indeed, the upstream face is a no-flow boundary due to symmetry , which implies that either h=0 or $\partial\phi/\partial x = \partial h/\partial x - \tan\theta = 0$. This is exactly the result given by eq. (5) for x=0. An additional boundary condition must be supplied at the downstream boundary, so that eq. (5) can be solved. The assumption made by McEnroe (1989a) is used in the present study, i.e. $(\partial\phi/\partial x)_{de} = -1$ where the subscript "de" denotes downstream end. Equation (5) was solved via a Runge-Kutta, fourth order algorithm.

3. HELE - SHAW MODEL

3.1. Apparatus

In order to simulate the flow described earlier, a vertical Hele-Shaw model was designed and constructed. The side and top views of the model are shown in Fig. 2. Features of the model of special interest to the present study are the top box which supplies the impingement rate and the movable bottom for simulation of inclined liners.

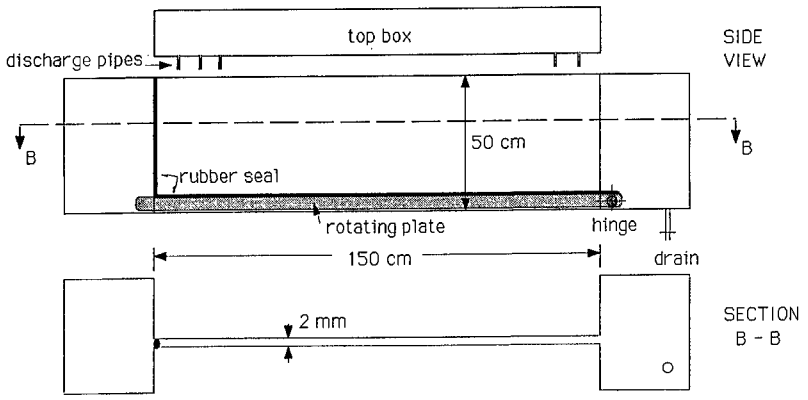


Figure 2. Schematic of Hele-Shaw model. Only features used in the present study are shown

The top box can be placed directly over the top opening of the Hele-Shaw and is fitted with a series of steel pipes 3 cm long with i.d. 0.7 mm discharging directly into the top, horizontal opening of the Hele-Shaw. Initially, 15 such pipes were fitted; however, it was found that the resulting impingement rates were rather small and the box was modified by installing 16 more pipes of the same length and diameter. Thus, two sets of experiments exist, one with 15 and the other with 31 discharge pipes.

In order to simulate the inclined liner, a 5 cm tall and 160 cm long aluminum plate was placed along the bottom of the Hele-Shaw. This plate is fixed to a hinge at the downstream end of the Hele-Shaw and can rotate in the vertical plane of the 2 mm model gap. It is suspended via a thin steel wire from a pulley, which holds it at the desired position. In this manner, it is possible to reproduce any bottom slope. Both the inclined bottom and the upstream vertical gap of the model were made impervious by placement of a rubber string with circular cross section, 2.5 mm in diameter.

3.2 Experimental Procedure

It is well established (e.g. Bear, 1972) that the equivalent hydraulic conductivity of a laminar flow through a vertical Hele-Shaw model is

$$K = \frac{\gamma b^2}{12\mu} \tag{6}$$

where b=gap width, γ=specific weight of fluid and μ=viscosity of fluid flowing through the model. The fluid used in this study was glycerin with ρ=1.263 g/cm^3. After several tests it was found that a less viscous fluid was needed in order to achieve continuous and satisfactory impingement rates through the pipes attached to the top box. Thus, the glycerin was diluted with water to a density of ρ=1.202 g/cm^3. The viscosity of the diluted glycerin was measured with a standard viscometer and is shown in Fig. 3 as a function of temperature.

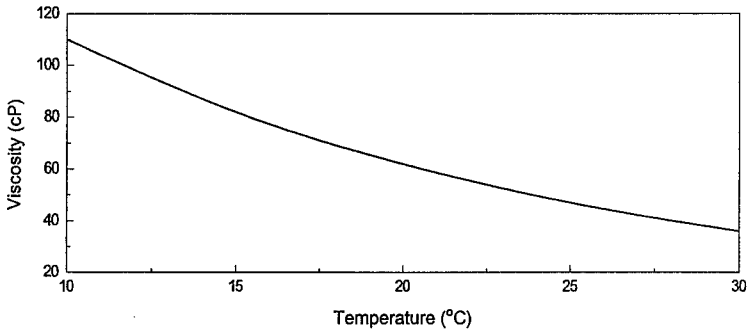


Figure 3. Viscosity variation with temperature

Impingement rates were determined by a quasi-steady state procedure in which the top box was filled quickly up to a desired level and then refilled to the original level after the liquid stage had dropped by 1 mm. The rating curves, for 15 and 31 discharge pipes , are shown in Fig. 4. Actual impingement rates can be obtained from the rating curves after dividing the discharge by 150×0.2 cm^2, which is the area of the model top horizontal opening.

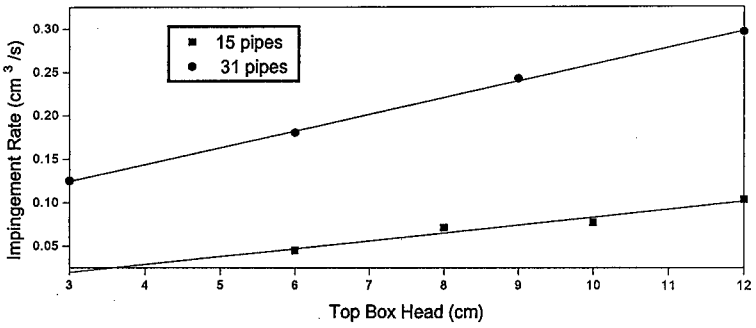


Figure 4. Rating curves for discharge from top box

With the aforementioned information known, each experiment proceeded as follows: Glycerin stage in the top box was maintained constant at the desired head (corresponding to a given

impingement rate) and the experiment proceeded until the liquid flowing over the inclined liner achieved steady state. At that time the free surface profile was recorded, making use of a grid placed on the back side of the model, and subsequently the particular experiment was terminated.

4. COMPARISONS AND CONCLUSIONS

Typical results are shown in Fig. 5 for 15 discharge pipes and in Figs. 6 and 7 for 31 discharge pipes. The irregularities of the experimental phreatic surface are caused by variations in the gap width of the Hele-Shaw model.

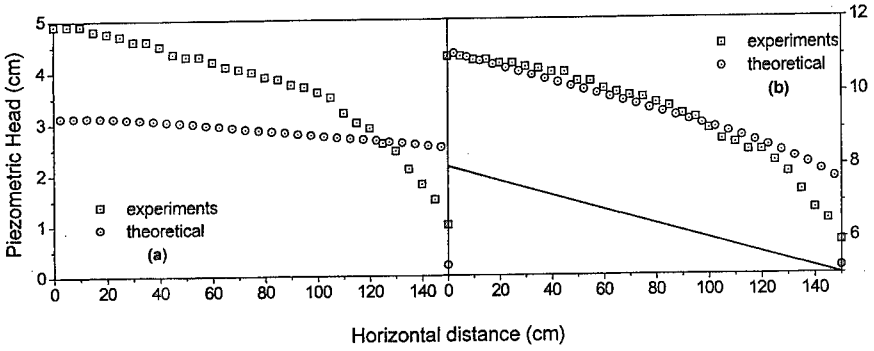


Figure 5. Phreatic surface profile for 15 discharge pipes and top box head 12 cm
(a) bottom slope 0%, (b) bottom slope 2%

Comparison of experimental and theoretical results reveals the following:

(a) Agreement is always poor in the region near the downstream end of the liner. This results from the boundary condition used for solution of the governing flow equation. It is apparent from the experimental data that the angle of inclination of the phreatic surface at the downstream end of the liner is substantially lower than 45°, which, according to eq. (3) would imply larger end depths. The data corroborates this assertion. For the range of impingement rates tested, the experimental values of this angle varied from 5.7° for horizontal liners to 11° for 25% liner slope. The corresponding values of the downstream depth ranged from 1 cm to 1.5 cm.

(b) With regard to the upstream region of the flow, the discrepancy between experimental and theoretical results becomes small as liner slope increases. This is attributed to the smaller flow depths over the liner, which result from the limitations in impingement rates imposed by the available top box and the discharge pipes. Thus, the phreatic surface profile has small curvature and the extended Dupuit-Forchheimer assumption holds well. When the liner slope decreases, the same impingement rates produce flows with larger depths and the experimental phreatic surfaces show more pronounced curvature. It is our contention that the same would hold true on the steeper slopes, for higher impingement rates. The aforestated support the hypothesis that the flow over the liner may be better simulated by a two dimensional (vertical plane) model, when the flow depths become substantial and the phreatic surface becomes more curved.

In summation, the extension of the present work must focus primarily on a better description of the downstream boundary condition for the one-dimensional model and secondarily on the application of a two-dimensional model of flow over an inclined liner.

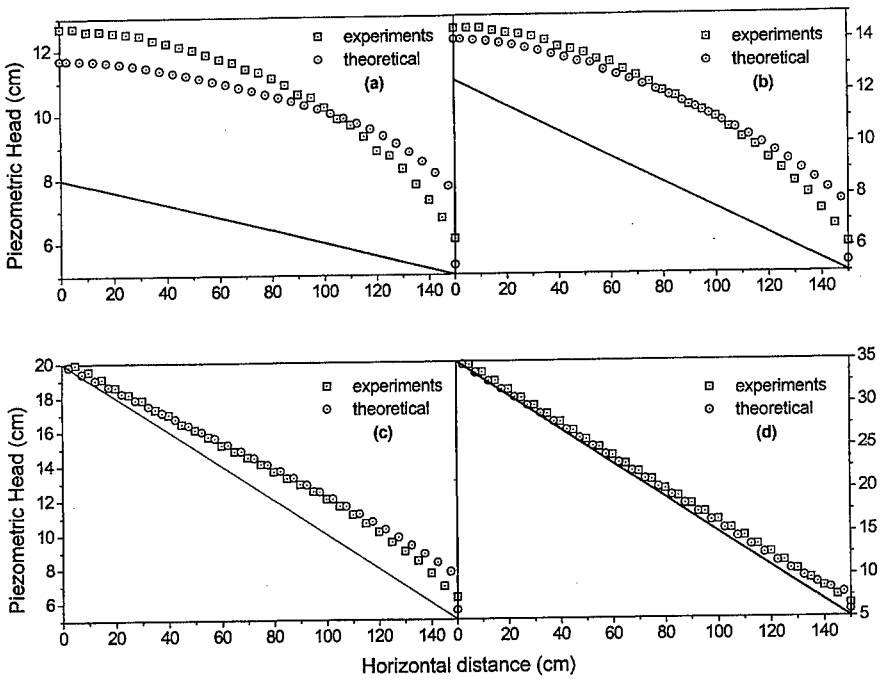


Figure 6. Phreatic surface profile for 31 discharge pipes and top box head 12 cm bottom slopes: (a) 2%, (b) 5%, (c) 10% and (d) 20%

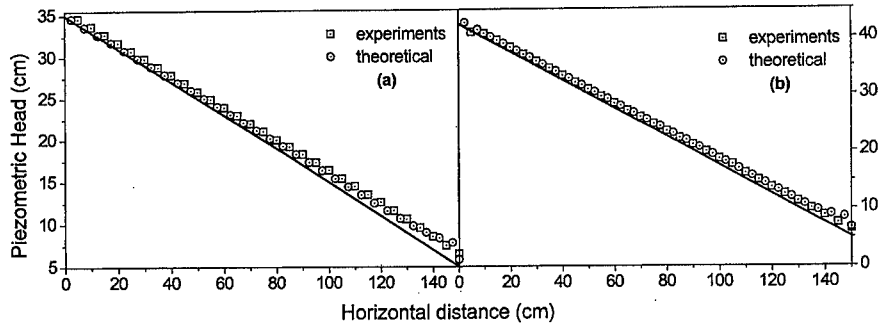


Figure 7. Phreatic surface profile for 31 discharge pipes and top box head 9 cm bottom slopes: (a) 20% and (b) 25%

ACKNOWLEDGMENTS

The experimental data were collected by I. Salmatani and E. Toulatos as part of their Diploma thesis.

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MANAGEMENT OF SOLID WASTES OF METAL PRODUCTION; THE CASE OF THE RED MUD FROM ALUMINA PRODUCTION

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ABSTRACT

Aluminum production by the Bayer Process requires the chemical treatment of the bauxite to extract the aluminum oxide from the ore with the production of the "red mud", a byproduct thrown into the sea. The quantities produced depend on the quality of the bauxite and range from 1 to 2 tons of red mud per ton of alumina produced. The possible use of this waste to replace anticorrosive iron pigments in anticorrosive paints for steel has been tried in the laboratory and in the sea, also under impressed cathodic current conditions. The polymeric vehicles tested were epoxy and chlorinated rubber. Results show that R. M. may be utilized towards substitution of iron oxide pigments for the temporary protection of metal surfaces. In this work the replacement of the usual pigments is attempted by the red mud, managing a troublesome industrial by-product and at the same time will decrease the imports of the iron oxide pigments. Results from laboratory and field experiments, for the first time, are included to support the replacement of Fe_2O_3 pigments by Red Mud.

ΔΙΑΧΕΙΡΙΣΗ ΣΤΕΡΕΩΝ ΑΠΟΒΛΗΤΩΝ ΑΠΟ ΠΑΡΑΓΩΓΗ ΜΕΤΑΛΛΩΝ: Η ΠΕΡΙΠΤΩΣΗ ΤΗΣ ΕΡΥΘΡΑΣ ΙΛΥΟΣ ΑΠΟ ΤΗΝ ΠΑΡΑΓΩΓΗ ΑΛΟΥΜΙΝΑΣ

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ΠΕΡΙΛΗΨΗ

Η παραγωγή του αλουμινίου με την μέθοδο Bayer απαιτεί την χημική επεξεργασία του βωξίτη με ταυτόχρονη παραγωγή Ερυθράς Ιλύος (Ε.Ι.) που απορρίπτεται στην θάλασσα. Για ένα τόνο αλούμινας παράγεται 1 με 2 τόννοι Ε.Ι. Στην παρούσα εργασία γίνεται προσπάθεια αξιοποίησης της Ε.Ι. ως αντιδιαβρωτικού πιγμέντου σε πολυμερείς φορείς από χλωριωμένο λάστιχο και εποξειδικό για προστασία του χάλυβα σε θαλάσσια διάβρωση και με χρήση καθοδικής προστασίας. Τα αποτελέσματα δείχνουν ότι μπορεί η ιλύς να λειτουργήσει και ώς πιγμέντο σε αντιδιαβρωτικά επικαλυπτικά, μειώνοντας την επιβάρυνση στο περιβάλλον από την απόρριψή της και ταυτόχρονα να μειωθούν οι εισαγωγές του οξειδίου του σιδήρου. Περιλαμβάνονται και αποτελέσματα από πραγματικές συνθήκες διάβρωσης χάλυβα με προστατευτικό επικαλυπτικό με Ε.Ι στην θάλασσα.

1. INTRODUCTION

Red mud is a solid residue obtained after the treatment of bauxites by the Bayer process to obtain Al_2O_3. It consists mainly of undissolved mineralogical components of the bauxite plus new phases formed during treatment. The quantities produced depend on the quality of the bauxite treated and generally range from 1 to 2 tons red mud per ton of alumina produced. Red mud contains several useful components, i.e. Fe_2O_3, Al_2O_3, TiO_2, Na_2O etc. (Table1) [1], but it is thrown into the sea and in general it creates a severe disposal problem with adverse environmental effects. The analysis of a typical red mud batch from the Aluminum of Greece installation in the Voiotia Aspra Spitia area, of the specified granulometric for use as pigment fraction, is displayed in Table 1. The red mud was sieved to obtain the fraction with the most iron oxide concentration.

Table 1: Chemical analysis of the granulometric fraction of the red mud used[1]

Compounds	As it is	-270/+400mesh
Al_2O_3	15.26	8.20
Fe_2O_3	39.11	64.83
SiO_2	6.05	1.94
TiO_2	5.22	3.12
CaO	18.72	11.11
Na_2O	2.07	-
Loss on Ignition	12.28	9.22
Rest	1.29	

The problem has forced the industry to face the disposal of the residue and many countries try to use the red mud in several applications. In Australia, it was suggested to use R.M. to neutralize municipal solid wastes by adding it to the compost. There, it absorbs metal ions which stay bound in the sludge [2,3]. In Japan, they propose a first treatment of the effluents in order to obtain the valuable components such as titanium, zirconium and the iron, before its utilization as component of building materials [4]. In Russia, R. M. is suggested to be used to modify iron ore pellets mechanical strength by replacing the expensive bentonite use [5]. In India [6] and in the USA[7], they suggest the use of R.M. as filler for polymers such as low density polyethelene (LDPE). In India, where they are the 2nd producer of red mud in the world (after Australia) they also use the material to stabilize soils [8] and Kaiser Al. (USA) [9] suggests the use of the R.M. for landfilling. In China they also propose its use as filler for polymers in composite waterproofing tapes and adhesives [10]. In Jamaica [11] they use it in concrete to minimize the addition of Portland cement. Red mud has been also proposed to be used as pigment in polymeric vehicles by German companies [12]. In Spain, they suggest the use of R.M. for manufacturing of ceramic blocks for heat accumulators [13]. In Greece, the recovery of lanthanides and yttrium is suggested from the R.M.[14,15]. The greek R.M. is thrown in the sea and there are two recent studies on the factors controlling the sedimentation in the Gulf of Corinth [16,17]. 500 to 1000 tons of iron oxide are imported in Greece for pigment use in the paint industry.

2.EXPERIMENTAL

Since the oxides included into the red mud have n-semiconductor properties [18-23], the red mud was tested as pigment in epoxy resin and in chlorinated rubber vehicles with different pigment concentrations to check its anticorrosive properties for steel in a saline environment.

Mild steel specimens (7X5 cm^2 and 0.25 mm thick) were prepared for corrosion immersion experiments. The steel used was of the following composition: Fe 99.60%, C 0.06%, Mn 0.27%, S 0.012%, P 0.009%, Cr 0.019%. As polymer vehicle chlorinated rubber and epoxy were tested, commonly used paint vehicles for the underwater parts of ships or for underwater constructions in general. The red mud before its employment was washed to remove the alkali compounds so that the vehicle could not get saponified by the pigment proper. Different concentrations of the red mud as pigment in the vehicle chlorinated rubber were tested: 10, 20 and 30%. Chloroparafin was used as plasticizer with a concentration of 35% in the paint, and toluene was employed as solvent. The same proportions of pigment were also tried in the epoxy. The painted coupons were tested under static immersion conditions in a thermostated solution of 3.5% NaCl, at 30°C. At regular time intervals coupons were taken out of the bath and tested for weight loss, after the removal of the paint by toluene and the cleaning by inhibited hydrochloric acid of the corrosion products. Electrochemical impedance tests were performed also on the specimens. For different concentrations of pigment (10%, 20%, 30%) the protection of the pigmented specimens as a function of time is shown in Fig.1, along with the non pigmented vehicle and the uncoated metal.

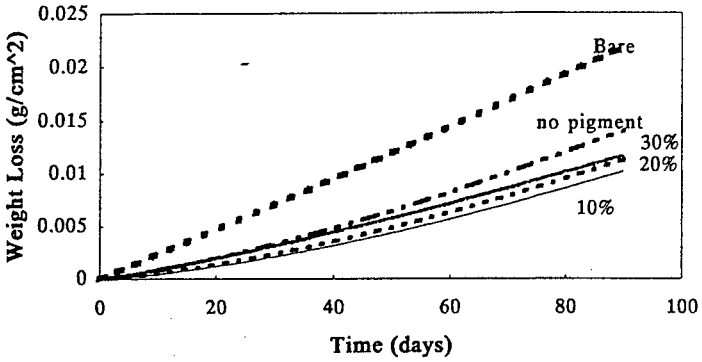


Fig. 1 Weight loss of steel painted with different pigment concentrations of red mud in chlorinated rubber exposed in 3.5%NaCl at 30°C for 60 days

The best protection is offered by the polymer with 10% of pigment for the 2 months tests but for the extrapolated for a yearly protection, the best behavior seems to be the one with the 30% content. The system with 30% red mud seems to perform better in the long run by providing better barrier properties, thus protecting the metal substrate. In general one might state that the results are similar regarding the pigment concentration influence and the curves are very close together.

Another series of experiments were done on coupons exposed in a salt spray chamber (ASTM B-117) with 5% spray of NaCl solution at 30° C, where the weight loss was measured after the removal of the coating and of the corrosion products along with electrochemical impedance measurements. In Fig 2 the results of the exposure are presented for all concentrations tested and for the bare metal and non pigmented vehicle. The best protection is offered by the 10% pigment concentration in the polymer for the 2000 hr exposure but for the one year extrapolation the bare steel along with the 10% pigmented polymer seems to have the same protection abilities. This result shows that the salt spray test is a very controversial test for a forecasting response compared to the results of the immersion tests.

The electrochemical impedance tests were performed with a three electrode system controlled by a computer. The reference electrode was a saturated calomel electrode and the counter electrode was

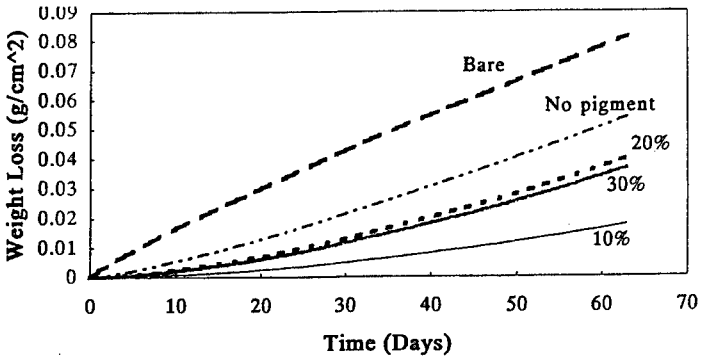


Fig. 2 Weight loss of steel painted with different pigment concentrations of red mud in chlorinated rubber exposed in salt spray chamber with 5% NaCl at 30°C for 2000 hours

a platinum foil. The solution employed was 3.5% NaCl at room temperature. The explored frequency range varied from 0.01-10Hz. The best fitted electrical equivalent model is shown in Fig. 3.

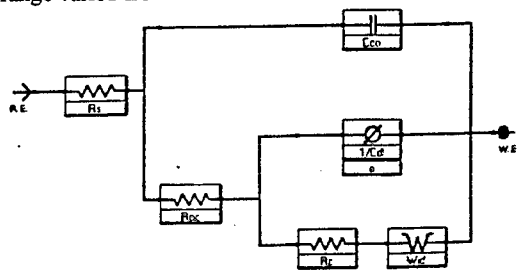


Fig. 3 Equivalent circuit, R_s: solution resistance, R_{po}: coating resistance, C_{co} coating capacitance, W_{id}: Warburg impedance, R_p: polarization resistance, C_{dl}: double layer capacitance

The results of the coating resistance of the exposed system in the solution bath as a function of time are shown in Fig. 4 where all the examined pigment concentrations exhibit the same protective behavior after 30 days to the end of the exposure. The 10% pigment curve shows that the electrolyte has reached the metal interface thus decreasing the coating resistance. The corresponding curves (Fig. 5) for the salt spray exposure show that the 10% curve has the highest coating resistance among all compared systems.

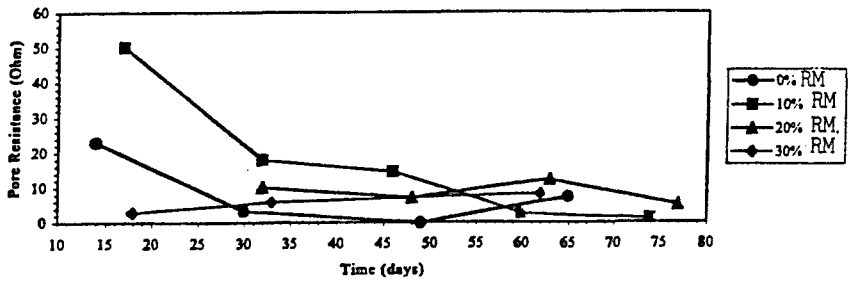


Fig. 4 Coating resistance of painted specimens exposed in a solution of 3.5% NaCl vs time.

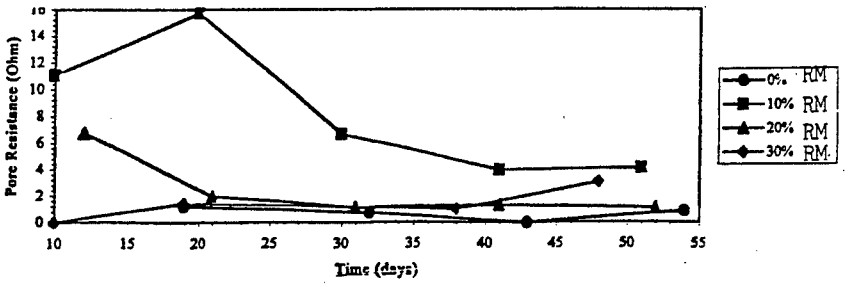


Fig. 5 Coating resistance of painted specimens exposed in a salt spray chamber with 5% solution of NaCl, as a function of time.

Cathodic protection was tested for a system that employed red mud pigment of different concentrations in chlorinated rubber vehicle in a 3.5% NaCl solution, lowering the voltage used in practice to gain energy, with a SCE as reference and a graphite rod as anode. The results are shown in Fig.6. The results display protection of the system containing 30% R.M. in C.R. with -740mV vs. SCE. The usually applied voltage is -780 mV. By introducing the pigment the required potential energy is lowered by 40mV. This is also shown in Fig. 7, where for the same weight loss a different voltage application required is needed.

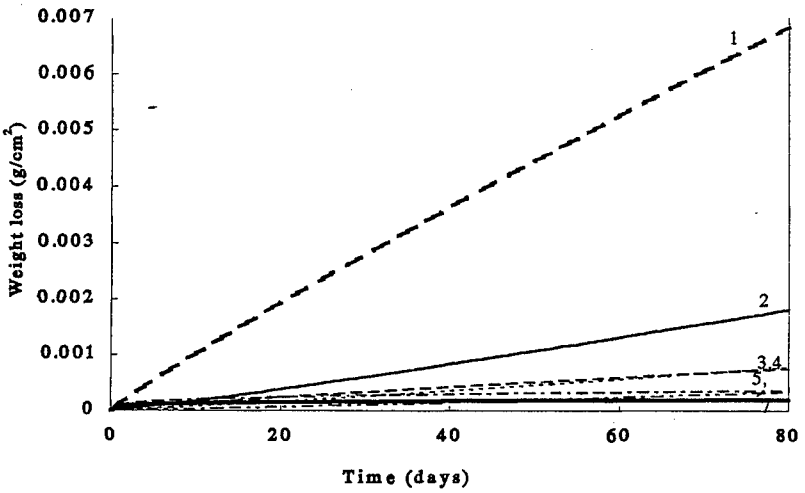


Fig.6 Cathodic voltage effect vs. SCE for different pigment concentrations in chlorinated rubber; 1: steel bare, 2: 20% R.M. (-700mV), 3: 20% R.M.(-740mV), 4: unpigmented CR (-780), 5: 30% (-740mV), 6: 30% R.M. (-780mV), 7: 20% R.M. (-780)

Another series of tests were performed with an epoxy vehicle and the red mud as a pigment. The weight loss of the steel specimen was measured after the exposure of the coupons for two months in a saline solution (3.5% NaCl at 30^0C) under cathodic protection conditions. The results are shown in Fig. 8 and the effect of the protection voltage in Fig. 9.

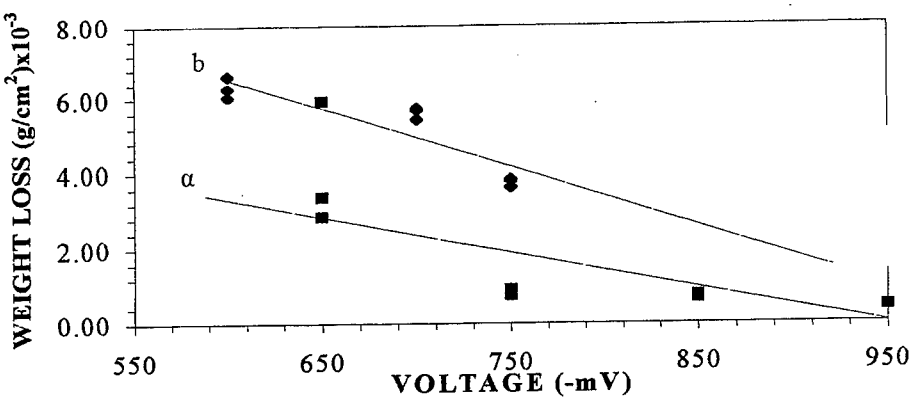


Fig. 7 Weight loss as a function of cathodic voltage for 30 days exposure of steel coupons coated with 30% pigmented chlorinated rubber (a) and vehicle without pigment (b).

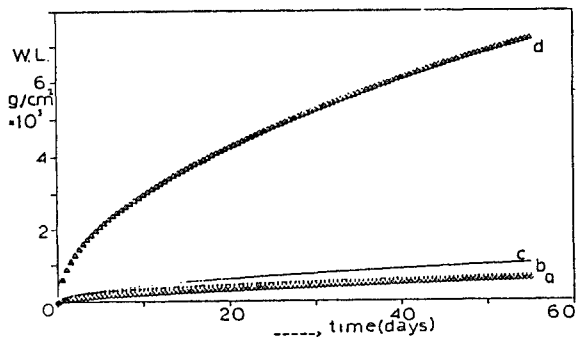


Fig.8 Weight loss as a function of time of steel coupons coated with 30% pigmented epoxy at different cathodic voltages: a: -950, b: -850, c: -750, d: -600 mV vs. SCE.

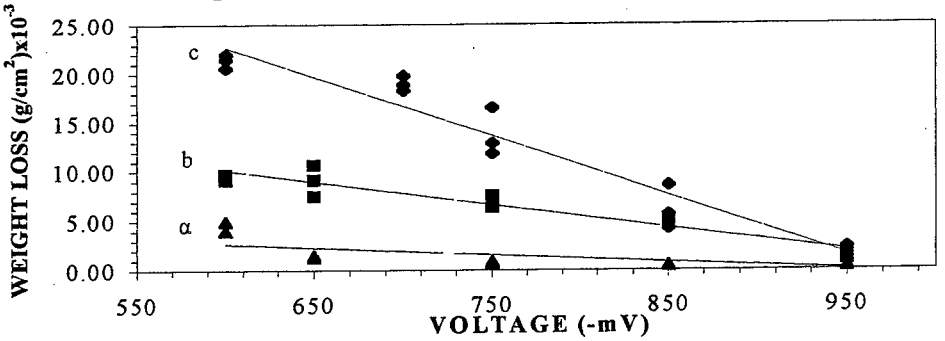


Fig. 9 Weight loss as a function of cathodic voltage for 30 days exposure of steel coupons coated with: a : 30% pigmented epoxy, b: 5% R.M. and c: epoxy without pigment.

Exposure tests were also undergone in the sea to test the resistance of the R.M. pigment in C.R. under real conditions. The surface was prepared by blast cleaning with expendable minerals. The weight loss is shown in Fig. 10 and the corresponding rate equations in Table II. There are also displayed the rate equations for bare steel. This coating can replace any commercial equivalent primer. The damage equations by commercial primers tested under the same conditions are similar: $y = 3.8 \pm 0.5 \times 10^{-4} t^{0.6}$ to the corrosion protection offered by R.M. primers.

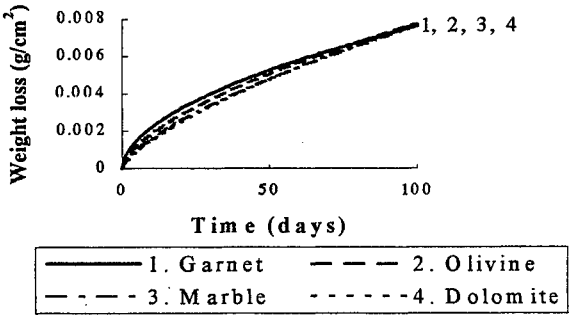


Fig.10 Corrosion damage equations of steel specimens blasted with expendable abrasives and painted with Chlorinated rubber with 10% red mud pigment after 83 days of exposure in the sea

Table II: Chlorinated rubber with 10% R.M. coatings on steel in the sea for a two month exposure

Abrasive	Corrosion equation 20%RM	R^2	Corrosion equation uncoated blasted steel	R^2
Garnet	$y = 6.36 \times 10^{-4} t^{0.54}$	0.97	$y = 1.786 \times 10^{-3} t^{0.59}$	0.99
Olivine	$y = 4.44 \times 10^{-4} t^{0.611}$	0.96	$y = 1.52 \times 10^{-3} t^{0.62}$	0.97
Marble	$y = 3.38 \times 10^{-4} t^{0.68}$	0.98	$y = 2.33 \times 10^{-3} t^{0.43}$	0.98
Dolomite	$y = 3.0 \times 10^{-4} t^{0.705}$	0.98	$y = 9.53 \times 10^{-4} t^{0.723}$	0.98

CONCLUSIONS

The results show that red mud does increase the anticorrosive properties of chlorinated rubber in a 10% pigment concentration when tested in immersion conditions or in an accelerated test as the salt spray test. Impedance measurements have quantitatively good correspondence with the weight loss method. The optimum concentration for cathodically protected coating is 30% of red mud in the vehicle. The red mud pigmented coating has a good performance (10% in C.R.), under sea immersion conditions, thus it can successfully replace the commercial primers which use iron oxide pigments as anticorrosive agent.

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CEMENT-BASED STABILIZATION/SOLIDIFICATION OF HAZARDOUS INDUSTRIAL WASTES

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ABSTRACT

This study evaluates the Cement-Based Stabilization/Solidification (S/S) of hazardous industrial waste sludges which resulting from three different types of industrial activities (tannery, dye and aluminium surface treatment industries). For the Stabilization/Solidification process various cementitious additives such as Portland cement, fly ash and cement kiln dust were used. After curing for different periods, the stabilized/solidified samples were physically tested measuring porosity, density and compressive strength and chemically tested using the Generalized Acid Neutralization Capacity (GANC) test. The S/S dye industry sludge appeared to have high porosity, low strength and low metal leachability. The S/S tannery and aluminium surface treatment industry sludges appeared to have satisfactory porosity and strength values and low metal leachability.

ΣΤΑΘΕΡΟΠΟΙΗΣΗ/ΣΤΕΡΕΟΠΟΙΗΣΗ ΜΕ ΒΑΣΗ ΤΟ ΤΣΙΜΕΝΤΟ ΕΠΙΚΙΝΔΥΝΩΝ ΒΙΟΜΗΧΑΝΙΚΩΝ ΑΠΟΒΛΗΤΩΝ

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ΠΕΡΙΛΗΨΗ

Η μελέτη αυτή αφορά στη Σταθεροποίηση/Στερεοποίηση (Σ/Σ) λάσπης επικίνδυνων βιομηχανικών αποβλήτων τριών βιομηχανικών μονάδων (βυρσοδεψείου, βαφείου και βιομηχανίας επεξεργασίας επιφανειών αλουμινίου). Για την εφαρμογή της τεχνολογίας Σ/Σ χρησιμοποιήθηκαν ως πρόσθετα τσιμέντο Πόρτλαντ, ιπτάμενη τέφρα και σκόνη υψικαμίνου τσιμέντου. Μετά τη ενυδάτωση και σκλήρυνση των δειγμάτων για τρεις διαφορετικές χρονικές περιόδους, στα Σ/Σ δείγματα έγινε μέτρηση του πορώδους, της πυκνότητας και της αντοχής σε θλίψη και ακολούθως μελετήθηκε η εκχυλιστικότητα των Σ/Σ δειγμάτων με τη χρήση του ελέγχου Generalized Acid Neutralization Capacity (GANC).

1. INTRODUCTION

Stabilization/Solidification (S/S) of industrial wastes is considered a suitable treatment technique since the hazardous components are locked into the solidified product and are not available for leaching [1].

There exists a wide variety of Stabilization/Solidification techniques such as cement-based [2-4], lime-based [5] and organic S/S [6,7]. Cement-based Stabilization/Solidification processes normally involve mixing of hazardous wastes with cementitious additives to form an inert and stable solid material, which can be safely disposed off to land. The types of wastes are most suited to this type of treatment are primarily inorganic solid wastes and sludges which contain significant concentrations of highly toxic heavy metals such as Cd, Cr, Cu, Ni, Pb and Zn.

Several materials may be used as additives in Cement-based Solidification/Stabilization techniques. These materials are: fly ash [8], silica fume [9], activated carbon [9] and silicates [10]. Clay materials, used as additives, could react with heavy metals. Due to the polarity difference of surface change at edge and at face of clay particles, inorganic ions could be adsorbed to the particles. Several processes have also used organophilic clays to adsorb organic compounds contained in wastewater [11,12].

In this work, sludges resulting from three types of hazardous industrial wastes were treated with the use of cement-based Stabilization/Solidification process. The additives used were Ordinary Portland Cement (C), Fly Ash (F) and Cement Kiln Dust (K) were used as additives. Fly ash is a byproduct of power stations and contains high percentage of SiO_2 (40-50%) and CaO (10-30%). Cement kiln dust is a byproduct of cement industries and contains almost 45% CaO.

There exist several physical and chemical testing techniques in order to assess the efficiency of S/S process used. The most commonly used physical tests are: Index Properties, Density, Permeability, Strength and Durability tests [13]. Chemical testing includes extraction and leaching tests. The extraction tests usually applied are: the Toxicity Characteristic Leaching Procedure (TCLP), the Extraction Procedure Toxicity (EP Tox) test, the California Waste Extraction Test (Cal. WET), the Multiple Extraction Procedure (MEP), the Monofilled Waste Extraction Procedure (MWEP), the Equilibrium Leach Test (ELT), the Acid Neutralization Capacity (ANC), the Sequential Extraction Test (SET) and the Sequential Chemical Extraction (SCE). The leaching tests most commonly used include: the Materials Characterization Center (MCC-IP) static leach test, the American Nuclear Society (ANS) leach test and the Dynamic Leach Test (DLT). (USEPA, 1989)

In this research the assessment of the S/S process was achieved by using porosity, density and strength tests (physical testing) as well as modified Generalized Acid Neutralization Capacity (GANC) procedure (chemical testing).

2. EXPERIMENTAL PROCEDURE

Sludge samples from a tannery, a dye and an aluminium surface treatment industry were brought into the laboratory and stored accordingly. The sludge samples produced by the tannery (sample T) and dye (sample A) industries are watery. The water content was found to be about 93.3% for the tannery industry sludge and 96.9% for the dye industry sludge. The sludge of the aluminium surface treatment industry (sample V) has low water content, about 50.5%.

The sludge samples were dried to constant weight at 105°C, ground and sieved to less than 105 μm. The additives were also sieved to less than 105 μm. In order to estimate the metal content of each sludge a portion was digested with conc. HNO_3 and conc. H_2SO_4. The metal content was determined by Atomic Absorption Spectroscopy (Perkin Elmer 2380). The pH was measured by a glass electrode method and the Total Organic Carbon (TOC) concentration by titrimetric method [14].

For the preparation of S/S mixtures, dried and sieved sludge samples and additives were mixed in ratios shown in Table 1. A 0.5 Water to Solid ratio (W/S=0.5) was selected. The samples were mixed until homogenous using a domestic mixer. Samples were cast in split greased plastic moulds of 11 mm diameter. Compressive strength was determined after 7, 28 and 112 days curing time, using an Instron instrument (maximum load 5 tones). The porosity and density of S/S samples, after 28 days curing time, were determined by the use of Porosimeter 2000 (Carlo Erba instrument).

TABLE 1: Mix designs used to solidify wastes

Additives			Sludge Samples		
% Cement	% Fly Ash	% Cement Kiln Dust	% V	% A	% T
100	-	-	-	-	-
60	40	-	-	-	-
60	-	40	-	-	-
90	-	-	10	-	-
90	-	-	-	10	-
90	-	-	-	-	10
50	40	-	10	-	-
50	-	40	10	-	-
50	40	-	-	10	-
50	-	40	-	10	-
50	40	-	-	-	10
50	-	40	-	-	10

V=Al surface treatment industry sludge, A=Dye industry sludge, T=Tannery industry sludge

After completing compressive strength measurements, the crushed samples were subjected to the Generalized Acid Neutralization Capacity (GANC) test. The GANC test is a single-batch leaching procedure in which a series of dried samples are extracted with increasingly acidic leachant [15]. In 1g of each sludge sample, water and acetic acid were added in several ratios. The mixtures were subjected to continuous shaking for 48 hours in ambient temperature conditions. The samples were allowed to settle for 15 min and were filtered. The pH value and the heavy metal concentrations were measured in leachates.

3. RESULTS AND DISCUSSION

The results achieved from the characterization of the three types of sludge samples are shown in Table 2. The pH of the samples was in the neutral area. The organic load, expressed as TOC, of the dye (sample A) and the tannery (sample T) were quite high, (14.77% and 8.33% respectively), while the TOC of the aluminium surface treatment industry was much lower (0.62%). The metal content of the sludge samples were high. Particularly, the tannery sludge sample contained high concentrations of Cr and Fe while in the dye sludge the most problematic metal was Fe. Finally, the sludge produced from aluminium surface treatment industry contained high concentrations of Cr, Fe, Ni and Zn.

TABLE 2: Sludge samples characteristics

	Sample T	Sample A	Sample V
pH	7.15	7.29	7.18
TOC (%)	8.33	14.77	0.62
Cr (mg/g)	22.300	0.285	87.500
Cu (mg/g)	0.061	0.320	0.067
Fe (mg/g)	2.886	6.750	5.915
Ni (mg/g)	0.069	0.057	1.010
Pb (mg/g)	0.140	0.106	0.177
Zn (mg/g)	0.149	0.240	3.100

V=Al surface treatment industry sludge, A=Dye industry sludge, T=Tannery industry sludge

The porosity and density measurements of mixed samples are presented in Figures 1-3. From the results obtained for porosity measurements on 28 days curing time S/S sludges the following can be remarked: the lowest porosity value, 28.7%, was measured for the sample containing only cement (100% C). The porosity of the samples with only C/additives ranged from 34.7-38.4 %, while for the samples with OPC/sludge a porosity of up to 43.4% was measured. Finally, the samples containing the combinations of C/additive/sludge had a porosity in the range of 40.9-54.6 %. The lowest porosity value was measured for the mixture C/K/sludge V, while the highest one was measured for the mixture C/F/sludge A.

The highest density value, 1.79 g/cm^3, was measured for the C sample. The density of the samples containing only C/additives was in the range of 1.44-1.6 g/cm^3, while the C/sludge samples had a density value that did not exceed 1.49 g/cm^3. Finally, for the combination of S/S samples containing C/additives/sludge, the lowest density value, 1.26 g/cm^3, was obtained in the mixture C/F/sludge A, while the highest one, 1.66 g/cm^3, was observed in the mixture C/K/sludge V.

The compressive strength measurements of mixed samples are shown in Figures 4-6. In general, the compressive strength values increases with increasing time of hydration and decreases with addition of sludge and/or additives. In particular, in the 7 days cured samples the compressive strength measurements were in the range of 260-4810 kPa, while after 28 days curing time the strength values ranged from 520-10330 kPa. For 112 days hydration, the lowest strength measurement was 610 kPa and the highest 10840 kPa. For all curing times used, the lowest strength measurement was found for the mixture C/F/sludge A and the highest for the mixture C/F/sludge T.

Overall, the physical testing results indicate that the S/S dye industry sludge appeared with very low compressive strength as well as high porosity levels due to the high percentage of TOC (14.77%). These S/S samples are considered as hazardous referring their physical characteristics since the U.K. value recommended for the disposal of S/S sludge samples is 700 kPa [16]. On the contrary, the physical characteristics of the S/S tannery and aluminium surface treatment industry sludges appear quite satisfactory.

As mentioned earlier, chemical testing using the GANC procedure, was applied on untreated sludge as well as on the S/S mixtures. The results obtained from the application of the extraction test for the three types of industrial waste sludges are shown in Tables 3-5.

The extraction test for the aluminium surface treatment sludge showed that Fe, Cu and Ni had the highest levels of extraction, while the total metal removal was in the range of 12-42% (Table 3). A

very low percentage of the metal content was removed during the GANC test of the S/S dye industry sludge (Table 4). According to the GANC test results on S/S tannery industry sludge, Cr and Fe were extracted in high levels, while a 10-62% of the total metal content was removed (Table 5).

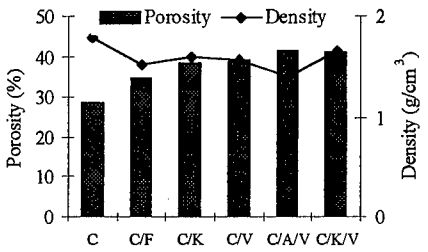


Figure 1: Porosity and Density values for S/S Al surface treatment industry sludge (V).

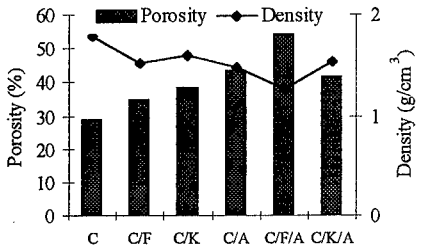


Figure 2: Porosity and Density values for S/S Dye industry sludge (A).

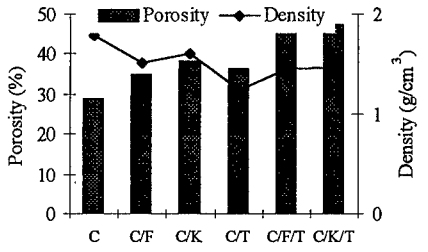


Figure 3: Porosity and Density values for S/S Tannery industry sludge (sample T).

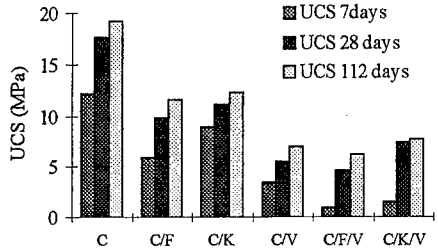


Figure 4: Compressive strength measurements for S/S Al surface treatment industry sludge (V).

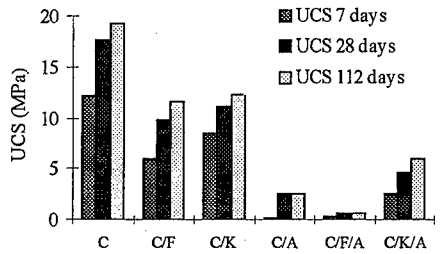


Figure 5: Compressive strength measurements for S/S Dye industry sludge (A).

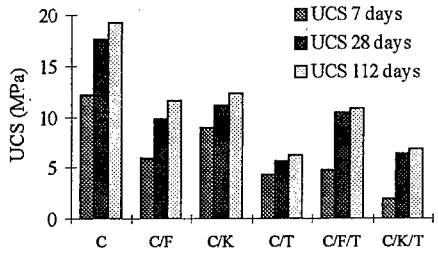


Figure 6: Compressive strength measurements for S/S Tannery industry sludge (sample T).

The GANC test results for the S/S sludge samples are shown in Figures 7-12. Figures 7-10 show the leachability of Cr, Fe, Ni and Zn, respectively, for the S/S aluminium treatment industry sludge, while Figures 11 and 12 show the leachability of Cr and Fe, respectively, for the S/S tannery industry sludge, since these were present in high concentration in the untreated sludge samples. The results of the S/S dye industry sludge are not presented, since the concentration levels of the metals in the leachates from the untreated samples were lower than the safe disposal standard limits.

TABLE 3: pH and metal concentration in leachates from Al surface treatment industry sludge (sample V) treated with GANC test.

Sample Iden. No	pH	Cr (mg/g)	Cu (mg/g)	Fe (mg/g)	Ni (mg/g)	Pb (mg/g)	Zn (mg/g)
0	7.05	0.080	-	0.021	0.006	-	0.001
1	5.44	0.110	-	0.025	0.176	-	0.034
2	4.66	0.790	0.003	0.041	0.234	-	0.107
3	4.31	3.010	0.008	0.369	0.253	0.008	0.116
4	4.12	4.020	0.010	0.725	0.267	0.012	0.135
5	4.02	4.910	0.013	1.315	0.270	0.020	0.166
6	3.90	5.730	0.016	1.732	0.290	0.016	0.212
7	3.82	6.180	0.019	1.912	0.307	0.022	0.278
8	3.75	7.080	0.021	2.122	0.315	0.027	0.344
9	3.70	8.280	0.024	2.212	0.335	0.044	0.412
10	3.69	10.520	0.025	2.502	0.338	0.035	0.508

TABLE 4: pH and metal concentration in leachates from dye industry sludge (sample F) treated with GANC test.

Sample Iden. No	pH	Cr (mg/g)	Cu (mg/g)	Fe (mg/g)	Ni (mg/g)	Pb (mg/g)	Zn (mg/g)
0	6.77	-	0.007	0.070	-	-	0.003
1	4.20	-	0.011	0.097	-	-	0.015
2	3.82	-	0.013	0.121	-	-	0.018
3	3.62	-	0.014	0.130	-	-	0.027
4	3.49	0.006	0.016	0.134	-	-	0.031
5	3.42	0.008	0.018	0.140	-	-	0.040
6	3.36	0.010	0.019	0.144	-	0.009	0.048
7	3.32	0.011	0.020	0.149	-	0.014	0.049
8	3.28	0.012	0.021	0.154	-	0.028	0.054
9	3.24	0.015	0.023	0.161	-	0.035	0.060
10	3.21	0.018	0.024	0.166	-	0.042	0.061

TABLE 5: pH and metal concentration in leachates from tannery industry sludge (sample T) treated with GANC test.

Sample Iden. No	pH	Cr (mg/g)	Cu (mg/g)	Fe (mg/g)	Ni (mg/g)	Pb (mg/g)	Zn (mg/g)
0	6.32	0.121	0.004	0.014	0.006	-	0.006
1	6.09	0.160	0.005	0.028	0.010	-	0.013
2	4.81	0.182	0.006	0.047	0.012	0.006	0.057
3	4.37	0.283	0.007	0.078	0.015	0.011	0.070
4	4.17	0.302	0.009	0.098	0.022	0.017	0.074
5	4.05	0.704	0.009	0.134	0.024	0.022	0.077
6	3.92	1.114	0.010	0.602	0.025	0.025	0.080
7	3.80	1.360	0.011	0.728	0.026	0.037	0.081
8	3.73	1.984	0.012	0.844	0.028	0.046	0.083
9	3.67	2.124	0.014	0.980	0.029	0.065	0.084
10	3.64	2.228	0.016	1.042	0.031	0.082	0.093

Overall, chemical testing results indicate that in the acidic pH values the metal concentration in leachates from the untreated sludge samples were higher than those obtained from the S/S samples. In addition, the pH levels in leachates from the original sludge samples ranged in the acidic and neutral area, while the pH levels for the S/S samples covered the whole pH range. This is due to the fact that cement and additives, fly ash and cement kiln dust, consist of chemical substances which dissolved in the extractant forming alkaline solutions. Furthermore, in most cases, the metal

concentration levels in the alkaline pH range were low due to the formation of insoluble metal hydroxides.

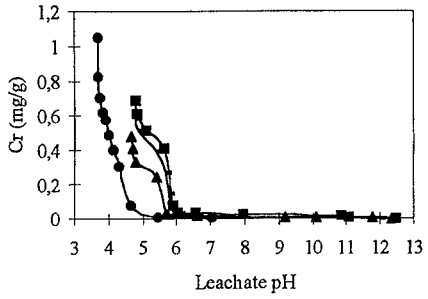


Figure 7: Cr concentration in leachate for S/S sludge samples from Al treatment industry (V).

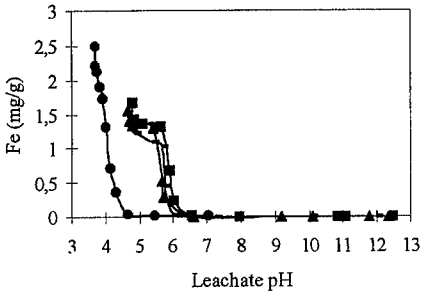


Figure 8: Fe concentration in leachate for S/S sludge samples from Al treatment industry (V).

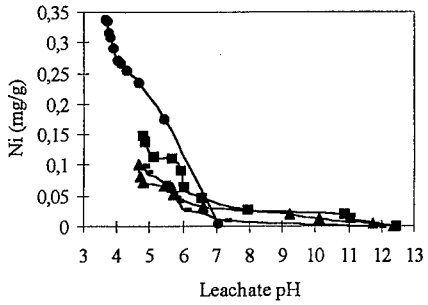


Figure 9: Ni concentration in leachate for S/S sludge samples from Al treatment industry (V).

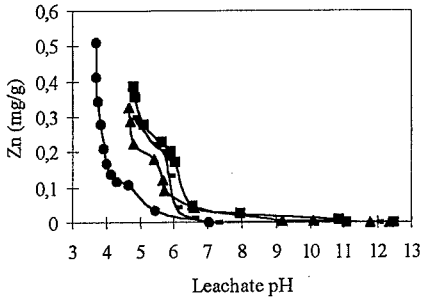


Figure 10: Zn concentration in leachate for S/S sludge samples from Al treatment industry (V).

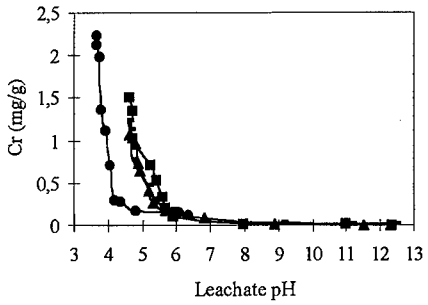


Figure 11: Cr concentration in leachate for S/S sludge samples from Tannery industry (T).

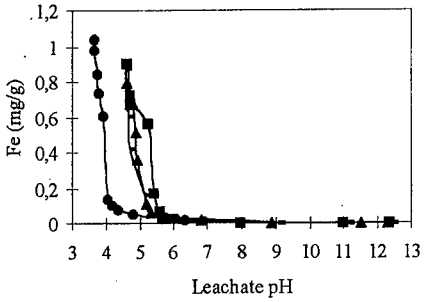
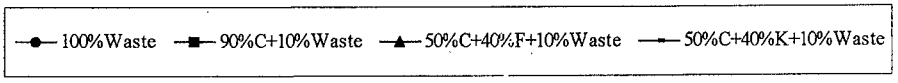


Figure 12: Fe concentration in leachate for S/S sludge samples from Tannery industry (T).



4. CONCLUSIONS

According to the results, the Stabilized/Solidified sludge samples from the tannery and the aluminium surface treatment industry appear to have satisfactory values of porosity and compressive strength. On the contrary the Stabilized/Solidified dye sludge sample appear to have low compressive strength measurements. The application of the Cement-based Stabilization/ Solidification process by using cement and/or pozzolanic materials, as additives, reduces the leachability of the metals. As a result, the Stabilized/Solidified sludge can be safely disposed in landfills.

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RECYCLING OF LEAD BATTERIES IN GREECE: PRESENT STATE - PERSPECTIVES

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ABSTRACT

This study is addressed to depict the present state of the disposal and exploitation of exhausted Pb/acid batteries in Greece and to recommend the application of modern recycling techologies in accordance with the European and Greek legislation. The international situation is reviewed, the general trends are marked and the main industries related to Pb/acid batteries treatment are reported. General recommendations are given regarding the collection of spent batteries and the installation of a recycling plant in Greece. The present study proves that a possible installation of a Pb/acid batteries recycling process unit, treating 17.000 ton/yr (estimated total quantity) and situated in the industrial area of Attiki region, seems to be economically profitable.

ΑΝΑΚΥΚΛΩΣΗ ΣΥΣΣΩΡΕΥΤΩΝ ΜΟΛΥΒΔΟΥ ΣΤΗΝ ΕΛΛΑΔΑ: ΠΑΡΟΥΣΑ ΚΑΤΑΣΤΑΣΗ-ΠΡΟΟΠΤΙΚΕΣ

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ΠΕΡΙΛΗΨΗ

Η παρούσα εργασία αποσκοπεί στο να αποτυπώσει την κατάσταση που επικρατεί στην Ελλάδα, αναφορικά με τη συλλογή, και επεξεργασία των χρησιμοποιημένων συσσωρευτών μολύβδου και να προτείνει την εφαρμογή σύγχρονων τεχνολογιών ανακύκλωσης σε συμφωνία με την Ευρωπαϊκή και Ελληνική νομοθεσία. Εξετάζεται η κατάσταση στο διεθνή χώρο, καταγράφονται οι γενικές τάσεις και αναφέρονται βιομηχανίες που σχετίζονται με την επεξεργασία των συσσωρευτών μολύβδου Τα πορίσματα της παρούσας εργασίας ενισχύουν την δυνατότητα εγκατάστασης μονάδας επεξεργασίας 17.000 τον/έτος (εκτιμώμενη συνολική ποσότητα) στην βιομηχανική περιοχή του Ν. Αττικής, προβλέποντας θετικά οικονομικά αποτελέσματα.

* *Corresponding author*

1. INTRODUCTION

The recovery of lead from lead/acid batteries is a process of great interest in the lead industry. The typical composition of a Pb/acid battery is presented on **Table 1**. **Table 2** lists the three general types of lead/acid batteries and their applications.

TABLE 1: Typical composition of batteries equiped with a polypropylene box [1]

Component	**%w/w**	**kg**
Acid (H_2SO_4)	28.5	3.85
Lead (total) Grid (metallic) Connections (metallic) Battery paste (oxide, sulfate)	64 (22.2) (5.9) (35.8)	8.64 (3.00) (0.80) (4.84)
Box (polypropylene)	5.0	0.67
Other materials (plastic, paper, wood, PVC)	2.7	0.37
Total	100	13.5

TABLE 2: Types and characteristics of lead-acid batteries [2]

Type	**Typical application**
SLI (starting, lighting, ignition)	Automotive, marine, aircraft, diesel engines in vehicles and for stationary power
Traction	Industrial trucks (material handling)
Stationary	Standby emergency power, telephone exchange, uninterrupted power systems, load leveling, signaling

2. THE NECESSITY OF LEAD RECYCLING

Lead rates fifth in terms of metal consumption throughout the world and its growth potential to the end of the century is foreseen to be 3.5%. Nearly all primary lead production is based on sulfidic ores (PbS), the world reserves of which is estimated to be approximately 80 million tones. These limited reserves are expected to be exhausted within 30 years [3]. Therefore, it is expected that the market price of primary lead will be continuously increasing. This fact forces the industries to be oriented on processes of recovering secondary lead by recycling lead containing products. **Table 3** depicts the importance of recycling in lead production.

TABLE 3: Importance of recycling in lead production (1990) [1]

	World (10^3 T)	**EC (10^3 T)**
Lead consumption	5653.1	1513.2
Lead production	5676.0	1389.1
Lead recycling	2676.1	737.3
Recycling/Production (%)	47	53

The recycling process has the following advantages [3]:

- The energy requirements for recycling lead is not more than 36% comparing with the primary lead, due to the fact that most metallic scrap is characterised by the high metal content existing in the metallic state

- The secondary lead industry using batteries as Pb source, needs less than 50% of the capital investments of the primary lead smelters
- The earnings of batteries industry based on recycled lead batteries are at least 10 times higher than those obtained from the current lead production

3. THE POLICY OF BATTERY RECYCLING IN THE EC

Regarding the existence of well-established collection networks, the recycling can be efficient, especially when the batteries are compared with any other recyclable product. In Western Europe, for instance, the lead/acid battery is well ahead the collection rate of glass, paper and metallic cans products that are in the forefront of recyclability.

In France, *B.J. Industries* have a capacity of 18.000tn/yr of recycling lead/acid batteries, giving special attention to the emissions' reduction and the wastes' elimination [4]. *Cookson Penarroya Plastiques* produces daily since 1988, 40 tonnes of polypropylene granules from 50.000 scrap battery cases [5].

In Italy, *Engitec Impianti* has developed the CX System Plant, by which, separation of the battery's components is achieved, as well as recovery of the contained lead and acid. The CX System process has been applied and improved in several plants in Europe, the United States and the Middle East since 1982.[6]

In Great Britain, *Brittania Refined Metals Ltd.* has a recycling capacity of 16tn/day of lead/acid batteries, by applying the above mentioned plant combinated with the Isasmelt process [7]. Other pioneer industries in the field of lead/acid battery recycling are *Arv. Anderson, Boliden* and *Exide*.

The EC's directives (91/157) & (93/86), referring to the recycling of batteries, aim the following:[8]

- Approximation of the laws of the Member States, on the recovery and controlled disposal of those spent batteries and accumulators containing dangerous substances (article 1,157)
- Separate disposal of used batteries (article 6v, 157)
- Efficient organization of separate collection, and when appropriate the setting of a deposit system. Furthermore, Member States may introduce measures such as economic instruments, in order to encourage recycling. These measures must be introduced after consultation with the parties concerned, be based on valid ecological and economic criteria and avoid distortions and competition (article 7, 157)
- Adoption by the Member States of appropriate measures to ensure full implementation of all the provisions of this Directive. Member States shall lay down the penalties to be applied in the event of an infringement of the measures adopted to comply with this Directive; such penalties must be effective, proportionate and deterrent in their effect (article 6, 86)

4. LEAD/ACID BATTERY RECYCLING IN GREECE

4.1 The existing Greek legislation

The problem of lead/acid battery recycling in Greece is not yet considered totally, despite the legislative framework (no. 73537/1438), which is in harmonization with the EC's instructions (91/157 & 93/96). Furthermore, according to this legislative framework: [9]

- The disposal in surface or sewage water or land, of the liquid content of the lead/acid batteries is strictly restricted (article 4, paragraph 1,c)

- The establishment of technical rules referring to the transportation of the batteries to the recycling plants is encouraged (article 5, paragraph 1,e)

4.2 Estimation of the number of batteries. Distribution in Greece

The estimation of the number of batteries is based on the following:

- The total number of vehicles in Greece **(figure 1)**
- The fact that the replacement of a battery is held every 3.5-4.5 years - according to the opinion of experienced people involved in the battery industry [14]- and is not influenced by the distance covered by a specific vehicle.
- The battery quantities that are imported annually **(figure 2)**, as well as the quantities that are produced at the largest Greek battery industries

Using the data retrieved by the National Statistic Service of Greece **(figure 1)**, the quantity of vehicles is predicted to be 4.000.000 for the year 1998 and 4.200.000 for the year 2000. According to this prediction, the total number of spent batteries in Greece for 2000 is estimated to be 1.200.000, which equals to 17.000 ton/yr. (see **Table 1**). This result is in agreement with the predictions from the data presented in **figure 2**, (~1.000.000bat/yr for the year 1998) combined with the fact that the annual domestic production is approximately 100.000 bat/yr.[10]

FIGURE 1: Cars and motorcycles in Greece (1982-2000) [10]

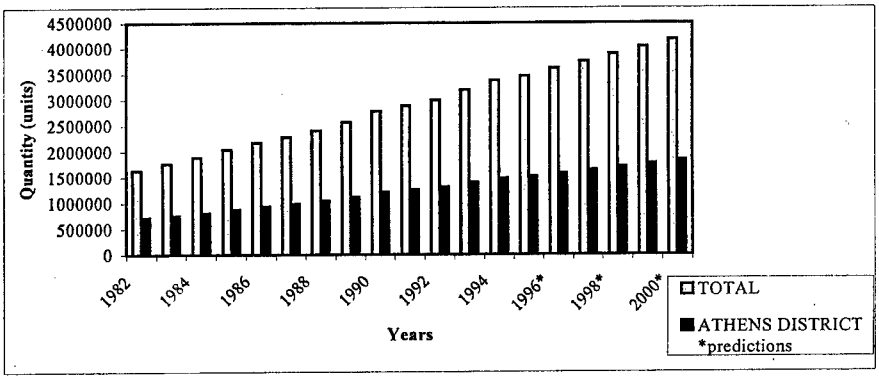
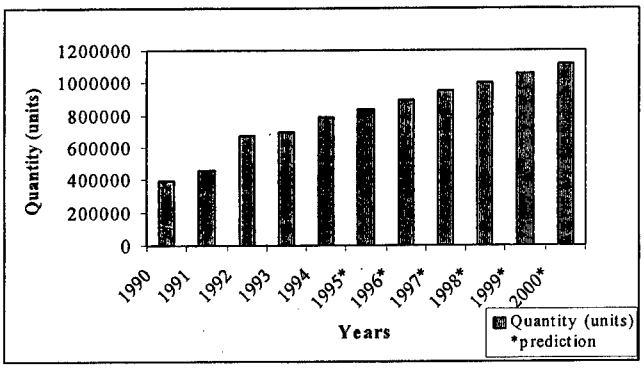
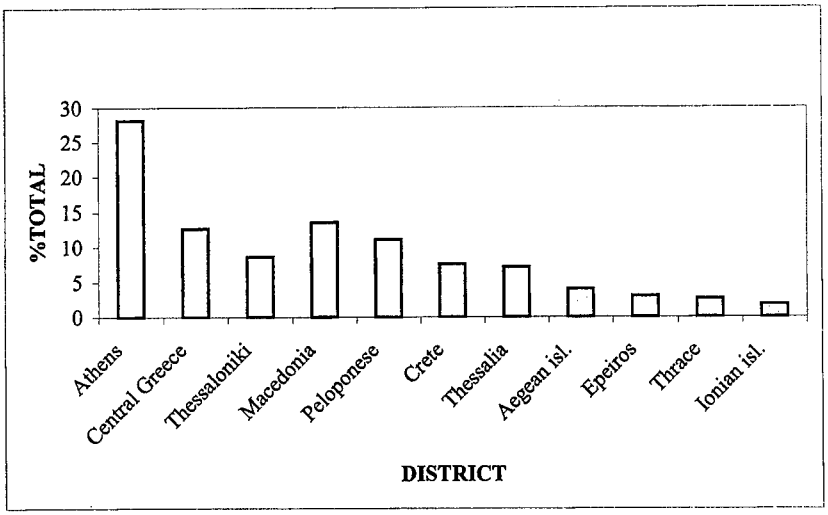


FIGURE 2: Battery imports in Greece (1991-2000) [10]



The geographical distribution of batteries in Greece, is given on **figure 3:**

FIGURE 3: The geographical distribution of batteries in Greece [10]



4.3 Battery -collection system

The battery-collection system is not properly organized, causing violations of the law and environmental problems. The existing alternatives for the collection of batteries are the following [11, 14,15]:

- The car-owner discards the used battery after its replacement, most commonly without any separation from other types of refuse.
- The car-owner leaves the used battery at the car-service station, where it is replaced by a new one. All the used batteries are transported by private lorry-owners (collectors of metal or other recoverable materials) and directed to junk yards. There, they are crushed and deprived of their valuable lead content. The rest of the material is discarded.
- The battery follows the above-mentioned procedure up to the junk yard. After being crushed and emptied from the acid, they are transferred by private lorries to a recycling plant for further treatment.

A main concern should be, therefore, the elimination of uncontrolled refuse of batteries or parts of them after treatment and the decrease in the number of mediators between the car-owner and the recycling industry, who cause the increase in the total cost of treatment.

4.4 Existing recycling plants in Greece

Approximately the 80% of the annual load of used lead/acid batteries is nowadays handled by the following three main industries:

- ALAKO (Lavrio- capacity of ~250.000bat/yr)
- ATHIMARITIS (Aspropirgos- capacity of ~200.000 bat/yr.)
- MAVROULIS-PYROVOLOS (Oinofita- capacity of ~450.000 bat/yr.)

The batteries treatment process used by these companies include the following main stages [11]:

- Battery braking and separation of its components.

- Smelting the grids and the active mass in a furnace under 1100°C, adding Fe, coke and silica compounds.
- Lead-refining in a kettle under 300-400°C, by adding NaOH, NaCl or NH_3NO_3.
- Molding lead into ingots.

According to the literature, the main disadvantages related to this process can be summarized as follows: [11], [12]

- The braking and the separation of the battery's components in two out of the three above-mentioned industries, is curried out before the transportation of the batteries to the recycling plant. Therefore, the disposal of the acid is being done without the adequate steps of the neutralization.
- All the quantities of $FeSO_4$ (estimated to be 14% of the feed, or 2.500 ton/yr.), which is the main by-product of the smelting process, are lost. This involves an environmental impact and reduction of profits from sales as well.
- The grids and the active mass are treated simultaneously. Therefore, there is a need of applying extremely high temperature (1100°C) demanded by the direct melt-reduction reaction of sulfate.
- The emissions of gases from the furnace contain a large amount of Pb particles (50kg Pb/150kg gas), which are emitted to the atmosphere. Considerable amounts of sulfur oxide and other malodorous or noxious compounds and dust are emitted to the atmosphere as well. Equipping the main unit with gas emissions abatement units would increase the investment and operating costs, considering the significant problems of corrosion and erosion related to the components of these gases.
- The process demands consumption of large amounts of reducing agents (Fe, coke, silica compounds) and desulfurization assistant (NaOH, NaCl, NH_3NO_3. Therefore, the operating costs are highly increased.
- The complicated reaction mechanism delimits the total efficiency (<70%).

Apart from the three major industries involved with the lead/acid batteries treatment, there is a plethora of small smelters all around Greece, which operate without conforming to the basic rules instituted by the law, against the uncontrolled polluting of air and ground.

Considering the three known companies, one could notice that the applied technology is not in complete accordance with the legislative framework (paragraph 3.1). Noticeable are the attempts carried out by the Ministry of the Environment of Greece, focusing in public and state awareness on subjects related to battery recycling [13]. For the reasons reported before, it seems to be a necessity for the improvement of the present situation of battery recycling in Greece, by applying effective methods of collection and by the modernization of the present technology.

5. RECOMMENDATIONS ON RECYCLING IN GREECE

Considering the data related to the techniques of collection ant treatment of lead/acid batteries in Greece, the need of modernization is obvious, as well as improvement of the existing technology, especially in the direction of harmonization with the relevant legislation. The following general recommendations could contribute to an effective solution of the problem of battery recycling:

- Installation of a central unit, treating the total amount of spent batteries, instead of more than one units of a lower capacity.
- Establishment of a well-organized collection network covering all the Greek territory.
- Installation of the unit in the industrial area of Attiki region, where –in combination with the district of Central Greece - almost 40% of the total amount of spent batteries corresponds (see **Figure 3**).

The suggested technology is presented schematically in **Figure 4**. It should be emphasized that lead recovery can be conducted by two different technologies: The **pyrometallurgical method** is based on the melting of the battery paste in a rotary furnace under 400-700°C and the **hydrometallurgical** on the leaching of the battery paste with fluoroboric or fluosilicic acid solution and the recovery of lead by electrowinning in a electrolytic cell. Comparing the two methods, the pyrometallurgical method seems more appropriate for the Greek industry, as it offers the following advantages:

- The pyrometalurgical is a well-tested commercial method.
- The large electric power demand, combining with the high price of electric energy in Greece, increase dramatically the operating expences.
- The pyrometallurgical process is a more simplified method compared with the hydrometallurgical

The quantities of the secondary products of the suggetsed technology using the pyrometallurgical method are shown in **table 4.**

TABLE 4: Quantities of secondary products per ton of battery [6]

Product	**Quantity (kg/tnbat)**
Metallic lead	550-600
Polypropylene	50
(Dry) Na_2SO_4	60
15%sol H_2SO_4	300
15%sol.NaOH	300

The results of the economic analysis of a future Pb battery recycling plant with a capacity of 17.000 tn/yr. are presented in **Table 5**

TABLE 5: Results of the financial analysis

Cost of Equipment	327.5 (10^3\$)
Total Investment Cost(I_F+I_W)	2425 (10^3\$)
Total Operating Cost (C)	4269 (10^3\$)
Total Income (S)	5095 (10^3\$)
Gross Earnings (R)	826 (10^3\$)
Venture value (V)	471.5 (10^3\$)
Venture Worth (W)	16005 (10^3\$)
Internal Rate of Return (τ)	0.28

6. CONCLUSIONS- SUGGESTIONS

- Despite the Greek legislation and the relative EC's instruction, the complete lack of state or private corporations undertaking the responsibility of organization and operation of a national batteries recycling network, is noticed.
- The quantity of used batteries have been estimated to be approximately 1.200.000bat/yr (17.000tn/yr). The fact that this capacity is similar with that of other process units in Europe (B.J. Industries- 18.000tn/yr), enforces the arguement of a single process unit in Greece, treating the total amount of spent batteries.
- The suggested technology is a widely used commercial process (Brittania Refined Metals Ltd., Bodigen, B.J.Industries) and has proved to combine a great variety of advantages

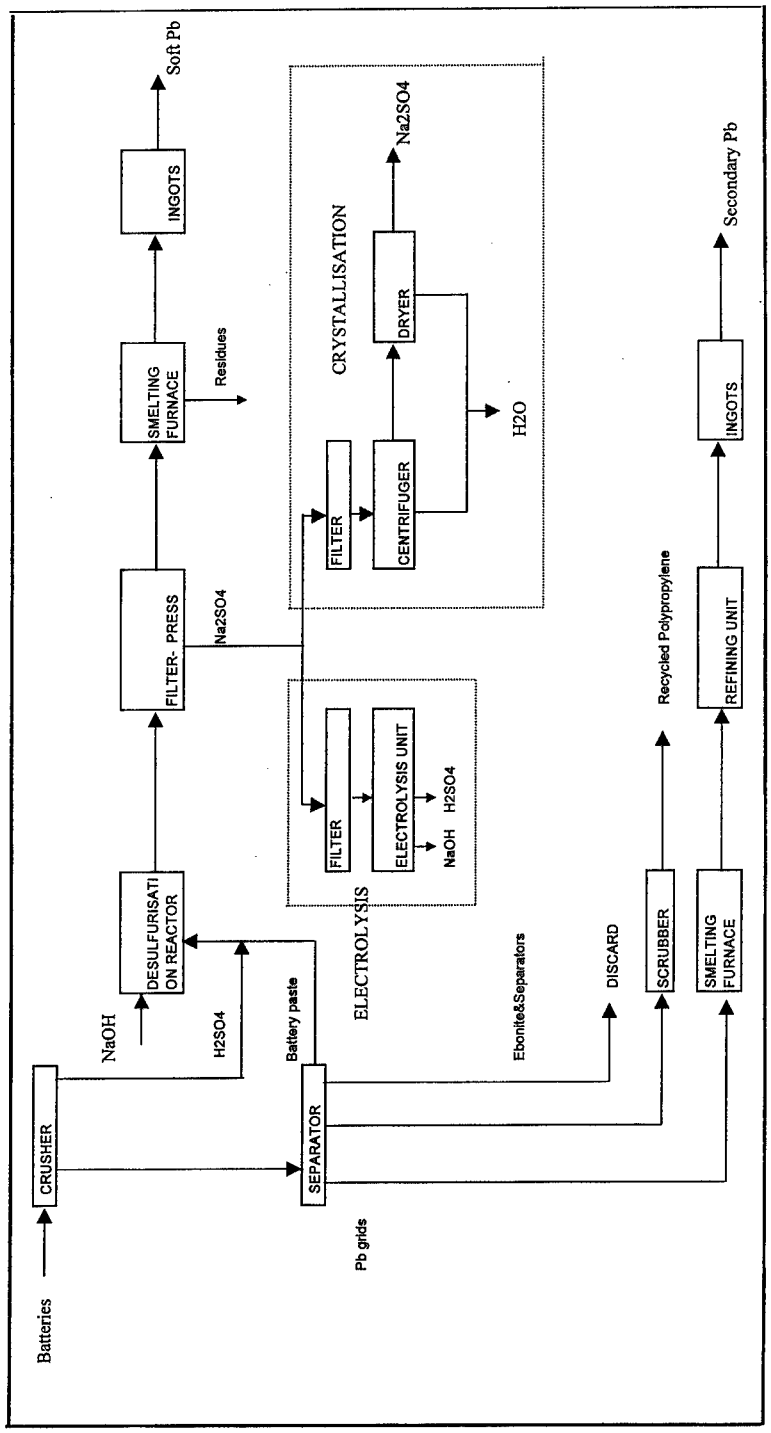


FIGURE 4: Typical generalised flow diagramme of Pb/acid batteries recycling process, depicting the two major process alternatives

- The already existing operation of small-scale battery-recycling plants should be discouraged, as they demonstrate a rather not acceptable recycling operation.

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THE RECOVERY PROGRAMME OF HERRA: AN ECONOMIC ANALYSIS

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ABSTRACT

The economics of recycling is an issue under research worldwide, although legislation seems to force to higher recycling rates. This paper attempts to contribute to this research by carrying out an economic analysis based on real life data of the multimaterial recovery programme organised by Hellenic Recovery and Recycling Association (HERRA) and five Municipalities in Athens. A comparative presentation of this programme and several European and American programmes based on a "cost vs. diversion rate" concept reveals the satisfactory results of the Greek effort.

ΤΟ ΠΡΟΓΡΑΜΜΑ ΑΝΑΚΤΗΣΗΣ ΤΗΣ ΕΕΑΑ: ΟΙΚΟΝΟΜΙΚΗ ΑΝΑΛΥΣΗ

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ΠΕΡΙΛΗΨΗ

Η νομοθεσία παγκοσμίως, και ιδιαίτερα στην Ε.Ε., προωθεί την ανακύκλωση, αν και το κεντρικό πρόβλημα της οικονομικής ανάλυσης και επομένως του κόστους της ανακύκλωσης δεν έχει πλήρως αποσαφηνιστεί. Η παρούσα εργασία επιχειρεί να αναλύσει τα οικονομικά μεγέθη του πολυσυλλεκτικού προγράμματος ανακύκλωσης που οργανώνεται στην Αθήνα από την Ελληνική Εταιρεία Ανάκτησης Ανακύκλωσης (ΕΕΑΑ) και πέντε Δήμους. Παρουσιάζεται η μέθοδος εκείνη που επιτρέπει τη συγκριτική αξιολόγηση προγραμμάτων που έχουν αναπτυχθεί σε διαφορετικές χώρες και εφαρμόζεται με τη βοήθεια στοιχείων από ευρωπαϊκά και αμερικανικά προγράμματα.

1. INTRODUCTION

The recovery and recycling of useful materials from Municipal Solid Waste (MSW) is generally considered an essential part of the Integrated Waste Management (IWM) system. Both the public and the opinion leaders force the legislation to make provisions for promoting recycling and setting up mechanisms to ensure the economic viability of recovery and recycling progammes.

Greece is currently preparing a law for the "alternative management of waste packaging and other products" which will harmonize the existing legislation framework with the EU directive 94/62 and in general with the European strategy on solid waste.

Under the context of either "producer" or "shared" responsibility, many European countries have introduced a new role for the packaging chain industry: to undertake a major part of the responsibility for the management of their products after the consumer gets done with it. In EU member countries, new organizations have been established by the involved industries such as DSD, ECO-EMBALLAGES, FOST-PLUS, ARA, VALPAK, etc. A similar organization will be formed by the Greek industry to help Greece fulfill the obligations in accordance with the EU directive.

It is therefore more than certain that new recovery programmes will be organized in the future primarily aiming at the packaging and paper waste. However, particularly in Greece, the economic as well as the environmental costs or benefits of recycling have been generally described rather than being calculated on the basis of real life data.

The present paper suggests a methodology for a proper reporting of the results of a recovery programme and uses the ongoing data from the recovery programme of Hellenic Recovery and Recycling Association (HERRA) as an example to carry out a comparative presentation of some European and North American recovery programmes.

2. THE RECOVERY PROGRAMME

The presented recovery programme has been carried out by HERRA and five municipalities in Athens (Maroussi, Vrilissia, Melissia, Pefki, Filothei), under the scientific supervision of the University of Aegean.

HERRA is a not for profit organization founded by Greek industries which produce and distribute consumer goods or/and packaging materials. The main aim of HERRA is to develop methods for alleviating the problems that go along with the environmental burden created by packaging waste.

The programme collects and recovers packaging waste (aluminium and steel cans, plastic bottles, glass bottles, paper and board) and paper waste (newsprint and magazines, office paper etc.) from the MSW of the five participating municipalities.

In the very first stage of the implementation of the project, the "communication team" of HERRA informs, door-to-door, the inhabitants about the recycling programme teaching them how to separate and prepare the recyclables. It distributes the reusable blue bag for recyclables in which the householders are asked to place the targeted materials of the project. Then, the householders empty the content of the bag in the blue bins which have been placed close-to-home. Finally, the commingled recyclables are collected and transferred to the Material Recovery Facility (MRF) by five single compartment collection vehicles.

At the MRF the recyclables are sorted along a transfer line by skilled workmen (hand sorting) with the aid of a tumbling screen and a magnet, into 12 different products: four paper qualities, five plastic materials, aluminium, steel and glass. Then these products are balled (except glass) and transferred to the secondary materials markets.

After three years of operation, the recycling programme has achieved significant results. Today, almost 150,000 inhabitants are served through a network of 2,500 close-to-home recycling bins. More than 300 tonnes of recyclables are recovered from the MRF each month, with a recovery and diversion rate of 30% and 8% respectively [1]. The recovered materials are diverted from the landfill contributing to savings on resources, clean air and water, energy and landfill space.

The "Recovery Rate" is the amount of the targeted materials recovered from the generators served over the total amount of the targeted materials present in the waste from the generators served. The recovery rate expresses the actual recovered amount of materials compared with the potentially ones. The "Diversion rate" is the amount of materials recovered from the generators served over the total amount of waste produced by the generators served. The diversion rate is a measure of the waste which is diverted from landfill due to the recovery programme.

3. ELEMENTS OF AN ECONOMIC ANALYSIS

3.1. Impediments in the Analysis

In general the economics of recycling and in particular the actual cost of recycling is still an unknown factor and it is so reported even in EU documents [2]. There are many and various reasons for this picture:

- The development of a large number of recovery programmes world-wide and in particular in Europe is a rather recent phenomenon (last two decades).
- Recycling has been introduced to an already existing waste management scheme in almost all the cases. It was therefore handled as an add-in component rather than a new productive function which should be effective on both economic and environmental grounds.
- The waste management issues are affected by numerous local factors, creating hence an excessive variety of applied techniques and methods. This is an important impediment for a common language between recovery programmes.
- Only during the present decade EU legislation trends have obliged industry to focus on the cost issues of recycling.

Moreover, there are some particular impediments for a detailed economic analysis of recycling in Greece that have to be reported:

- Recycling programmes in Greece are in the early stage and the sample is not large enough.
- Municipalities or their associations are by law (Ministerial Decree 69728/96) responsible for the waste management. Therefore the recycling programmes are run by municipalities and are faced as an environmental beneficial action which should be provided at almost any cost, or at least without any serious cost consideration.
- It is extremely difficult to collect actual data from the municipalities related to recycling activities or even waste management systems. Until now, the local taxes are mainly justified on the grounds of financing the local waste management scheme. The waste management issue appears to be in the heart of the fund-raising mechanism of the municipalities. It is then not surprising that some other activities or services provided by the municipalities are recorded under

the general title "Public Cleansing", even though they have little to do with waste management. Consequently, the accounting system applied by the municipalities is not very helpful.

3.2. Cost Accounting Systems

In the international bibliography a variety of cost accounting systems for recycling have been reported such as:

- on a "per tonne" basis: usually the costs are expressed per recovered or diverted tonne. In general, this approach is not suitable for comparative evaluations between different programmes, as it can be misleading in the absence of a more detailed analysis. For example a higher content in paper of the MSW in the area of project B may lead to a lower per tonne cost due to high apparent density of paper, even though project B is not effective as another project A developed in an area where the content of MSW in paper in not so high.
- on a "per material" basis: the costs are expressed on a targeted material basis such as the cost of plastic bottles recycling, or the cost of newsprint or on a "per activity" basis such as the cost of the recyclables collection. This approach should be based on a fully detailed recording system. However in particular for costs expressed per material some additional assumptions have to be made, for example to allocate the cost of the used equipment among the recovered materials.
- on "difference in cost", "system", "incremental" or "marginal cost" basis: the costs are expressed as the impact (= the net increase or decrease) on the costs of the existing local waste management scheme caused by the recycling programme. It is sometimes expressed in percent, as in ERRA/UCL (ERRA: European Recovery Recycling Association, UCL: Universite Catholique de Louvain) database reporting system. This is an overall approach which automatically includes the cost savings on other sides of the waste management scheme due to recycling, i.e. the saving in landfill expenses of the diverted materials. Furthermore the "difference in cost" approach permits the comparative analysis between projects in different countries. Certainly as an overall indicator, it cannot provide a detailed picture of the system. The "difference in cost" ratio of the HERRA programme is 16% [1].

4. ASSUMPTIONS AND LIMITATIONS OF THE PRESENT ANALYSIS

The economic analysis of the programme of HERRA presented here is not complete; it is only a step towards the overall analysis. Here, the following types of costs are considered:

- refuse (= non recyclable wastestream or "normal refuse") collection costs both operating and capital,
- recyclables (= the materials separated by the participants into the blue bins, or " the targeted materials") collection operating and capital costs,
- processing operating and capital costs of the recyclables in the MRF,
- costs for the final disposal of the refuse,
- general and administrative costs, included in the operating expenses of the relating activity,
- revenues from the sales of the recovered materials.

The following costs are not taken into consideration:

- Cost for land: The opportunity cost of the land is assumed to be zero; the land is presumed to be owned by the municipalities or the state.
- The costs for public communication campaign. These costs surely affect the effectiveness of the programme, and they are based mainly on the budget of the operator and not on the quantities of

the targeted materials. Moreover, the communication campaign costs vary highly among the programmes developed in European countries.

- The organizational costs of HERRA; therefore, a part of a somewhat "design" and "monitoring" cost.
- The costs for the buildings used by the waste management services of the municipalities. These services usually share the same building with many other activities of the municipalities. The rents are included, if paid.
- The costs for the bulky waste. In many cases these costs were subtracted from the raw data, because the recovery programme does not target to these materials. The cost allocation between the costs for refuse and bulky waste is based on the personnel working on each stream, time of the equipment used or quantities collected. These data have been collected by personal communication.

All operating costs concern the 1996 fiscal year (1/1/-31/12/1996). The capital expenditure is calculated by applying the annual capital charge method for all equipment or facility, based on the actual investment. The discount rate is 10% and the periods of the cash flow are the timelife periods (years) of each equipment: vehicles 15; bins 10; MRF building 25; MRF main machinery 15; other equipment 10; recycling bags, administration equipment and miscellaneous 5.

The costs covered by HERRA, that is the operating expenses for the MRF and the capital expenditure for the recyclables collection and processing equipment are fully recorded and accurately presented.

All costs related to refuse collection and disposal and the operating expenses of the recyclables collection are collected from the collaborating municipalities. Because of the aforementioned insufficiencies of the waste management accounting systems a "data processing" stage had to be applied on the raw data of the municipalities, a brief description of which follows. It is estimated that the results of the present analysis have an accuracy of $\pm 10\%$.

The landfill costs were considered to be the contribution of each municipality to the Association of Communes and Municipalities in Attica Region (ACMAR), responsible for the disposal area in Athens. These contributions are the 5% of the annual revenues of the municipality, including the compensating fees to the municipalities close to the landfill area.

5. RESULTS

It should be noticed that the served area for the refuse and for the recyclables is not the same, because the programme was expanded during 1996. The data collected from the records of HERRA and the five municipalities are presented in Table 1. Each expense or capital charge (or revenues) is allocated by a related activity: collection, processing, disposal (sales for the revenues). The same data are allocated by the type of the related wastestream: the recyclables and the refuse. All data are expressed in per tonne costs (or revenues) and in per inhabitant served by the collection of each wastestream.

The today recorded figures for 1997 (the processing operating costs and the total capital charge) have reduced about 16% to 25,500 and 26,000 Drs. per recovered tonne respectively.

TABLE 1: Costs of the local IWM scheme (Drs.).

Activity	*Recyclables stream* (Drs. per Tonne Recovered)	*Refuse stream* (Drs. per Tonne of Refuse)	*Recyclables stream* (Drs. per Inhabitant served)	*Refuse stream* (Drs. per Inhabitant served)
Collection-operating	24,506	14,319	621	4,507
Collection-capital charge	20,390	2,361	517	743
Processing- operating	30,216	NA[1]	766	NA
Processing- capital charge	10,869	NA	275	NA
Disposal	-[2]	4,360	-	1,482
Sales Revenues	16,513	NA	418	NA
TOTAL COST	85,982	21,388	2,179	6,732
TOTAL NET COST (DEFICIT)	69,469	21,388	1,760	6,732

Regarding the capital charge, it is noticed that there is a great difference of the collection capital charge between recyclables and refuse (Table 1). The first reason for this is that the collection vehicles in use are sometimes more than 15 years old and some of them were bought second-hand. To find out what the impact to the refuse collection capital charge would be, if all the used vehicles were replaced in 1990 a new calculation of the capital charge was done: then, the increase of the collection capital charge is almost 30%. A second reason for the observed difference is that the collection infrastructure a recovery programme requires is usually more sophisticated than the one used for the refuse collection. For example there are not any refuse bins in the half of the area served by the recovery programme. Certainly, further research is required on the issue.

The costs for the recyclables in Table 1 are expressed in Drs. per recovered tonne, however when collection operating costs between recyclables and refuse are compared, a cost per collected tonne should be used instead, which is 25% lower (about 18,500 Drs. per collected tonne). Taking in account the distances the collection vehicles cover and the transferred tonnage for both recyclables and refuse, there is not any significant difference between the two streams regarding the costs per kilometer-tonne of the two streams.

It is interesting that the average cost over the total managed quantities of the MSW summing up the two streams, recyclables and refuse, is 23,397 per managed tonne, which is fairly close to those concerning the existing waste management system in Athens [3].

6. CONCLUSIONS AND DISCUSSION

Recycling should be considered under the context of the local Integrated Waste Management scheme, otherwise the benefits recycling offers are not fully incorporated. That is the main advantage of the "incremental" or "difference in cost" approach. This is more than obvious in figure 1, where the savings from refuse collection and disposal shown in Table 1 are taken into account for the

[1] Not Applicable

[2] The residue of the MRF is transferred to the landfill on behalf of the Municipality of Amaroussion, therefore no extra charge is paid. The related transfer cost is included in the MRF operating costs.

estimation of the total net "extra" cost of recycling, which for the HERRA programme is about 19,000 Drs. per recovered tonne.

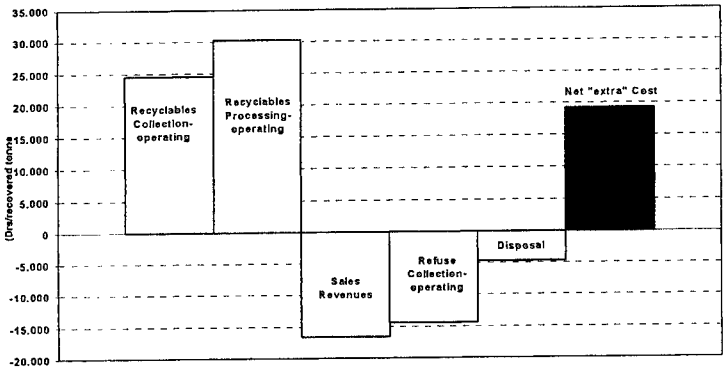


Figure 1: The operating costs, revenues and savings of the local IWM scheme.

Unfortunately, in the case of Athens these savings are potential. The aforementioned existing accounting system for the landfill fees is irrational, since they are not based directly on the disposed quantities of the waste . Moreover, the collaborating municipalities have not actually benefited from the decrease of the waste that has to be collected and transferred to the disposal area, i.e. by re-organizing the refuse collection routes. It is more likely that the benefit is gained by those crews.

The figures presented here could be used to estimate an upperbound for the cost of a recycling scenario in Greece. Since the majority of the Greeks (~60%) live in cities where the presented costs per inhabitant (Table 1) could be valid, we can conclude that an annual budget of roughly 10 billion Drs. is required to establish and operate similar recovery programmes in all the major Greek cities achieving a recovery rate of 30%.

Knowing the apparent density of each "item" (=one newsprint or magazine or one whole packaging, bottle, box, can etc.) and the content per material of the recovered materials in the MRF, the "extra" cost of recycling shown in Fig. 1 can be approximately estimated in the order of 2 Drs. per "item". Certainly, this estimation can only be used as a slight indication, because a much deeper analysis is required to allocate the recycling costs by materials.

A comparison is made among the European (ERRA/UCL) and American (EPA and SWANA) recovery programmes here presented [4,5,6]. When a per tonne cost is used then the programme in Athens seems to be among the costly programmes (Fig. 3). However, when the more appropriate method of the difference in cost is applied the HERRA programme shows similar results to most of the programmes (Fig. 2). The ERRA/UCL network has rejected the use of the per tonne approach for comparative evaluations and this is why a European programme is not included in Fig. 3.

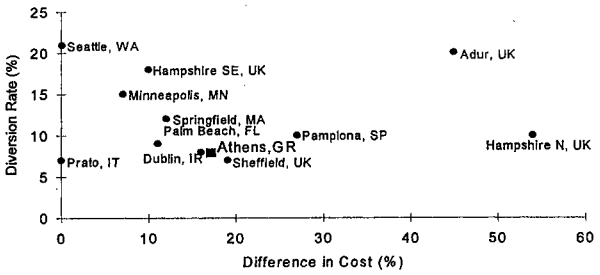


Figure 2: Diversion Rate vs. Difference in Cost.

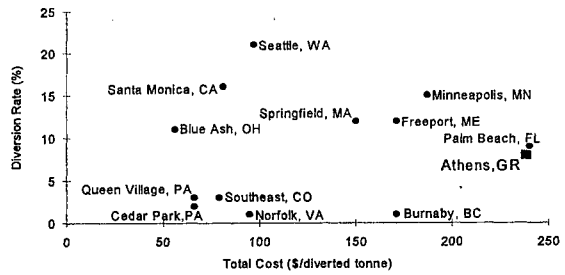


Figure 3: Diversion Rate vs. Average Cost per tonne[3].

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[3] US tons converted to Metric tonnes, 1$=290 Drs.

RECOVERED SCREENED MATERIALS FROM CONSTRUCTION AND DEMOLITION DEBRIS

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ABSTRACT

Before the recycling of construction and demolition (C&D) debris the waste is passed over a screen. Recovered screened materials (RSM) may comprise 30% of the C&D waste. Previous analyses of RSM indicated high arsenic (As). RSM samples were collected and analyzed from seven C&D debris recycling facilities. The average As content found in RSM ranged mainly between residential and industrial soil clean-up goals. Chromium and lead levels were very low. RSM quality depends mainly on the incoming waste stream. Recycling procedures do not have any major effect on the RSM. Arsenic in natural soils showed a wide variability with half of the samples having an As level comparable to that of RSM.

ΑΝΑΚΥΚΛΩΜΕΝΑ ΛΕΠΤΟΚΟΚΚΑ ΑΠΟΒΛΗΤΑ ΟΙΚΟΔΟΜΙΚΑ ΥΛΙΚΑ

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ΠΕΡΙΛΗΨΗ

Πριν απο την ανακύκλωση τους τα οικοδομικά απόβλητα κοσκινίζονται. Τα λεπτόκοκκα υλικά αποτελούν περίπου το 30% των οικοδομικών αποβλήτων. Αναλύσεις οικοδομικών αποβλήτων έδειξαν υψηλή περιεκτικότητα σε αρσενικό (As). Δείγματα απο λεπτόκοκκα υλικά συλλέχθηκαν και εξετάστηκαν απο επτά εγκαταστάσεις ανακύκλωσης οικοδομικών αποβλήτων. Το As που βρέθηκε στα δείγματα ήταν κυρίως μεταξύ των επιτρεπομένων ορίων για οικιστικές και βιομηχανικές εφαρμογές. Η περιεκτικότητα σε χρώμιο και μόλυβδο ήταν πολύ χαμηλή. Οι ανακυκλωτικές διεργασίες δεν επιδρούν στην ποιότητα των λεπτοκόκκων. Επειδή τα φυσικά εδάφη έχουν την ίδια περιεκτικότητα σε As με τα λεπτόκοκκα υλικά, περιορισμένη εφαρμογή αυτών των υλικών είναι εφικτή.

1. INTRODUCTION

Disposal of solid waste in municipal landfills is the least desirable solution to the waste management problem. Urban growth, concerns of human health, ecological issues, and the NIMBY (Not In My Back Yard) syndrome make selection, implementation and operation of a landfill site a very difficult task [3]. A viable alternative to landfill disposal is waste reduction at the source along with recycling of the solid waste.

Depending on the type and volume of the waste stream, recycling operations and facilities may vary considerably. In urban areas besides municipal and yard waste, a major amount of solid waste is generated by the construction and demolition (C&D) industry. In case of a catastrophic event such as earthquake, hurricane, flooding or fire, the resulting C&D debris from a destructed densely populated area can reach emergency proportions. A recent example of C&D debris overloading was during Hurricane Andrew that hit southeast Florida on August 1992.

Construction and demolition debris is comprised of a wide variety of materials of different composition and size such as fill dirt, mulch, glass, metals, treated wood, cardboard, plastic, tar paper, concrete, gypsum wallboard, ceramic tiles, etc. Utilizing the physical properties of the different waste material, separation can be accomplished automatically by using appropriate processes (e.g. floating for wood separation, magnet separation of metals, etc). More commonly however, waste separation of C&D debris involves a combination of automation and intensive human labor. During pre-processing of the C&D debris the waste stream to be recycled is forced through a shaking screen or a rotating perforated tumbler so that the fine material, which is hard to collect manually, is removed [8]. The fine material passing through the openings is known as Recovered Screened Material (RSM). This fine material may constitute up to 30% by volume of the incoming waste stream.

A special interest on the disposal of C&D material was initiated in the State of Florida after the destruction caused by Hurricane Andrew. The demolition debris was stored temporarily at a location in Homestead, Florida owned by a construction company. The amount of debris stored was estimated to exceed 440,000 tons. The company planned to utilize the RSM for residential fill dirt or topsoil for agricultural purposes rather than dispose it at landfills. As a result, the Florida Department of Environmental Protection (FDEP) requested sampling of the debris in order to determine whether or not an unrestricted application of RSM would pose any potential health risks.

The initial (unprocessed) composition of the solid waste which originated from Hurricane Andrew was an identifiable mixture of mulch, rock, concrete, metals, glass, ceramics, textiles, plastics, household items and agricultural debris mixed with soil. The material was sieved using a 2-inch screen. In some cases, ferrous-metals were removed using a magnet. The RSM was placed on the ground in several piles in adjacent sections of the land. During testing, different sampling groups were collected and sent for analysis to various environmental analytical laboratories. The analyses revealed the presence of arsenic (As), chromium (Cr) and lead (Pb) as well as other trace metals and organic compounds in the RSM samples. Special emphasis was given on the presence of As since its levels exceeded the FDEP soil cleanup goals. Therefore, the only allowable usage of the RSM was disposal in a permitted landfill including a daily initial cover application.

However data obtained from the Hurricane Andrew debris was not considered as being representative of the solid waste generated by everyday C&D operations. Indeed household and other waste items would have been removed under normal operating conditions. In addition, this data was site specific since it was taken solely from the vicinity of the Homestead area.

The focus of the present study was to establish a comprehensive database of RSM quality and to compare RSM characteristics to those of natural soils. For that purpose RSM samples were collected from seven C&D debris recycling facilities during a time period of five months. In addition, top soil samples were collected from other miscellaneous sites including parks, children playgrounds, school yards, residential and commercial construction fill, and agricultural lands. All samples were taken from the tri-county metropolitan area of Palm Beach, Broward and Dade counties in southeast Florida. The samples were analyzed for arsenic, chromium and lead. Also, the percentage of organic content was determined and the physical composition of the samples was characterized visually.

2. C&D RECYCLING OPERATIONS

The seven C&D recycling facilities that participated in the study were:

- Atlas Waste Magic, Inc., Davie, Broward County, Florida
- Atlas Waste Magic, Inc., Loxahatchee Road, Palm Beach County, Florida
- Browning-Ferris Industries, Inc., Tall Pines, West Palm Beach, Palm Beach County, Florida
- Dade Recycling Center, Inc., Miami, Dade County, Florida
- Florida Resource Management-W.M., Inc., Riviera Beach, Palm Beach County, Florida
- Waste Management, Inc. of Florida, Pompano Beach, Broward County, Florida
- Waste Management, Inc. of Florida, Medley, Dade County, Florida

There are a lot of similarities regarding the operational procedures in all of these seven recycling facilities. Generally, the raw solid waste is dumped into piles where loaders and/or bobcats are removing the bulky material while feeding the rest to a conveyor belt. The belt moves the material through a perforated rotating tumbler or over a shaking screen. In some facilities, before screening the size of the waste material is reduced by using an impactor or a shredder. The screen size varied from ¾-inch (1.9 cm) to 4-inches (10.2 cm). Some facilities used more than one screen size generating two piles of different RSM size. After screening the solid waste was manually separated into different materials such as cardboard, wood, concrete, ferrous-metals, aluminum, paper and plastic. Then the refuse was collected at the end of the processing/recycling line and was removed for disposal into landfills. The RSM was placed on concrete-lined areas to avoid leaching of chemicals into groundwater. A typical recycling operation (Florida Resource Management-W.M., Inc.) is schematically presented in Figure 1.

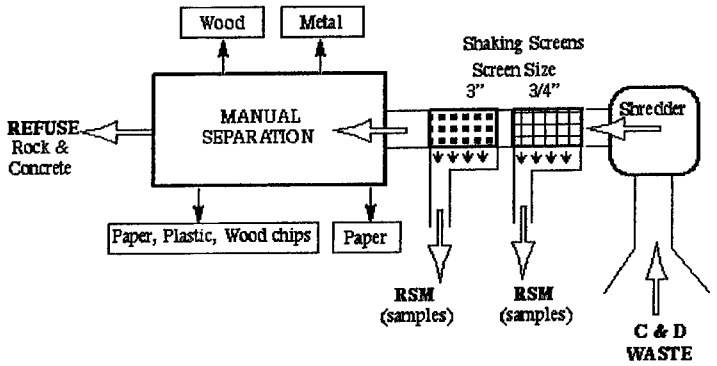


Figure 1. C&D recycling operation- Florida Resource Management, W.P. Inc., Riviera Beach.

3. SAMPLE COLLECTION AND ANALYSES

3.1 Sample Collection

The RSM and soil samples were collected according to the "FDEP Standard Operating Procedures for Laboratory Operations and Sample Collection Activities" (DEP-QA-001/92). For that purpose, an approved Comprehensive Quality Assurance Plan was properly obtained from FDEP. Sample collection involved the following procedures and equipment [5].

After a particular sampling site was selected, samples were collected using a stainless steel (SS) trowel. For fresh (occurring) material, RSM was taken from a maximum depth of 1-ft (30 cm) from the surface of the pile and then placed on a 16-inch (40.6 cm) diameter SS tray where it was thoroughly mixed with a SS spoon. The trowel, tray, and spoon used were all pre-cleaned at the laboratory, wrapped in aluminum foil and placed in zip-lock plastic bags. The sample mixing involved separation in four portions, individual mixing of each portion and then re-mixing of the whole sample. RSM samples taken from old stockpiles were obtained from depths ranging from ½ to 6 feet (15.24 cm to 1.83 m). The mixed sample was placed in wide-mouth, screw-capped 4-oz. (0.118 liter) labeled pre-cleaned containers. The containers were put immediately in zip-lock plastic bags and placed in an icebox. At the end of the sampling effort, the containers were transported to the laboratory and there they were frozen for a period of one to ten days until their chemical analysis. The sampling equipment was cleaned at the laboratory using a stainless steel brush, de-ionized (DI) water and Liquinox. During cleaning and/or sampling latex gloves were always used. In case, that the gloves were powdered, the powder was rinsed off with DI water.

During sampling, field notes were kept regarding any particular features of the site and special characteristics of the RSM including average particle size, color, texture and predominant type of material (i.e., wood, wallboard, concrete, etc).

3.2 Chemical Analyses

Chemical analysis of the samples was performed according to methods approved by the U.S. Environmental Protection Agency (EPA). The analysis for the three metals As, Cr and Pb was accomplished utilizing either a Varian Model 800 Zeeman Graphite Furnish Atomic Absorption Spectrophotometer (AA) or a Thermo Jarrell Ash Simultaneous Inductively Coupled Plasma Emission Spectrophotometer (ICAP). More specifically, arsenic was analyzed using AA and EPA methods 7060A or 206.2; chromium was analyzed using ICAP and EPA methods 6010A or 200.7; and lead was analyzed using either the IPAC (method 6010A) or AA (method 239.2). Spike and duplicate analyses were conducted for each sample batch. The Relative Percent Difference (RPD) and Spike Recoveries ranged from 0 to 13% and from 92 to 113% respectively.

In addition, samples were analyzed for moisture and volatile material content. For that purpose the samples were heated first for 1 hour at 104°C and then heated again for 30 minutes at 550°C. By weighting the samples before and after heating the moisture and volatile content were defined as percentages by weight. Since, moisture content in samples depended heavily on weather conditions before and during sampling this parameter was not of any practical significance.

3.3 Physical Analyses

Besides chemical analysis, the physical characteristics of the samples were examined. The physical analysis included sieving, macroscopic and microscopic examination of the material. Sieving was conducted using three U.S. Standard stainless steel sieves, i.e., No. 10 (2-mm), No. 18 (1-mm) and No. 35 (½-mm). After sieving, the composition of the four resulting particle groups was identified either by naked eye or by using a Wild M420 microscope at a 30-X magnification.

4. ARSENIC, CHROMIUM AND LEAD IN RSM FROM C&D DEBRIS

4.1 Soil Cleanup Goals

The current FDEP guidelines (soil cleanup goals) suggest 0.8 mg/kg (ppm) of arsenic in RSM for residential and 3.7 mg/kg for industrial applications. If any of the RSM samples contains more than 10 mg/kg of As then the entire pile must be properly disposed in a permitted landfill. The EPA guidelines for arsenic for residential applications are lower than the FDEP limit, suggesting an ingestion level of 0.4 mg/kg [9]. The cleanup goals for chromium are based on its particular valent form. For chromium (+6) the residential limit is 290 mg/kg and the industrial 430 mg/kg; for chromium (+3) the residential and industrial limits are 6,600 mg/kg and 540,000 mg/kg respectively. For lead, the proposed cleanup goals are 500 mg/kg for residential and 1,000 mg/kg for industrial applications. The risk analysis for the residential guidelines was based using a child's and an "aggregate" resident's (considered both as child and as adult) health risk while for the industrial the on-site adult worker occupational exposure risk formula was applied [1]. These guidelines apply to a soil depth of 2-ft (60.96-cm). It is also suggested that any comprehensive evaluation of RSM quality should take into consideration the site-specific soil background levels and the applied Method Detection Limits (MDLs) [2].

4.2 Preliminary RSM Quality Data

The arsenic, chromium and lead levels compiled from the existing RSM quality data from Hurricane Andrews and regular C&D recycling operations are listed in Table 1 [6].

TABLE 1. As, Cr and Pb in RSM collected from Hurricane Andrews C&D debris.

Trace Metal	No. of Samples	Range [mg/kg]	Mean [mg/kg]	Remarks
Hurricane Andrews Data:				
Arsenic	111	1.7- 52.0	9.97	No outliers
	113	1.7-200.0	11.76	With outliers
Chromium	93	4.6-153.0	24.04	
Lead	91	4.6-153.0	46.23	No outliers
	93	4.6-390.0	50.62	With outliers
Recycling Operations Data:				
Arsenic	27	1.2- 5.7*	3.56+	
Chromium	27	0.4-15.0*	9.63+	
Lead	27	9.0-30.0*	23.00+	
* Five data points were Below Detection Limit (DL = 5 mg/kg).				
+ Mean was estimated by using the maximum value of 5 mg/kg for the BDL data				

From this limited information it was evident that the Hurricane Andrews data may have been contaminated by other sources unrelated to construction and demolition materials.

4.3 Arsenic in RSM

Throughout the present study a total number of 214 samples were collected (192 RSM and 22 natural soils). All of the samples were tested for arsenic while only 37 were tested for chromium and 35 for lead. The levels of arsenic found in all RSM samples collected and analyzed during this study are presented in Figure 2. From this pie-chart it is evident that only a small amount (12.80%) of the

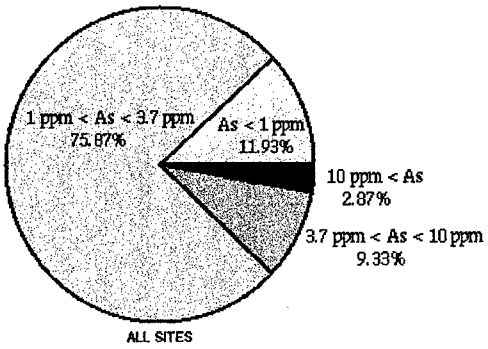


Figure 2. Arsenic levels in RSM from C&D recycling facilities.

RSM samples had As exceeding the industrial limit of 3.7 mg/kg while the majority (75.87%) of the values were between 1.00 and 3.7 mg/kg. The detection limit for arsenic was 1.0 mg/kg. In only three of the recycling facilities, occasionally did the arsenic level exceeded the10 mg/kg limit. Three data points were considered as outliers with values of 18.0, 39.0 and 50.7 mg/kg. The total average for arsenic was 2.50 mg/kg without the outliers or 3.02 including the outliers [5]. This average was consistent with previous RSM data from recycling operations but much lower than the average found in the Hurricane Andrews data (Table 1). The main source of arsenic in RSM is arsenic-based wood preservatives such as the chromated copper arsenate (CCA).

4.4 Chromium and Lead in RSM

The levels of Cr and Pb in the RSM samples were consistently lower than the suggested soil cleanup limits thus testing for these metals was discontinued. Chromium concentrations ranged from Below Detection Limit (DL=1.0 mg/kg) to 35.8 mg/kg with a mean of 10.71 mg/kg. Lead ranged from BDL (DL=0.5 mg/kg) to 202.0 mg/kg with a mean of 35.05 mg/kg [5]. Again, these values are comparable with other recycling data but much less than the Hurricane Andrews data (Table 1).

5. ARSENIC, CHROMIUM AND LEAD IN NATURAL SOILS

In order to access the significance of the arsenic levels found in RSM the data must be compared to the arsenic content of background soils. Arsenic is a very widespread and ubiquitous element. Arsenic occurs naturally in the Earth's crust at an average concentration of 2 to 5 mg/kg [4]. A number of soil samples taken from uncontaminated coastal sites throughout the State of Florida are summarized in Figure 3 [7]. Comparing figures 2 and 3, it is evident that overall, background soil arsenic values are comparable to those from RSM. However, this comparison may be deceiving since the natural soil samples were taken throughout State of Florida and spatial variability is expected. For this reason, soil samples were collected and analyzed from the same geographic area of the recycling operations [5]. Out of 22 samples, 5 had an As content that was higher than 1 mg/kg but lower than 3.7 mg/kg. The sites were these five samples were taken included residential dirt fill, a park, a natural preserve, an industrial street curb and a produce farm. In all other 17 samples As was below detection limit (DL = 1.0 mg/kg).

6. DISCUSSION

Based on existed background soil data taken within the State of Florida, arsenic, chromium and lead are approximately correlated according to the relationships [5,7]:

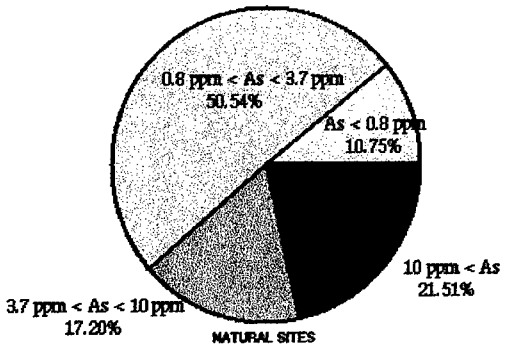


Figure 3. Arsenic concentrations found in natural soils in Florida.

- log [Cr in ppm] = 0.470 + 0.87 log [As in ppm]
- log [Pb in ppm] = -0.015 + 1.16 log [As in ppm]

Plotting the above relation (straight line) and the RSM data on a log-log paper it is evident that RSM samples are enriched in lead as compared to natural soils (Figure 4). The same result although less pronounced applies for chromium.

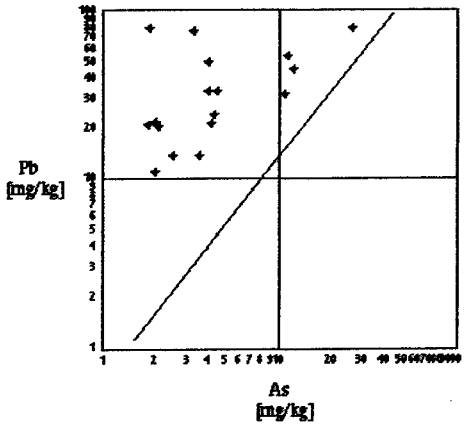


Figure 4. Correlation between arsenic and lead found in RSM.

In order to investigate the presence of arsenic in four different particle-size subgroups samples were sieved and the resulting particle groups were tested separately for arsenic. Although there was some variability in arsenic among the different groups no particular trend was evident and As content was at about the same level regardless of the particle size. Although, the percentage of wood reduced substantially in the small particle RSM groups (less than 0.5 mm) arsenic content remained almost unaffected [5]. This observation leads to the conclusion that some other source of arsenic must contribute besides CCA treated wood. Soil/dirt mixed with RSM is the most possible alternative source of arsenic.

Volatile material decreased with decreasing size particle groups. This is in accordance to the visual observation of reduced wood content in small particle groups. Comparison of arsenic versus volatile content showed no particular correlation. This result reinforces the belief that RSM may be cross-contaminated from external sources during their collection and recycling processes.

Any possible effects on arsenic levels relating to the age of the RSM were also examined. Samples were collected from RSM stockpiles (more than a year old) located at three recycling facilities. Data from two of the facilities did not show any difference between the fresh and old RSM. In the third facility As content was higher in the stockpiles than in the fresh RSM. However, this discrepancy was attributed to "poor quality" of the original RSM placed in the stockpiles rather than to any release of arsenic by chemical reactions or biological degradation of the waste.

7. CONCLUSIONS

Based on the findings of this study the following conclusions are derived:

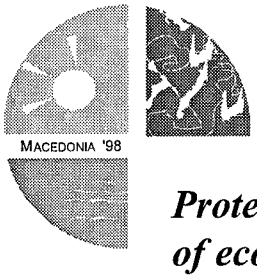
- Arsenic may be the only problematic metal contained in RSM
- Chromium and lead levels although safe are higher in RSM than natural soils
- CCA treated wood is not the sole source of arsenic in RSM
- The age of RSM does not effect its quality
- Arsenic levels in RSM are comparable to those in natural soils of Florida

8. ACKNOWLEDGEMENTS

Financial support for this project was provided by the Florida Center for Solid and Hazardous Waste Management, at University of Florida and Florida Center for Environmental Studies, at Florida Atlantic University. Also, the cooperation and assistance of the personnel of recycling facilities and FDEP is greatly appreciated.

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Protection and restoration of ecosystems

STRATEGY FOR WOODLAND CREATION IN THE SHERWOOD FOREST: THE USE OF GIS TO PRODUCE A LANDSCAPE PLAN

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ABSTRACT

Intensive arable agriculture and extensive commercial conifer afforestation have led to the loss and fragmentation of semi-natural broad-leaved woodland in the Sherwood Forest Area. This in turn has resulted in the reduction of local landscape distinctiveness. In this paper, the concepts of landscape ecology are applied to develop a strategy for the location of new woodlands. This approach integrates nature conservation values, existing land uses and restoration of local landscape character. Particular emphasis is placed on the habitat requirements of locally important or threatened species. A Geographic Information System is used to combine spatially referenced data and to enable the production of a coherent landscape plan for the area.

ΜΕΘΟΔΟΣ ΔΗΜΙΟΥΡΓΙΑΣ ΔΑΣΥΛΛΙΩΝ ΣΤΟ ΔΑΣΟΣ ΤΟΥ SHERWOOD : Η ΧΡΗΣΗ ΤΩΝ GIS ΓΙΑ ΤΗΝ ΠΑΡΑΓΩΓΗ ΕΝΟΣ ΣΧΕΔΙΟΥ ΤΟΠΙΟΥ

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ΠΕΡΙΛΗΨΗ

Εντατικοποίηση της γεωργίας και εκτεταμένη αναδάσωση με κωνοφόρα για εμπορική εκμετάλλευση οδήγησαν σε απώλεια και κατακερματισμό του φυσικού δάσους πλατύφυλλων του Sherwood σε μικρότερα δασύλλια. Αυτό είχε ως αποτέλεσμα την υποβάθμιση της ιδιαιτερότητας του χαρακτήρα του τοπίου. Στην εργασία αυτή, οι έννοιες της οικολογίας τοπίου εφαρμόζονται για την ανάπτυξη μεθόδου για ανεύρεση των κατάλληλων τοποθεσιών για δημιουργία νέων δασυλλίων. Η μέθοδος αυτή συνδυάζει αρχές προστασίας του φυσικού οικοσυστήματος, υπάρχουσες χρήσεις γης και αποκατάσταση του χαρακτήρα του τοπίου. Ιδιαίτερη έμφαση δίνεται στις απαιτήσεις του βιότοπου σημαντικών ή απειλούμενων ειδών της περιοχής. Γεωγραφικά Συστήματα Πληροφοριών χρησιμοποιούνται για να συνδυάσουν χωρικά δεδομένα και για να παράγουν ένα ολοκληρωμένο σχέδιο τοπίου για την περιοχή.

1. INTRODUCTION

Over the last fifty years agricultural intensification has resulted in widespread habitat fragmentation in the UK. Habitat fragmentation implies loss of habitat, reduced patch size and an increasing distance between patches. These in turn may lead to a decrease in the population size or even disappearance of some species [1-3], as well as loss of landscape character and local distinctiveness.

Landscape ecology is concerned with issues of landscape structure and function, and can play a key role in solving problems related to the disruption of landscape function, and in the spatial allocation of land-uses. In this paper we describe the application of some of the principles of landscape ecology to the production of a land-use plan for the Sherwood Forest area in Nottinghamshire, England. The Sherwood region was formerly characterised by extensive oak-birch woodland and heathland, much of which has been lost to arable agriculture. The aim of the work presented here was to devise a strategy for increasing the amount of woodland cover in the region and to predict which locations would be most effective for new planting. This was based upon the requirement to improve woodland habitat quality and to increase patch size and connectivity within the existing landscape framework. A GIS-based approach was employed to integrate new woodlands with other land-uses of nature conservation value (notably heathlands), economic and recreational value, and to enhance landscape character. The significance of GIS in landscape ecology lies in its ability to store, manipulate and analyse spatially distributed data and to generate new spatial data in graphic form [4]. GIS has facilitated our study in decision making for the allocation of the woodlands.

2. METHODS

The GIS system, Idrisi for windows - a raster based system, was used as a tool for the method.

2.1 Policy Framework

The strategy was devised in association with Nottinghamshire County Council and the UK Forestry Commission. The Sherwood region has been subdivided into 6 smaller landscape units by the County Council, each with a definable landscape character. The Forestry Commission has established targets for new woodland planting in each unit, based upon the amount of existing woodland and the landscape character of the unit. Although the strategy is concerned with the Sherwood region as a whole, only the results for the Forest Sandlands unit will be presented here. The Forest Sandlands includes the remnants of ancient woodlands and is the most wooded type in relation to the other landscape types of Sherwood, yet has moderate needs for new woodland planting [5]. While much new planting in the past has been of coniferous woodland, all new planting will be of broad-leaved trees. A further constraint was that the new woodland network had to be in agreement with the Heathland Restoration Strategy for Sherwood [6].

2.2 The 'key species' approach

While enhancement of landscape character and woodland cover were general aims, it was decided that the specific size, location and shape of new woodlands and corridors would be based upon objective criteria. To achieve this, a *key species* approach was adopted [7], whereby precise parameters were established for habitat quality, patch size and isolation to ensure colonisation and persistence of the species. Selection of an attractive and high-profile key species could also provide a focus for the implementation of the plan. The chosen species was the Redstart, *Phoenicurus phoenicurus*, a migrant hole-nesting passerine, because it is locally and regionally threatened [8-10]. Redstart is an interior species of mature deciduous woodland, and in particular oak wood is its preferred habitat [10,11].

Redstart is sensitive to fragmentation and during its breeding season will cover its feeding needs in the immediate surrounding area [2,12]. Opdam *et al.* [3] found in The Netherlands that the probability of occurrence of Redstart in a woodlot was significantly affected by the amount of nearby woodland within a 3 km radius, and that the larger the woodland area, the higher the probability that the species is present. The species has a minimal critical area needed to satisfy its breeding and feeding requirements: the smallest wood where the Redstart was recorded was 2.5 ha, with maximum presence being recorded in woods of 100 ha and over [13].

Due to fragmentation, the size of the remnants in Sherwood is much smaller, therefore a patch of size of 50 ha was accepted as the area that could sustain a population of Redstart. However, when a habitat is very rich in its structural and floristic characteristics, habitat physiognomy and patch isolation can compensate for the small size of the patch, providing it is above a critical minimum acceptable area [2]. Therefore, for woodlands with high habitat quality the size of 5ha was taken as the minimum area for covering the bird's foraging needs and to sustain 3-4 pairs for conservation purposes.

2.3 Developing the plan

Because the study area already contained moderate (but fragmented) amounts of woodland, the strategy for new planting was based upon increasing the area of the existing remnants, and reducing the isolation of small or distant woods by creating corridors. This was achieved in two ways:

1. identifying potential woods for enlargement, with high probabilities of being successfully colonised and low probabilities of extinction
2. identifying those woods with small probabilities of colonisation, so that construction of corridors would increase their probability of being colonised.

2.4 Predicting potential locations for new woodland planting

A series of steps was undertaken to identify where new woodland planting would occur:

1. Prediction of woods that could function as "source" areas for dispersing individuals. A logical assumption was to consider as sources all the ancient remnants of oak-birch wood, a preferred habitat of Redstart. The size of these woods was generally 5ha. From the rest of the deciduous woodland, all woods with an area of 50ha and over were selected. The only exception to this was for woods designated as County Wildlife Sites because of their floristic diversity with a size of ≥5ha, which were also taken into account as potential sources. In addition to habitat size, the population of Redstart may also be influenced by the isolation of a wood i.e. the amount of nearby woodland. Isolation was measured as the amount of deciduous woodland in a 3km radius. For small woods less than 50ha, the probability of occurrence and persistence of Redstart was taken as being proportional to the amount of nearby woodland [14]. To ensure a high probability of presence and persistence of Redstart, only wildlife sites with area of ≥200ha of surrounded deciduous woodland were regarded as sources.

2. Identification of potential woods for enlargement. The probability of a wood being successfully colonised depends on two main factors in addition to the dispersal capacity of the key species: the distance of the particular wood from the source wood, and the resistance of the interjacent landscape between the source wood and the considered wood to wood-dwelling birds, indicating the relative resistance of various landscape elements to movement across the landscape of forest-interior species. The amount of woody vegetation in the landscape is an important factor in defining resistance [14,15]. To determine the effect of the resistance of the intervening landscape the Idrisi module 'COST' was used. COST calculates a distance/proximity surface where distance is measured as the least cost distance in moving over a friction surface [16]. From the module a map was created showing the potential colonisation value of each wood in terms of its distance from the sources and

the characteristics of the intervening land-uses to the dispersal of Redstart. In the module each land use was assigned a resistance value according to its suitability as a habitat for Redstart. Thus, deciduous woodland was given the least resistance value (1) as being the most preferred habitat of Redstart with mixed and coniferous woodland given values of (2) and (3), whereas arable land, urban and open water land uses were given higher values: (10) and (20) respectively. Woods with a small cost surface (meaning there is a small cost of moving over the landscape/friction surface from the sources towards to these woods either due to the short distance or the favourable nature of the intervening landscape or a combination of these factors) were determined as woods with high colonisation value.

3. Identification of the minimum critical area to which the selected woods must be enlarged to enable newly colonising populations of Redstart to persist. Although, for the purposes of this study, the minimum critical area for a wood to enable persistence of the population was determined as 5ha, in most cases the actual increase was to approximately 10ha to ensure a higher probability of persistence [17]. For woods with relatively less surrounding woodland there was an increase of the size even up to 17 ha [2]. Generally, we tried to keep the patch size at an average area of 10 ha so it could also be in agreement with the designated needs for planting of the Forest Sandlands unit. Arable land, as the main agricultural land-use and cause of fragmentation, was targeted for new woodland planting. In accordance with the Heathland Strategy, no new planting was designated on sites with high and medium potential for heathland habitat creation. Idrisi modules applied for the enlargement were DISTANCE, RECLASS and AREA.

4. Enlargement of the woods and allocation of the corridors. A second factor that influences the persistence of the species population is the amount of area of nearby deciduous woodland. Unlike the sources where the probability of occurrence and persistence needs to be the highest possible, for the new woodland locations the determination of the threshold level was more flexible and woods with a surrounding area of ≥160 ha of deciduous woodland were considered to have high persistence value. Thus, for those woods with high colonisation and persistence value enlargement was decided to take place. For woods with high cost surface value but holding a good persistence value, corridors connecting them to source woodlands were created to reduce their isolation and increase their colonisation potential. Idrisi modules used for the construction of the corridors were COST and PATHWAY. PATHWAY was used to identify the least cost path across the landscape for the dispersal of Redstart between the source and the target wood, given a cost surface produced by COST [16]. Therefore, in the friction surface of COST the land use of deciduous woodland, being the favourite habitat of Redstart, was assigned the lowest value so that the corridors would cross the deciduous woodland patches and connect them. Arable land was assigned a very high value and heathland with pasture the highest ones, so that with the application of PATHWAY the corridors wouldn't cross these habitats and thereby cause their fragmentation.

3. RESULTS

The plan entails the development of about 900 ha of new woodland area (an increase of 80% over the existing amount) derived mostly from planting around the urban edges and adjacent to the existing remnants. The latter was a preferred solution to increasing the number of patches, since it could offset the fragmentation result of reduced patch size and provide a chance for present populations of Redstart to increase and become a source of dispersers [19]. Further woodland area was also achieved by the creation of the corridors, which apart from reducing the isolation of the woods can also provide additional habitat .

As a result of the assignment we gave to the land uses in the friction surface for the operation of PATHWAY, the corridors incorporated most of the existing deciduous woodland, avoiding as much

as possible crossing inhospitable arable land. In some cases, the path goes through mixed and conifer woodland which would be replaced by deciduous woodland planting to provide an optimal environment for Redstart. In cases, where the path crosses arable land because of lack of significant amount of intervening woodland, emphasis should be given to the structural characteristics and width of the corridor so that it can constitute a good breeding and feeding habitat as well as a dispersal route [20]. An expanded network of roads and rail dissects the landscape contributing to a further fragmentation, therefore there are some gaps in the corridors. However, due to the small length of the gaps it is not considered to be a problem for the dispersal.

Figure 1 illustrates the potential colonisation value of each location in the landscape in relation to the sources. On the map, the relative accessibility of the target woods is expressed in 2 ordinal classes for simplification reasons, but in the simulation more classes were created. Locations relatively near to the sources have high accessibility, whereas moving away from the sources and with the occurrence of non-favourable land for habitat the accessibility becomes smaller and their colonisation value decreases respectively.

Figure 2 shows the woods with high colonisation and high persistence value(as defined in the 2.4 section), comprising potential cores for enlargement. It also displays the woods which have small colonisation value and high persistence value. Corridors could improve the accessibility and increase the colonisation potential of these woods.

Figure 3 illustrates the implementation of enlargements and corridors. Enlargement did not take place for woods which, although having high colonisation and persistence value, are not surrounded by arable land. After the enlargement, the size of the new woods ranged from 6 ha to 17 ha according to the amount of the surrounding woodland. A large patch size not only increases the probability of occurrence of a single species in the patch but also the total species number. In addition, only woods with a minimum size of 1ha were connected. Sizes smaller than this were not considered to provide sufficient interior habitat.

4. DISCUSSION

The aim of this study was achieved in giving guidelines for determining the best locations for new woodland planting and producing a moderate increase of woodland area according to the requirements of the Forest Sandlands. This was done by not exceeding an average patch size of 10ha and enlarging only a certain number of patches characterised by high colonisation and persistence value.

The new woods are located only on arable land and adjacent to existing sites. In this way, not only a valuable habitat is provided but this would also help to diversify the woodland resource. A number of Forestry Commission financial incentives e.g. The Sherwood Initiative, Farm Woodland Scheme could enable the implementation of woodland creation on arable land.

A significant step in this process is the identification of a key species, whose requirements are adopted as objectives for the development of the woodland framework. The use of the key species approach has enabled the production of a landscape ecological plan with specified ecological goals. [7]. From a landscape ecology point of view this framework can be regarded as a network for the dispersal and persistence of the Redstart, accommodating its basic needs for patch size and connectivity. Providing that these basic needs have been met, the requirements of each landscape unit for woodland area are also taken into account and further woodland increase can be produced if it is needed. The plan without aesthetic objectives, achieves to enhance both the ecological and visual

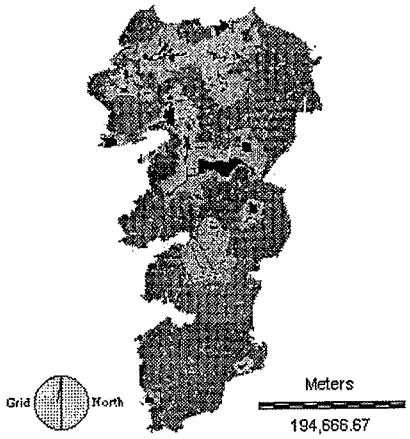


Fig. 1. Colonisation value of the landscape. Black indicates the source areas. Light shading indicates the high colonisation value areas and dark shading the small colonisation value areas.

diversity of the landscape; massing and grouping of structures in a landscape composition may provide greater cohesion and a more sound visual impact. The plan has also satisfied the landscape character requirement for large scale woodland planting around the urban edges with the creation of new woodland structure to contain the urban fringe. Once the plan is implemented, the ecological parameters that are used in the process can be adjusted. It is also important that sufficient information is available on the habitat requirements and population dynamics of the species and that its requirements should match wider requirements, in terms of woodland size and type. Further research could be carried out in recording field data and thereby testing the validity of the model by comparing the results with the actual distribution pattern of Redstart.

5. CONCLUSION

The method presented in this paper has the potential to be a valuable tool for landscape planning. It develops a systematic and reproducible process for a decision support system in order to provide a solution for the problem of landscape fragmentation. GIS facilitates the production of a coherent plan where conservation values, land uses and landscape character are integrated. However, the contribution of GIS to a small scale design is little. Although, it has produced the enlargements it is difficult to say how these can be integrated into the landscape, mostly from a visual point of view. Further design work must be implemented to accentuate and develop in detail the visual and aesthetic part of the plan. Another point to consider is that the production of COST SURFACE modules has been generated as a result of the assignment we gave to the land uses, based on our judgement regarding the needs of the species. This subjective element could be partly compensated by the presicion of the information about the behaviour of the species.

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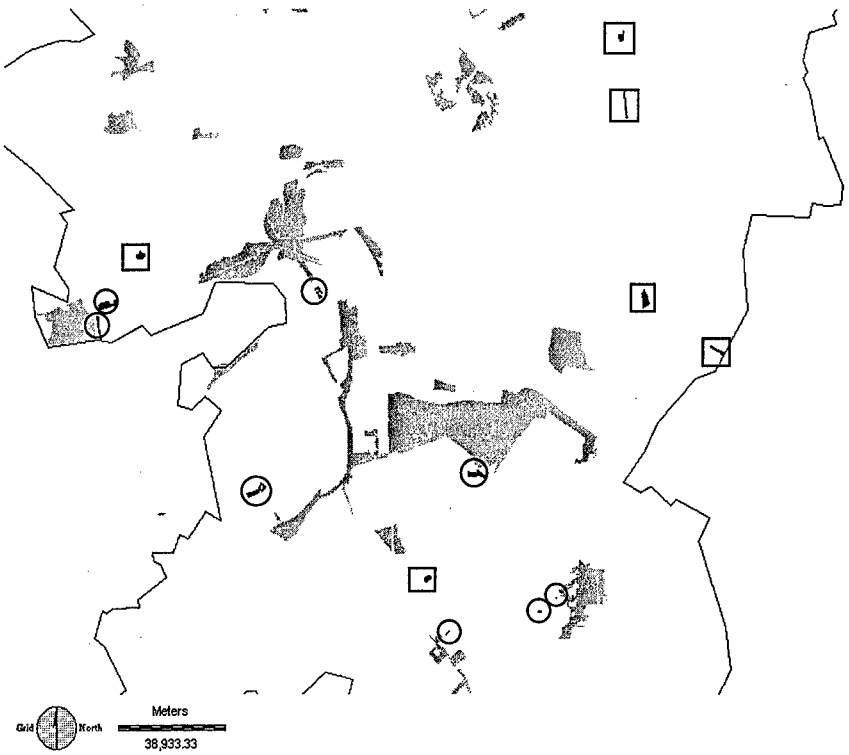


Fig. 2. Potential locations for new woods. Circled woods are those with potential for enlargement and those enclosed in squares have potential for corridor creation. Grey = sources.

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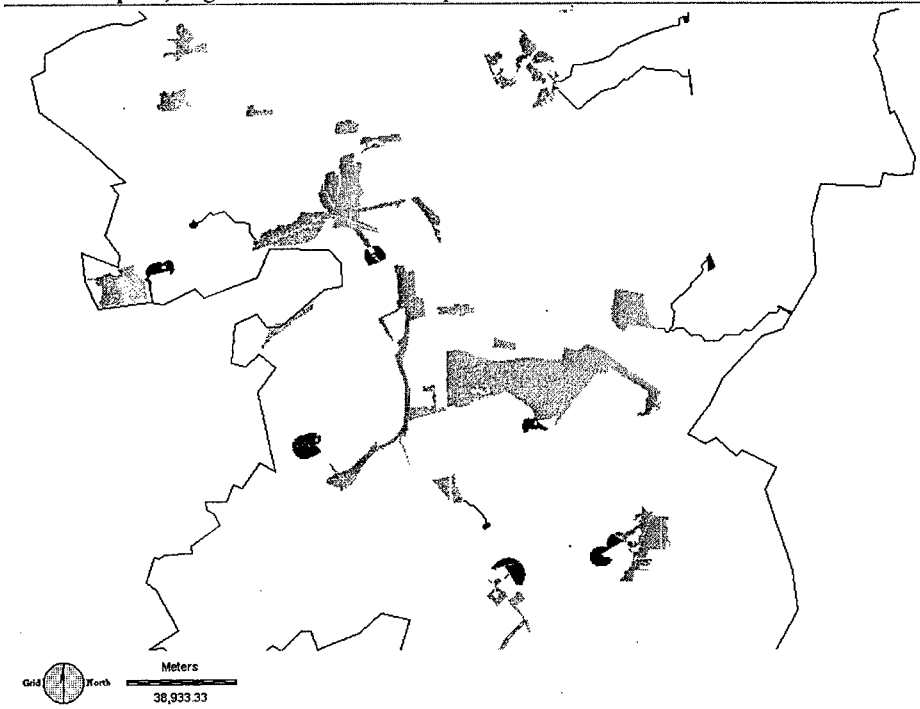


Fig. 3. New woodland planting. Grey indicates the sources and black indicates the enlargements of existing woods and woods with corridors connecting them to the sources.

FOREST PROTECTION USING GEOGRAPHICAL INFORMATION SYSTEMS

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ABSTRACT

In this paper the use of G.I.S. for the development of a model for the delineation and mapping of areas with high fire risk is presented. The objective is to use this type of cartography to help the assumption of the prevention and fire fighting actions. The final product is a fire risk map which will allow each Greek Forest Department to prepare the protection acts for a possible forest fire. In this way the protection of the environment will be based on scientific conclusions and only on practical efforts.

ΠΡΟΣΤΑΣΙΑ ΤΩΝ ΔΑΣΩΝ ΜΕ ΤΗ ΒΟΗΘΕΙΑ ΤΩΝ ΓΕΩΓΡΑΦΙΚΩΝ ΣΥΣΤΗΜΑΤΩΝ ΠΛΗΡΟΦΟΡΙΩΝ

Δρ. Ιωάννης Μελιάδης [1] και Αλέξανδρος Κωνσταντινίδης[2]
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ΠΕΡΙΛΗΨΗ

Στην εργασία αυτήν παρουσιάζεται η χρήση των Γ.Σ.Π. για την ανάπτυξη ενός μοντέλου για την οριοθέτηση και χαρτογράφηση περιοχών που έχουν υψηλό κίνδυνο φωτιάς. Ο σκοπός είναι να χρησιμοποιηθεί αυτός ο τύπος της χαρτογραφίας για να βοηθηθεί η έγκαιρη πρόληψης μιας πιθανής δασικής πυρκαγιάς. Το τελικό προϊόν είναι ένας χάρτης επικινδυνότητας , ο οποίος θα βοηθήσει κάθε δασαρχείο να προετοιμαστεί για μια πιθανή φωτιά στην περιοχή ευθύνης του. Με αυτόν τον τρόπο, η προστασία του περιβάλλοντος θα βασίζεται σε επιστημονικά δεδομένα και όχι σε πρακτικές προσπάθειες.

1. INTRODUCTION

Forests and forest lands are common inheritance for all people and consist of a piece of national wealth that must be handled over to the next generation, in the best possible conditions.

Fire is not a newcomer to Mediterranean areas. It is so old and frequent, that it has become one more of the ecosystems surrounding this basin. Fire is so closely associated with this area and its human population that, throughout history, it has been present as either an agricultural aid or a more destructive weapon i.e. shepherds and agricultural workers use fire to clear the land, just as their forefathers had done 5.000 years ago. Nevertheless, one of the most important factors of deteriorating wildland ecosystems in Greece and other Mediterranean countries is fire. Forest fires constitute also public danger because they affect strongly the natural living and social environment. Every year an area of 5,000 sq. Km is destroyed by fire [4]. Le Houerou (1981) estimated that each plot of forest will burn once every 25 years.

The problem of forest fires seems to concern the difficult ecological conditions, the arrangement and smoothing of the relationship between forest and "man", the consequences of forest fires, administrative organisation of Greek forest service, the way of voting, applying and enacting legislative patterns, the research and use of technological means and the application of a more effective forest policy. Under these circumstances forest and forest land fires result from a great number of macro-demographic and economic factors in combination with political and cultural changes.

Based on the fact that foresters are scientists dealing with environmental and ecological problems every day [1] and the shortage of accurate, well defined and designed maps with (ecological) data this paper presents the development of a model that can be used by the Greek Forest Department in order to map areas with high fire risk rates and where the probability of the occurrence of a forest fire is high. These areas can be found with the combination of the use of G.I.S. and the knowledge that derives from the Forest Science. Having in mind that this paper introduces some of the best possible solutions for the foresters in order to define the corrective measures, which will act on the existing environment and prepare the implement defensive actions which will minimized the occurrence of fire ignition.

The parameters that have been used are:

1. Forest species (1 level)
2. Slope
3. Distance to roads
4. Distance to rivers and existing reservoirs
5. Aspect
6. Human impact on the environment
7. Recreation areas - Monasteries.

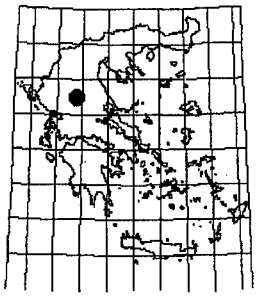
Physiographic factors

Man-made factors

A coefficient of importance is then given to each of these variables in order to allow its computation in the model, according to existing fire statistical data. The final product is a thematic map, which should be of great importance for each Forest Department in Greece, when the preliminary development of defensive plans take place every year. Specifying the areas with high fire risk it is possible to find the suitable areas for the construction of fire control towers. The design of the above is based, in this way, on scientific results and measurements and not on the empirical efforts of the local staff.

2. THE STUDY AREA

The area which has been selected for the purpose of this study was the Mountain Meteora - Antixasia found in the middle part of Greece (Map 1). The area is almost 56.000 Ha and belongs to the Mediterranean zone. The range of the altitude is between 250 to 1.400 m. The area is characterised by the presence of well developed ecotypes, which appear as a mosaic of high trees, maquis and brushlands. The percentage of the main forest species in the area are presented in Figure 1. [7]. The main rocks are limestone and flysh. The main rivers are Pinios, Lithaios and Mourgas which produce different ecotypes for the fauna of the area.



Map 1. Orientation of the study area

The area has a poor economic development, the people deal with agriculture, animal husbandry and forestry.
This zone has been characterised as an Important Bird Area (IBA) according to the EC Instruction 79/409/EC, while the Monasteries in Meteora as Historical Places. The whole area belongs to the C area (meaning that the fire risk is moderate), according to the map of fire risks of Greece. Forest fires and burnt areas (in stremmata) that occurred in the area, according to the Forest Departments of Kalabaka and Trikala are showed in Figure 2.

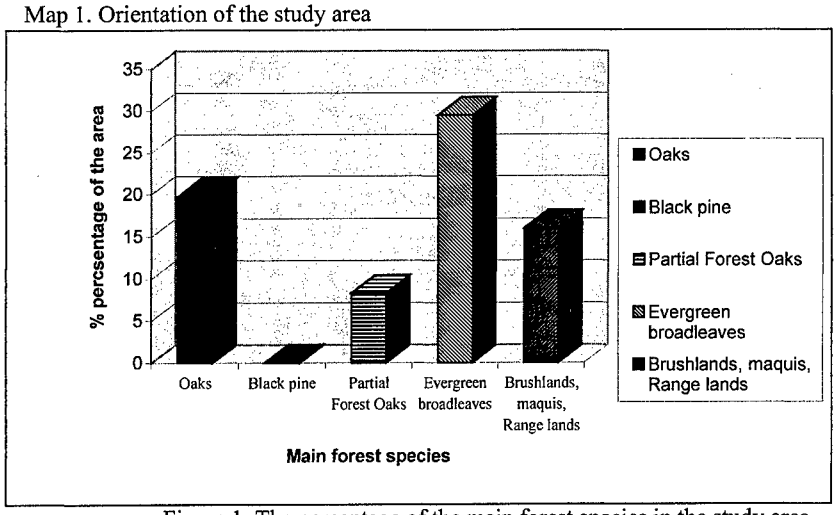


Figure 1. The percentage of the main forest species in the study area

3. THE DATA

Each Forest Department in Greece has the following data (in many cases in analogue form) which are management oriented data and are not updated thematically:

1. Vegetation map (a mixture of 1 and 2 level)
2. Land use map
3. Road network
4. Rivers network
5. Elevation (20 m)

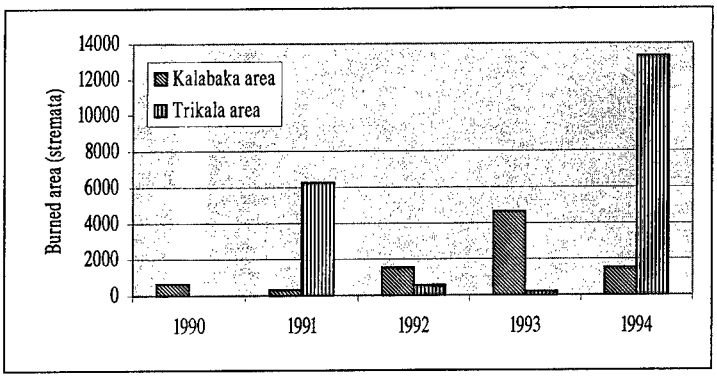


Figure 2. The burnt areas in the study area.

A serious problem is the lack of data about forestlands in Greece, which prevents, most of the time, the effective fire prevention policy. For the study area the following sources of data have been used:

1. Aerial photographs at a scale 1:20.000
2. Management map of Trikala and Kalabaka Forest Departments at a scale 1:20.000
3. Topographic map of the Hellenic Military Geographical Service at a scale 1:20.000.
4. Land Resource Map (surficial geology/aspects/slopes) of the area at a scale 1:50.000.
5. The register book of fires of the mentioned Forest Departments.

4. ANALYSIS - METHODOLOGY

The interpretation of the aerial photographs of the study area enables to the construction of the (analogue) vegetation map, which was next digitised. The other data, such as topographic, hydrographic and the road network, recreation areas were also digitised. The data for the human impact were taken from the land resource map and concentrated on the data base of the geological map.

Then each factor was classified according to its meaning of its influence to the start of a forest fire. This classification was based on the existing statistical data of forest fires in the study area (thematic parameter, frequency and number of fires), on relevant studies on similar subjects [2, 6,8] and in the empirical suggestions of the local forest staff. This statistical and empirical classification was based on the following acceptances:

1) The forest species were classified to the fire risk coefficients. The classification scale 0-3 is referring to an increasing flammability value, not measuring directly any physical characteristic (Beeches, Oaks, Black pine- Brush lands, maquis, range lands - Evergreen broadleaves). It is consequently a very subjective approach.

2) Distance to roads: roads represent areas of higher risk due to the influence of human activities. The number of fires with a localized start across the major roads is very high. Four different categories have been used with decreasing rates of influence (0-50, 50-100, 100-300, > 300m)

3) Distance to rivers: is important because of their influence in humidity and of course in the vegetation formations and types. Three categories have been used with decreasing rates of influence to forest fires (0-50, 50-500, > 500 m)

4) The slope factor is important because the fire risk increases with the slope. In the steepest slopes the flame of a forest fire is closer to the forest cover, and fire can reach to dangerous dimensions.

Three categories have been used with increasing rates of influence to the forest fire (Gently, Medium and Steep)
5) The aspect factor is important in the fire risk hazard, because slopes facing South are the warmest, while the ones facing North have a lower fire risk. In this model 4 categories were used (North, South, Flat and Various).
6) The human impact refers to the influence of man to the natural vegetation. When all the vegetation is removed than the agricultural lands appear, meaning that all the forest vegetation has been removed. Six categories were used for the model.
7) Places with high concentration of people due to some seasonal events or for some specific reasons (recreation) increases, as it is expected, the possibility of a forest fire. Four categories with decreasing rates were used (0-50, 50-100,100-500, >500 m).

5. RESULTS

All the mentioned parameters were processed with the ARC/INFO and ARCVIEW software, in order to create thematic maps with different risks to forest fires. Each thematic map was rasterised. For each parameter a coefficient was used, which was the result of a statistical analysis Table 3 presents the G.I.S. analysis approach followed in the paper:
Finally, a model was produced, which is the following:

$$F.R. = 0.008V_1 + 0.148V_2 + 0.107V_3 + 0.168H_1 + 0.098H_2 + 0.068H_3 + 0.058H_4 + 0.051H_5 + 0.04H_6 + 0.14\ DR_1 + 0.052DR_2 + 0.036DR_3 + 0.001DR_4 + 0.004\ DP_1 + 0.014DP_2 + 0.029DP_3 + 0.0039S_1 + 0.031S_2 + 0.1\ S_3 + 0.08S_4 + 0.0038A_1 + 0.006A_2 + 0.024A_3 + 0.019\ A_4 + 0.04\ M_1 + 0.017M_2 + 0.002M_3 + 0.0015\ M_4$$

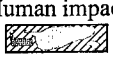
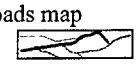
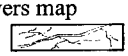
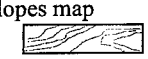
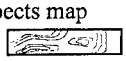
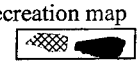
Where: F.R.= Fire risk
V = forest species variable
H = human impact variable
DR = distance to roads variable
DP = distance to rivers variable
S = slopes variable
A = aspect variable
M = recreation place variable
(1,2,3,.., subclasses of each variable)

This model was applied to the thematic maps and the result was the fire risk map for the study area. This map was reclassified in the next three fire risk area classes: high, moderate and low (Map 2)
The Digital Elevation Model (DEM) of the area was next combined with the produced thematic map in order to find the best places for the construction of forest control towers. The evaluation of the towers was based on the assumptions that the Forest Service presuppose (height, visibility) for these constructions.

6. DISCUSSION

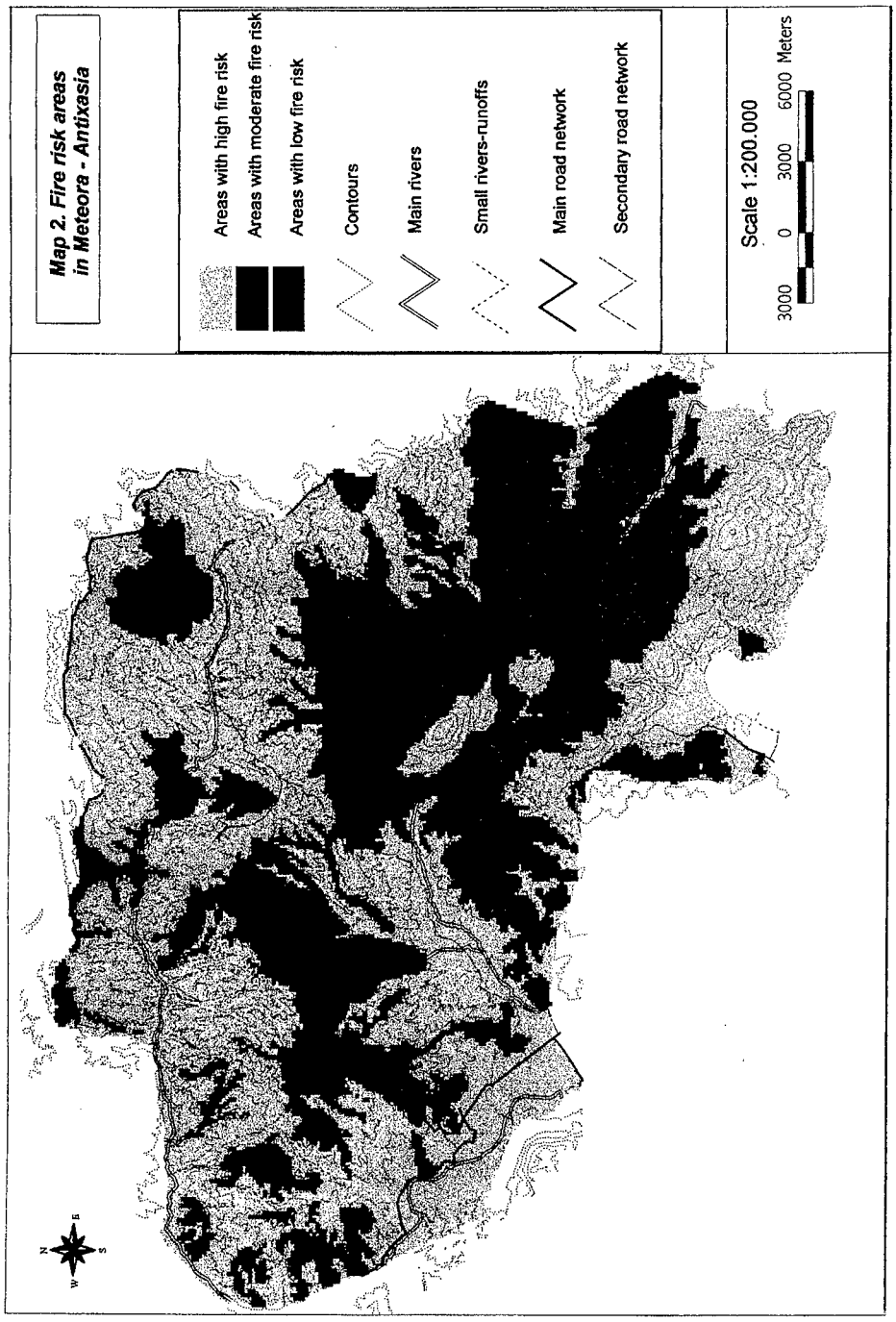
During the last decade it became obvious that wildland fire planning is basically a land management operation which has an ample need for the spatial distribution and map presentation of the pyric elements that influence forest fires [9]. With the use of G.I.S. theoretical fire management models or fragmented fire information for a given area, can be organised and spatially expressed, thus providing different fire planning or estimates.

Table 3. G.I.S. approach and coefficients used for the parameters of the model

	Parameters	Coefficients
Vegetation map	Beech, Black pine, oak	0.008
	Maquis, Rangelands, Agricultural lands	0.148
	Broadleaves	0.018
Human impact	Weak	0.168
	Medium	0.098
	Intense	0.068
	Bare	0.058
	Brushlands	0.051
	Agricultural lands	0.040
Roads map	0 - 50	0.100
	50 -100	0.052
	100 - 300	0.036
	> 300	0.001
Rivers map	0 - 50	0.004
	50 - 500	0.014
	> 500	0.029
Slopes map	Gently	0.004
	Moderate	0.027
	Steep	0.080
	Very steep	0.100
Aspects map	North	0.003
	South	0.006
	Flat	0.024
	Various	0.019
Recreation map	0 - 50	0.040
	50 - 100	0.017
	100 - 500	0.002
	> 500	0.001

Fire hazard mapping can help:
- to determine a better management of exposed areas knowing their natural and anthropogenic characteristics
- to realize several development, to build better road network and to avoid an uncontrolled urbanization in high risk areas
- to map and determine of zones exposed to risk will allow to elaborate a coherent and efficient fire fighting policy. Then to establish an actual strategy.

In this study the physiographic and man-made factors show a different impact in the fire risk hazard. High scores were found in places with low vegetation, near roads, in very steep slopes and flat areas, away from rivers and in places where human intervention is not intensive. Eventhought these factors were based on a short time data (8 years), they present in a good way the actual situation of the study area. Many of these coefficients must be recalculated with more accurate data, that for the time being don't exist. The philosophy of this model is to activate the Greek Forest Service to concentrate, manipulate and use the inventory data through the use of G.I.S.


Map 2. Fire risk areas in Meteora - Antixasia
Areas with high fire risk
Areas with moderate fire risk
Areas with low fire risk
Contours
Main rivers
Small rivers-runoffs
Main road network
Secondary road network
Scale 1:200.000
3000 0 3000 6000 Meters
N
S
W
E

For the model used in this paper:
- The model that described in this paper uses all the G.I.S. advantages: the thematic maps are precise, detailed, low cost and can be updated and provide spatially distributed data for wild land fire management and planning.
- New spatial data must be added in this model, such as the ownership situation, the price of the land, etc, but for the time being only for very few areas these data exist.

7. CONCLUSION

This paper showed a fire risk hazard in a specific forest environment. It can be said that the methodology used, based on G.I.S., is an excellent tool for the assessment of forest areas with high probabilities to be burnt. Many problems arose during the estimation of this model, because of the absence of accurate, well defined data.
The technology of G.I.S. is used with rapid rates for the solution of problems related with the management of natural ecosystems all over the world. The intensive use of natural ecosystems will demand management interventions of high level and objective. Forest fires are a serious problem for the Mediterranean basin. The use of G.I.S. can help in a better approach of this problem through the capabilities that it offers. The assumptions that are needed for the use of this technology, such as updated and well defined data, standarization must be followed especially by Greek users. As general conclusions for the use of new technologies in fire risk mapping the fact that can be emphasized is different models for fire risk can be produced but for maximum efficiency the spatial data bases should be designed to serve a range of resource inventory, planning, protection and management functions.

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THE USE OF GIS IN RECORDING AND MANAGING THE BIOMASS AND ITS ENERGY POTENTIAL IN THE REGION OF CENTRAL MACEDONIA

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ABSTRACT

The use of Geographic Information Systems (GIS) is widespread and provides help in managing and planning. The biomass and its energy potential are mainly unexploited in the Region of Central Macedonia. This paper examines the rural biomass according to its energy potential with the use of GIS in the Region of C. Macedonia. Specific data from the National Statistical Service of Greece (NSSG) for the biomass has been collected, processed, and analyzed for every department of C. Macedonia. Finally, with the aid of the Geographic Information Systems, conclusions are extracted and provided for decision making, for the management and utilization of the biomass.

ΧΡΗΣΗ ΓΣΠ ΣΤΗΝ ΚΑΤΑΓΡΑΦΗ ΚΑΙ ΔΙΑΧΕΙΡΙΣΗ ΤΗΣ ΒΙΟΜΑΖΑΣ ΚΑΙ ΤΟΥ ΕΝΕΡΓΕΙΑΚΟΥ ΤΗΣ ΔΥΝΑΜΙΚΟΥ ΣΤΗΝ ΠΕΡΙΦΕΡΕΙΑ ΤΗΣ ΚΕΝΤΡΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ

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ΠΕΡΙΛΗΨΗ

Η χρήση των Γεωγραφικών Συστημάτων Πληροφοριών (GIS) είναι ευρέως διαδεδομένη και βοηθά στη διαχείριση και το σχεδιασμό. Η βιομάζα και το ενεργειακό της περιεχόμενο δεν έχουν αξιοποιηθεί στην περιφέρεια της Κεντρικής Μακεδονίας. Στην παρούσα εργασία εξετάζεται η βιομάζα (ζωική και φυτική) από άποψη ενεργειακού δυναμικού με τη χρήση ΓΣΠ στην Περιφέρεια Κ. Μακεδονίας. Συγκεκριμένα στοιχεία από την Εθνική Στατιστική Υπηρεσία της Ελλάδας (ΕΣΥΕ) για τη βιομάζα, συλλέγονται, επεξεργάζονται και αναλύονται για κάθε Νομό της Κ. Μακεδονίας. Τελικά μέσω ενός Γεωγραφικού Συστήματος Πληροφοριών διατυπώνονται συμπεράσματα για τη διαχείριση και την αξιοποίησή της.

1. INTRODUCTION

The evolution of technology and the consequence of increase in volume and different type of data that are available for the Geo-sciences made necessary the use of Geographic Information System (GIS). The GIS software has the necessary flexibility in managing all relative data, the capability of immediate connection and correlation of geographic and descriptive data in real-time. This gives a complex information with better visual presentation and not only the renewal of an existing cartographic system. In the case of biomass in Central Macedonia the automated cartography with the use of MapInfo was chosen in order to display the available data and manage the potential energy value of biomass that remains largely unexploited.

The term biomass indicates:
a) The material, the by-products and the remains of plant (agriculture & forest), animal and fish production, b) The by-products which comes from the industrial process of the aforementioned materials, c) The municipal and solid wastes, d) The natural matter which comes from natural ecosystems (forest) or from energy agricultural and forest plantation.

Moreover the plant origin biomass can be further analysed:
Large one-year plants biomass (wheat, cotton, corn, tobacco, other one-year plants) - Tree trimmings biomass (fruit-bearing trees and vineyard trimmings) - Forest by-products - Energy agricultural and forest plantation by-products - Agricultural industrial by-products (core or cell of nuts).

The biomass is the solar energy accumulator. The solar energy is transformed to chemical energy through the plant photosynthesis and it is estimated that a percentage of 0,5% of solar energy reaching the surface of earth is accumulated [1].

The different types of biomass (plant or animal origin) have useful energy value, if their economic value for immediate use or after process is lower or less needful than their energy exploitation gives. The animal origin biomass can be characterised of economic value when concentrated in large quantities. This requirement implies the existence of large livestock breeding units with the capability of processing the wastes that comes from a large number of animals (200 cows, 1000 calves, 200 pigs, 10000 chickens).

2. BIOTECHNOLOGY FOR BIOMASS CONVERSION

Anaerobic digestion: is a biological process used for stabilising waste organic matter and salvaging energy and nutrients from it. With the aid of anaerobic digestion the agricultural by-products and residues can be stabilised and energy produced by methanisation can be used to cover energy needs. The design of an anaerobic digester and the engineering associated with it depends upon the type and volume of waste it is required to process. Consequently digesters vary widely with regard to complexity and layout [7].

Ethanol from wood: The potential for ethanol production from wood is much greater than that from corn. Wood harvesting operations can produce large quantities of wood residues that can be used for ethanol production. Excess growth in unmanaged forests can produce large quantities of small diameter, low-grade wood. In many areas, excess dead, down and diseased timber accumulates to present a fire hazard. These materials could likewise be converted into ethanol and other fuels [3].

Energy crops: Using liquid fuels from renewable biomass can actually decrease the accumulation of greenhouse gases while providing clean, efficient energy for transportation. In the future woody and herbaceous bioenergy crops could provide clean-burning fuels for a renewable fuel economy. Examples of such crops include fast growing poplar, willow, and various perennial grasses.

Environmental benefits: One of the principal benefits of ethanol from biomass fuels is that it provides a storable transportation fuel while reducing the effects of greenhouse warming. During growth, plants remove carbon dioxide from the air and convert it into starch, cellulose and hemicellulose. Fermentation converts these carbohydrates into ethanol, which is in turn converted back into carbon dioxide when used for fuel. This closed cycle makes no net contribution to the accumulation of carbon dioxide in the atmosphere.

There are many possible paths to successful bioconversion, and the exact combination employed will depend on the specific opportunity. The principal components include a large biomass feedstock, an appropriate pre-treatment, saccharification, fermentation and recovery technology [4].

3. GIS APPLICATION PROJECT IN THE REGION OF CENTRAL MACEDONIA

An information system may be formally defined as a combination of human and technical resources, together with a set of organising procedures, that produces information in support of some managerial requirement. The basic resource in all decision making is information. In practice, many decisions are made on the basis of inadequate information, in a disjointed and incremental way, and for reasons that are often subjective. The availability of good information can prevent neither mismanagement nor the taking of wrong decisions. It can however reduce the level of ignorance of the consequence of action or inaction [8]. The GIS application project developed for the Region of the C. Macedonia is presented here after and in this project the following steps were made:

a) *Acquisition of data.* Spatial data including maps of C. Macedonia (scale 1:200.000 (NSSG), and alphanumeric data for the agricultural production (NSSG) has been collected. The key-unit chosen is the Department.
b) *Data processing.* In this stage the data are transformed into such structures as to serve different functions. This includes the processes of the available data (biomass, energy potential) and their management in a database so that it can be used from the GIS software. This task was accomplished with the use of Excel for computation and Dbase for the formation of the alphanumeric databases. The fields were chosen according to the available information, every polygon (Department) has a unique ID number and the key-unit is the Department. The digitised maps were created using ArcInfo. Finally MapInfo was used for joining the two different types of databases and the development of the GIS project. The key record for joining the two databases is the ID number of each polygon (Department).
c) *Retrieval, analysis and dissemination.* The aforementioned processed data are now visually displayed. A potential user of this project has either maps or professional advice using the query tools of MapInfo [9], in real-time upon matters that concern:
   -Retrieval, visualisation and presentation of plant and animal biomass information by Department
   -Retrieval, visualisation and presentation of energy produced from biomass by Department
   -Retrieval, visualisation and presentation of biogas produced from biomass by Department
   -Decision-making based on compared data, such as the installation of an anaerobic digestion unit.

This project provides data of biomass and it's energy potential, in the form of a product (such as a map, see Figures) or in the form of a service (such as professional advice, see Discussion). It can

supply attribute data that may be presented in verbal or numerical form, spatial data that may be shown on maps, and temporal data that indicates their currency.

4. DISTRIBUTION OF BIOMASS IN THE REGION OF CENTRAL MACEDONIA

The Region of Central Macedonia is a wealth-producing area with many agricultural and livestock-breeding activities. A large percentage of the population is living and working in the mountainous forest areas of the Departments Imathia, Pella, Serres and Chalkidiki.

		Plantations (tonnes) by department					
	Imathia	Thessaloniki	Kilkis	Pella	Pieria	Serres	Chalkidiki
Wheat (soft)	5649	122246	88403	15900	31588	24538	12058
Wheat (hard)	23766	161359	187949	64659	36120	191236	95320
Barley	9739	65291	28820	27738	30734	84297	71610
Trees trim.	204713	21299	13253	223670	50100	46163	153326
Vineyards trim.	5905	12662	2885	2081	1296	5734	13559

TABLE 1. Plantations of Central Macedonia & departments (NSSG)

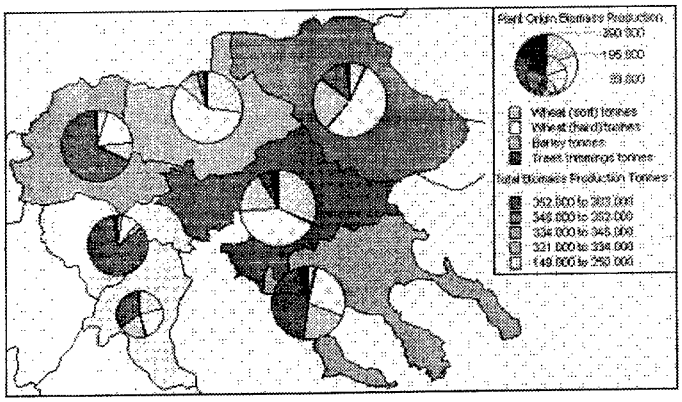


Figure 1. Plant origin biomass production

The exploitation of plant and animal origin residues and byproducts contributes in the protection of the environment saving energy and introducing alternative energy solutions. The bioenergy from the biomass can satisfy more or less the needs of agricultural activities for heating, electricity and transportation.

Energy Value of biomass (MJ) by department							
	Imathia	Thessaloniki	Kilkis	Pella	Pieria	Serres	Chalkidiki
Wheat (soft)	37283400	806823600	583459800	104940000	208480800	161950800	79582800
Wheat (hard)	166266936	1128867564	1314891204	452354364	252695520	1337887056	666858720
Barley	81418040	545832760	240935200	231889680	256936240	704722920	598659600
Trees	1351107450	140570100	87471450	1476218700	330660000	304672500	1011953250
Vineyards	38971350	83565900	19042650	13731300	8553600	37842750	89491050

TABLE 2. Energy Value of Biomass (MJ) by department

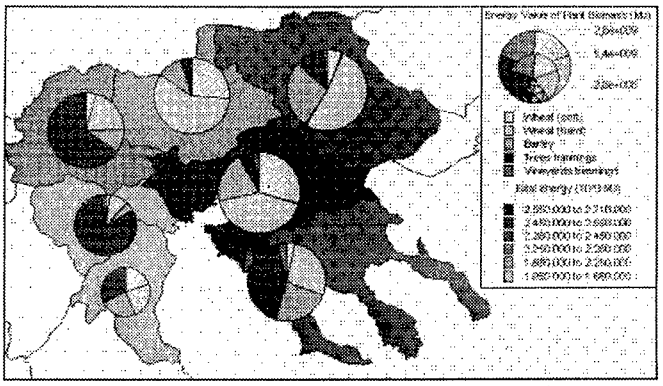


Figure 2. Plant origin energy value of biomass

The chart of C. Macedonia (Figure 1) shows that Thessaloniki is the major-wealth producing area followed by Serres, Pella and Chalkidiki comes next and the departments of Imathia and Pieria are last. The distribution of wheat (soft - hard), barley and trimmings (trees-vineyards) appears in the pies. The energy value of the biomass (Table 2) is depicted in Figure 2. An assumption was made that the trimmings of the trees and vineyards are equal, because vineyards need strict trimming almost 80% of the vine whereas trees need less. The biogas from the plant biomass [5] is calculated in Table 3.

Biomethane (10^3m^3) production by department							
	Imathia	Thessaloniki	Kilkis	Pella	Pieria	Serres	Chalkidiki
Wheat (soft)	1695	36674	26521	4770	9476	7361	3617
Wheat (hard)	7558	51312	59768	20562	11486	60813	30312
Barley	3701	24811	10952	10540	11679	32033	27212
Trees	61414	6390	3976	67101	15030	13849	45998
Vineyards	1771	3799	866	624	389	1720	4068

TABLE 3. Biomethane produced from biomass (10^3m^3) by department

The numbers of animals (Table 4) are according to NSSG [2] and all calculations are based upon these numbers. BOD_5 calculations [6], for the Region of Central Macedonia are shown in Table 5 and Figure 3 depicts the geographic information data

Livestock (animals) by department							
	Imathia	Thessaloniki	Kilkis	Pella	Pieria	Serres	Chalkidiki
Oxe,cows,etc	25806	64745	40457	27122	3988	51210	5324
Sheep,goats	105136	308876	167560	213025	143829	289975	181804
Pigs	34147	20257	8268	6523	46779	16888	10335
Hens	259923	2091660	241065	613295	343540	874990	194670

TABLE 4. Livestock by department (NSSG)

BOD5 (kg/day tn of livestock) by department							
	Imathia	Thessaloniki	Kilkis	Pella	Pieria	Serres	Chalkidiki
Oxe,cows,etc	46450,8	116541	72822,6	48819,6	7178,4	92178	9583,2
Sheep,goats	94622,4	277988,4	150804	191722,5	129446,1	260977,5	163623,6
Pigs	75123,4	44565,4	18189,6	14350,6	102913,8	37153,6	22737
Hens	935722,8	7529976	867834	2207862	1236744	3149964	700812

TABLE 5. Production of BOD_5 by department (kg/day), [6]

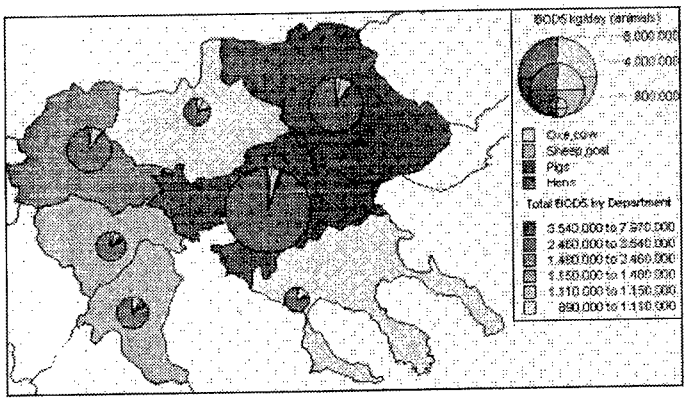


Figure 3. Production of BOD_5 by department

Energy value-anaerobic fermentation (MJ/day) by department							
	Imathia	Thessaloniki	Kilkis	Pella	Pieria	Serres	Chalkidiki
Oxe,cows,etc	334445,8	839095,2	524322,7	351501,1	51684,48	663681,6	68999,04
Sheep,goats	136676,8	401538,8	217828	276932,5	186977,7	376967,5	236345,2
Pigs	88782,2	52668,2	21496,8	16959,8	121625,4	43908,8	26871
Hens	57183,06	460165,2	53034,3	134924,9	75578,8	192497,8	42827,4

TABLE 6. Energy Value of Biomass (MJ/day) by department

The energy value (Table 6) shows in Figure 4 and the biogas production (Table 7) shows in Figure 5.

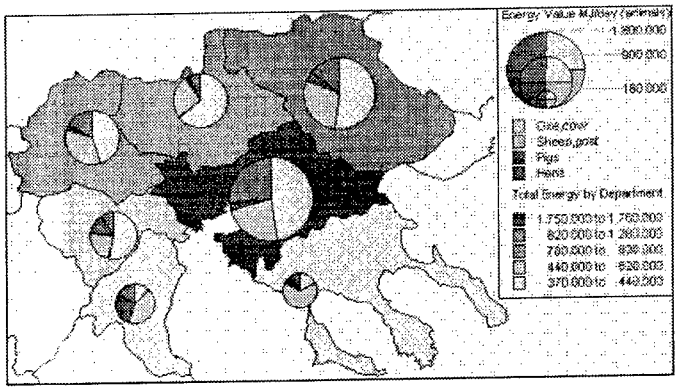


Figure 4. Energy value of biomass by department

Biomethane-anaerobic fermentation (m^3/day) by department							
	Imathia	Thessaloniki	Kilkis	Pella	Pieria	Serres	Chalkidiki
Oxe,cows,etc	15483,6	38847	24274,2	16273,2	2392,8	30726	3194,4
Sheep,goats	6308,16	18532,56	10053,6	12781,5	8629,74	17398,5	10908,24
Pigs	4097,64	2430,84	992,16	782,76	5613,48	2026,56	1240,2
Hens	2599,23	20916,6	2410,65	6132,95	3435,4	8749,9	1946,7

TABLE 7. Biogas produced (m^3/day) by department, [5]

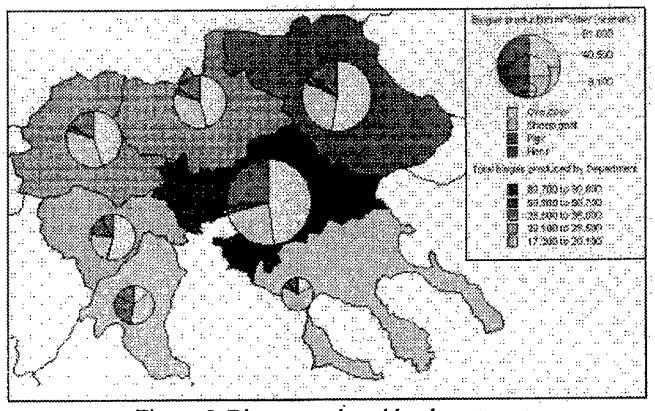


Figure 5. Biogas produced by department

5. INTERPRETATION OF THE GEOGRAPHIC INFORMATION DATA - DISCUSSION

The produced maps can be used to extract information, which can lead to decision planing. Furthermore the data can be used inside the GIS software, logic expressions can be made and as a result the user can get the answers to decision making.

In the Region of Central Macedonia the tables and the charts shows that the departments of Thessaloniki and Serres are abundant in resources. It is important and therefore noticed that Figure 3 and Figure 4 presents a case concerning animal biomass. The largest BOD_5 production comes from the hens (Figure 3), but when we examine the energy value of the biomass (Figure 4), it is clear that the biomass from oxe, cows, etc. has more energy value. A decision can be made about the potential energy exploitation scheme regarding the place of a large anaerobic digesting facility and about the type of animal wastes that should be treated for their energy potential.

The departments of Pella and Kilkis follow the two aforementioned departments in biomass production, with Pella having more plant biomass potential than Kilkis. Finally the departments of Imathia, Chalkidiki and Pieria follows the previous departments in the available potential energy quantities of biomass. The geomorphology plays a significant role therefore in the mountainous areas the rural production is less resulting in reduced biomass accumulation volumes.

From the above extracted results a proposal can be made concerning the establishment of a large anaerobic digestion facility which can valorise the available biomass. The best position for this unit would be in the borders of Thessaloniki, Serres and Kilkis departments. This facility could stabilise the total biomass of the Region of Central Macedonia and produce bioenergy from methane gas.

The recording of the large livestock breeding units in the Region could give a more precise information that can lead to accurate planning and development of the biomass resources.

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PROTECTION SYSTEM OF MOUNTAINOUS WATERSHEDS THROUGH A QUANTITATIVE ESTIMATION MODEL OF THEIR DEGRADATION

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ABSTRACT

This paper presents a new version of a well-known stochastic model to quantitatively assess drainage basin degradation in order to determine erosion in 4 torrent basins. This new version, 3D-structured and using G.I.S. for data processing, can provide a quantitative assessment of the degradation of any torrent basin in a very short time. Furthermore, a system to prevent erosion and degradation by means of agricultural and technical forest works is presented; the system was originally designed for these 4 basins, but it is flexible and easy to adapt to any torrent basin.

ΣΥΣΤΗΜΑ ΠΡΟΣΤΑΣΙΑΣ ΟΡΕΙΝΩΝ ΛΕΚΑΝΩΝ ΑΠΟΡΡΟΗΣ ΜΕ ΤΗ ΒΟΗΘΕΙΑ ΜΟΝΤΕΛΟΥ ΠΟΣΟΤΙΚΗΣ ΕΚΤΙΜΗΣΗΣ ΤΗΣ ΥΠΟΒΑΘΜΙΣΗΣ ΤΩΝ

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ΠΕΡΙΛΗΨΗ

Στην παρούσα εργασία παρατίθεται μια προσαρμογή ενός γνωστού στοχαστικού μοντέλου ποσοτικής εκτίμησης της υποβάθμισης λεκανών απορροής για τον προσδιορισμό της διάβρωσης σε 4 χειμαρρικές λεκάνες. Το προσαρμοσμένο αυτό μοντέλο λόγω της 3D κατασκευής του αλλά και της μέσω G.I.S. επεξεργασίας των πληροφοριών του μπορεί να δώσει ταχύτατα την ποσοτική εκτίμηση υποβάθμισης σε οποιαδήποτε χειμαρρική λεκάνη. Στη συνέχεια παρατίθεται ένα σύστημα προστασίας από την διάβρωση και απόπλυση με την βοήθεια αγροφυτοτεχνικών έργων, αρχικά σχεδιασμένο για τις 4 λεκάνες, αλλά επίσης με ευελιξία προσαρμογής για οποιοδήποτε χείμαρρο.

1. INTRODUCTION – DESCRIPTION OF THE PROBLEM

Drainage basin erosion and degradation is one of the most complex environmental problems worldwide. Thus, it has naturally been the subject of research for many decades in countries representative of all the main climatic types on the planet. The problem is fairly aggravated in the Mediterranean countries, due to their temperature range and other factors (irregularly distributed rainfall, insufficient plant coverage, etc.). In our country, plagued by forest fires in the past decades, it tends to acquire the dimensions of a real disaster for mountainous areas, due to the degradation of the soil it implies.

The assessment of mountainous soil degradation due to the erosive action of rainwater runoff is of two types:

a) Qualitative assessment (intensity, degree, speed, etc.)

b) Quantitative assessment, usually calculated in total m^3/year/basin, or in m^3/year/Km^2, or finally in mm/year/basin.

Quantitative assessment is more difficult than the qualitative one, since it implies an attempt at calculating magnitudes and volumes which are hardly measurable in practice and are related to a diachronic effect. In the past few years several methods have been developed for the quantitative assessment of degradation.

The more known methods are refered to be the USLE, WEPP, AGNPS[1], CREAMS, ANSWERS[2], EPIC, the method of Rydgren[3] and Terry[4], and the method of Mitas-Mitaseva[5], as well as the contemplative methods of Fournier, Corbel and Gavrilovic. The most of them have been used mostly in United States and less in Europe.

However, according to Kotoulas[6] the main feature of these methods is that "they require the existence of basic data which however can not be often designated precisely so that the precision and the potential of their application is reduced". Therefore, according to the same author "the methods being developed to date are far from the point to provide precise and reliable forecasts". Moreover, in the chapter of erosion-degradation this is not the only difficulty. There is questioning even on how to confront the phenomenon particularly in situations during which we have intensive procedures (e.g. after a fire).

In the present paperwork one from the above mentioned methods was selected, the stochastic Gavrilovic[7] model, by the help of which effort was made to estimate the degradation in the selected under research area. This estimation was conducted by the help of specific G.I.S. software (GRASS), which has helped out to simplify the model application on one hand and to increase the precision of the results to an impressive way on the other. After the estimation of degradation was implemented, the quotation of a protection and how to handle a problem was attempted, by applying a system easy-to-use, flexible and particularly effective, as proved by the experience gained to date.

2. RESEARCH AREA

As research area was selected the broader area of Kastoria Prefecture and especially four small torrential watersheds from which two were directly adjacent. As a reason of the above selection is quoted the fact that the aforesaid area -because of its geomorphologic condition- has many, in direct or less direct proximity, small runoff basins* which particularly show a special vegetative and geological diversity.

Of course, it is easily comprehensible why a model, in order to be elaborated, requires watersheds of small size. Regarding the highest possible proximity, an identification of the attack climatic factors

* By the term small torrential basins we refer to the basins 8-10 Km^2 (Kotoulas[6], Emmanouloudis[8])

in all parts of the sample is essential, so that the results obtained by the research are directly comparative. Following these thoughts we selected the above stated sample of four watersheds.

3. RESEARCH METHOD

The morphometric characteristics of the selected watersheds have led us "necessarily"* to the selection of the Gavrilovic method, because it is uniquely appropriate to estimate the degradation in small mountainous watersheds, as the ones included in our sample.
In Table 1 the morphometric characteristics of the sample watersheds are quoted, which define the mountainous character of the specific torrents.

TABLE 1: Morphometric characteristics of the sample watersheds.

		$F_{WAT.}$ (Km^2)		H_{max} (m)	J_{mW} (%)
No	**Torrents**	**Projective**	**3D****		
1	Riganorema	9,43	10,03	1420	30,90
2	Fotini	4,23	4,46	1190	29,41
3	Mylos	5,05	5,24	1080	23,00
4	Triantafillia	8,42	8,98	1580	33,32

The above data was obtained from maps 1: 50.000 of the G.A.S. (sheets KASTORIA, MESOPOTAMIA).
According to the Gavrilovic method, the type providing the average annual degradation in a watershed is:

$$W = Th\pi\sqrt[3]{z}F$$

Where T is coefficient of temperature given by the type:

$$T = \sqrt{\frac{t_o}{10} + 0,1}$$

With t_0: average annual temperature in the watershed
h: average annual height of rain (mm)
π: 3,14
F: area of watershed (Km^2) and
z: coefficient of erosion given by the ratio: $z = x\,y\,(\varphi + \sqrt{j})$

with χ,y,φ being the partial coefficients that depend on the vegetation, the geological base and the erosion degree of the watershed respectively whereas j is the average slope of the watershed area expressed as angle tangent.
It is implied that the values of χ,y,φ are given analytically in tables by Gavrilovic. The selection of the suitable values assigned to each case are at the aptitude of the researcher who applies the formula when needed.
By applying the method, each watershed under research was divided by the authors in spots

* We say "necessarily" because the so called method provides particularly good results when estimating the degradation in small basins of mountainous areas (Gavrilovic[7], Pintar[9], Kotoulas[6]).
** F_{3D} stands for the watershed area, not as it results from the calculation on the map ($F_{PROJ.}$) but for the actual area of the basin in three-dimentional format, as it results from the calculation after a 3D construction of the watershed by the help of GRASS. The F_{3D} is slightly bigger than F_{PROJ} and the deviation from each other depends on the average surface slope of the watershed (Emmanouloudis, Filippidis)[10].

depending on:
-the vegetation species prevailing in each part
-the geological base it was consisted of
-the seats of producing debris material.
Therefore, for example, there could be 6 vegetation spots distributed as follows: 2 spots of forest, 1 spot with shrubby plants, 1 spot with pastures, 2 spots with arid lands. There could also be 4 spots of geological base, 2 of them having geological base of granite, 1 gneiss and the other schists and so on. It is implied that the spots of vegetation, geology, seats of producing debris material are not identical as far as their boundaries are concerned.
Given that often the spots of vegetation, geology, etc., were numerous, it becomes clear that this method was knotty, time-consuming and not particularly accurate*
To overcome this insufficiency, we stretched further the Gavrilovic model by improving the ways of spot separation. The G.I.S. GRASS[11] served greatly this effort. The following methodology was applied:
In sheets of the G.A.S., the research area was scanned on GIS layers and converted to image with the use of image processing software.
Then, converted into an appropriate image file format readable by GRASS, the scanned area was imported in GRASS in raster image format.
Image rectification or registration of the research area was the next processing step. The rectification was originally carried out by digitization of 4 points, that is 4 angles, of the area on the HATT grid, and then by conversion of the raster co-ordinates imported in GRASS (which were in accordance to a local reference system) into projectional co-ordinates, with the use of linear affine transformation.
Then, using the scanned rectified map, the research area was digitized[12]; more specifically, digitization involved basin frontiers, peaks and contours (for peaks and contours the relevant elevation data were provided). Following this, the spots of vegetation, geology and erodibility were digitized, as suggested by the Gavrilovic formula on the basis of its x,y and φ. These spots were numbered and their respective values were provided according to the Gavrilovic tables.
Following the above processing, all the data were exported in vector format and, after topology building, were converted in raster format, in view of producing all necessary maps and proceed to the necessary calculations.
More specifically, from the 3 rasters of the contours, the Digital Elevation Models (DEM) were produced, 3D-views of which can be seen on figures 1,2,3.
Then, on the basis of these Digital Elevation Models, the slope maps were created. In order for the DEMs to be accurate, the very same slopes were used, which of course differed for every cell of the slope rasters, i.e. an area of approx. 67 m^2 (8,17m X 8,18m) for the torrents of Fotini and Riganorema and 36 m^2 (6m X 6m) for the torrents of Triantafillia and Mylos.
Then the GRASS software tool r.mapcalc[13] was used; this is a program that allows users to manipulate, analyze, and create map data by performing mathematical calculations on raster map layers.
The under process and adjustment model by this way shows an improvement in the following points:

a. Precision of calculations: By the help of segmentation into cells we have a complete splitting of the basin in very small areas of 36-67 m^2 which are worked out one by one as to the erosion coefficient, which is impossible without the G.I.S. process*. Besides, the most important American models such as ANSWERS, AGNPS, etc. run with such sort of splitting.

* The Gavrilovic method functions by the same slope for the whole watershed.

FIGURE 1 : 3D View of watersheds Riganorema and Fotini

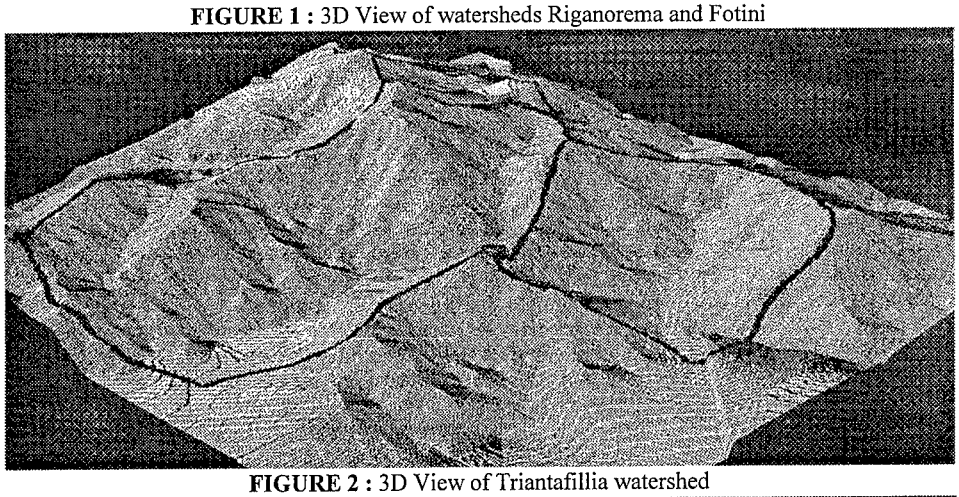
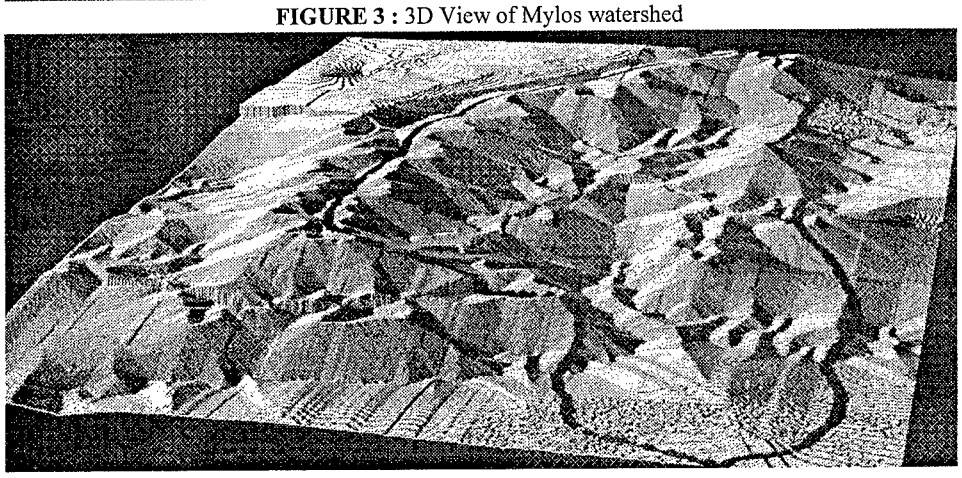


FIGURE 2 : 3D View of Triantafillia watershed



FIGURE 3 : 3D View of Mylos watershed



b. Ease at entering unlimited parameters: By entering the parameters in the form of raster maps in various layers, the participation process of many variables into the same model becomes much more easier.

c. Convenience in processing the variable values: By applying the GRASS tool mapcalc, any mathematical elaboration on the above mentioned raster maps is feasible resulting that the most complex combinations of parameter values become simple as to their calculation.

d. Appearance: 3D construction provided by the new model improves the appearance of the "real" picture of watersheds, depicting them as they are in nature and not as on the map.

4. RESEARCH RESULTS

The elaboration of the coefficients χ, y, φ and the other factors of the method come up the erosion z coefficients for each watershed.The final coefficient z of each watershed was the weighed result of partial coefficients z_i from which each one represents the erosion coefficient of a group** of cells. It is evident that all cells of the same group have the same z_i. The groups for each watershed, depending on the case, were ranging from tens to several hundreds. Meanwhile, the size of the used analysis through the GRASS is extremely remarkable, considering that each group may include some tens of cells. In Table 2 the partial coefficients z_i of the cells groups of Riganorrema are quoted.***

TABLE 2 : Partial coefficients z_i of the cells groups of Riganorrema

RASTER MAP CATEGORY REPORT

LOCATION: ekdosi — Thu Feb 1 20:32:39 1998

REGION: north: -17850.83, south: -24125.39, res: 8.17; east: -6866.64, west: -13173.42, res: 8.18

MASK:basin1 in kastoria, categories 1

MAP: float(@blast1*@geoly*(@f1+float(sqrt(@slope))))*100 (z1 in kastoria)

Z Values	Category Information	square kilometers	cell count
0	. . . . .	0.045512	681
1	. . . . .	0.000401	6
3	. . . . .	0.000200	3
4	. . . . .	0.016039	240
5	. . . . .	0.002005	30
6	. . . . .	0.029272	438
7	. . . . .	0.031410	470
8	. . . . .	0.033081	495
9	. . . . .	0.006015	90
10	. . . . .	0.001604	24
. . . . .	. . . . .	. . . . .	. . .
. . . . .	. . . . .	. . . . .	. . .
206	. . . . .	0.008287	124
210	. . . . .	0.006884	103
213	. . . . .	0.017443	261
TOTAL		4.241805	63471

* In this adjustment model the watershed area slope is given "pointly" thus it is very important for the estimation of erodibility.

** The grouping was done automatically from GRASS

*** Due to space shortness the partial coefficients z_i of the other watersheds are not quoted.

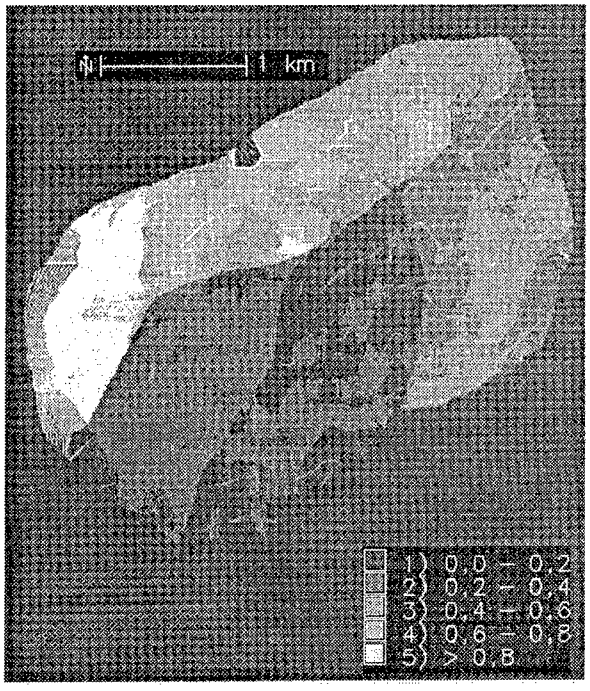
In addition, in Table 3 the values of the final z estimation for all the watersheds of the sample but also the total respective annual sediment and debris yield W, are quoted.

TABLE 3 : Final z values and W values.

Torrents		Coefficient z	Average annual sediment and debris yield, W (m^3/year)	Average annual degradation (mm)
No	Name			
1	Riganorrema	0,78	15.823	1,57
2	Fotini	0,66	5.484	1,22
3	Mylos	3,92	20.570	3,92
4	Triantafillia	0,75	6.823	0,75

The analysis of the results gave the following findings:
The bigger annual degradation is displayed by the Mylos torrent and the smallest one by the Triantafillia.
The first one has a geological base of silt-mixed marls and sandstones whereas the second one has pure granites. Also, the first one has relatively sparse vegetation of degraded coniferous forests and grasslands while the second one has extensive forest stands and shrubberies in good condition. Thus, the bigger average annual productions of debris material of the first one in relation to the second is clearly explained. Finally, the other two watersheds, displaying intermediate values of degradation, have respective intermediate values χ and y of the vegetation and geology coefficients as well.

FIGURE 4: Grey-toned map of potential degradation with legendary classification (Triantafillia t.)



Map and legend study indicates that the areas with light chromatic tones are the ones with higher risk from erosion and leaching and which need immediate protection.
In other words, we notice that degradation from watershed to watershed differs quite, and surely in all cases is bigger than the average degradation given by Kotoulas for the Greek inland and which equals to 0,67 mm. Therefore, we realise that they are watersheds of mountainous character with a significant output of debris material and especially, according to the Gavrilovic classification, 3 of them belong to the second one from the 5 risk categories and 1 (Mylos) to the first.
Finally, in order to have an even more integrated picture of the z distribution upon all watersheds of the sample, we drew some maps as follows:
For the construction of maps we classified the values of z_i into 5 categories, arising from the tables such table 2. This classification has applied a different colour of grey tone for each category. Thus, surfaces with the same colour tone corresponding to each particular category z_i have arisen. In fact, by this way we had one more (but much more synoptically) grouping of z_i so that to have a final result which is a coloured map of potential degradations with constant categorised annotated chromatology (figure 4).

5. PROTECTION SYSTEM

The protection system recommended in the present paperwork for the erodible areas, as mentioned earlier, is a mixed system of agro-plant-artificial works. The agro-plant-artificial works is a relatively old protection technique against erosion however specialised and with best results usually in the area of hillsides in respect to area of gullies.
The selection of species and number of works depend on the slope of hillsides or gullies as well as on the soil type and the aspect. So, the standardisation of these works is possible (Emmanouloudis[14]) according to the case, when we are aware of the above factors in an interference area. However, the elaboration of the Gavrilovic model through the GRASS, in addition to its other mentioned earlier advantages, provides higher possibility of having in each area the surface slopes along with the aspect map.
Thus, in conjunction to the aforesaid standardisation, according to Emmanouloudis[14], we may suggest per z category the following agro-plant-artificial works:

Area of hillsides

$Z_{0,6 - 0,8+}$	Construction of mosaic clusters with very tolerant species
$Z_{0,4 - 0,6}$	Construction of envelopments

Area of micro-gullies

$Z_{0,8+}$	Construction of picketfence belt
$Z_{0,6 - 0,8}$	Construction of envelopments belt
$Z_{0,4 - 0,6}$	Construction of clusters belt

6. CONCLUSIONS

Summarising all the above mentioned, we drew up the following conclusions:
For the quantitative estimation of mountainous watersheds degradation a new model was used. The contemplative model of Gavrilovic served as a starting-point, which has been further stretched out by initiating appropriate adjustments by the use of the G.I.S. GRASS. In the case of the four runoff

basins, the average annual degradation has been calculated with a remarkably high precision due to this improved model.
Actually, it is a combination of the Gavrilovic and the most known American definition model. Also, an attempt was made so that the "Balkan" parameters of the first one (which resembles the Greek torrential environment) and the American G.I.S. detailed techniques are blended.
Four maps of potentional erosion came out after calculating degredation; their study, along with a standardised system of protection works, can provide an integrated protection system planning. What's more important, this improved model of estimation and the protection works system may be applied on any watershed.

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COOLING WATER REUSE IN THE POWER PLANT OF HERAKLION CRETE FOR HEATING GREENHOUSES

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ABSTRACT

The power plant in Heraklion Crete is disposing large amounts of cooling water into the sea. The temperature of the water is low (23-33°C), however it can be used for heating greenhouses which can be developed in the nearby areas.
In the following work a presentation of the characteristics of the cooling water from the power plant and some estimations for the greenhouses heating are made. It is proved that large areas of greenhouses can be heated in nearby sites of the power plant.

ΕΠΑΝΑΧΡΗΣΙΜΟΠΟΙΗΣΗ ΝΕΡΟΥ ΨΥΞΕΩΣ ΑΠΟ ΤΟ ΕΡΓΟΣΤΑΣΙΟ ΠΑΡΑΓΩΓΗΣ ΕΝΕΡΓΕΙΑΣ ΣΤΟ ΗΡΑΚΛΕΙΟ ΚΡΗΤΗΣ ΓΙΑ ΘΕΡΜΑΝΣΗ ΘΕΡΜΟΚΗΠΙΩΝ

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ΠΕΡΙΛΗΨΗ

Το εργοστάσιο παραγωγής ενέργειας στο Ηράκλειο Κρήτης αποβάλλει μεγάλες ποσότητες νερών ψύξεως στη θάλασσα. Η θερμοκρασία του νερού είναι χαμηλή (23-33°C), όμως αυτό μπορεί να χρησιμοποιηθεί για θέρμανση θερμοκηπίων, τα οποία μπορούν να αναπτυχθούν σε γειτονικές περιοχές.
Στην παρούσα εργασία παρουσιάζονται τα χαρακτηριστικά των νερών ψύξεως του εργοστασίου, καθώς και ορισμένοι υπολογισμοί για τη θέρμανση των θερμοκηπίων. Αποδεικνύεται ότι μεγάλες επιφάνειες θερμοκηπίων μπορούν να θερμανθούν από τα νερά ψύξεως σε γειτονικές περιοχές του εργοστασίου.

1. HEATING GREENHOUSES WITH NON-CONVENTIONAL METHODS

Heating of greenhouses with non-conventional methods which means without using oil, gas or electrical power comprises
a) Heating with solar energy
b) Heating with biomass
c) Heating with geothermal energy
d) Heating with heat recovered from industries.

Today the aforementioned methods do not have a lot of applications in Greece. For heating greenhouses low enthalpy heat is required, which can be recovered from an industry and be used in greenhouses which are nearby or can be created in nearby sites.

The advantage of using cooling water from industries for heating greenhouses in comparison with heating them with geothermal fluids, is that the cooling water does not contain various pollutants as is usually the case with geothermal fluids.

2. COOLING WATER IN THE POWER PLANT IN HERAKLION CRETE

The cooling water of the power plant in Heraklion-Crete is coming from
a) The sea
b) The Almyros river

The flow rate and the characteristics of the cooling water are presented in table 1.

TABLE 1: Cooling water characteristics in the power plant of Heraklion

	Almyros river Flow rate 6500 m^3/h Salinity 0-10 gr/Kg		b) Sea Flow rate 17500 m^3/h Salinity 33,2 gr/Kg	
Month	Water inlet Temperature (°C)	Water outlet Temperature (°C)	Water inlet Temperature (°C)	Water outlet Temperature (°C)
J	14	25	16	24
F	14	25	15	23
M	15	25	14	23
A	15	26	15	24
M	16	26	17	26
J	18	28	21	30
J	18	28	25	31
A	18	27	26	32
S	17	27	27	33
O	16	26	24	31
N	16	26	20	30
D	15	25	18	27

From table 1 is obvious that during the months J-F-M-A is better to use water from Almyros river for heating the greenhouses and during the months O-N-D water from the sea, since it has higher temperatures.

In table 2 the mean monthly air temperatures in Heraklion are presented.

TABLE 2: Mean monthly air temperatures in Heraklion (°C)

J	12,3
F	12,5
M	13,4
A	16,1
M	19,4
J	23,4
J	25,3
A	25,5
S	22,9
O	20,0
N	17,3
D	14,3

3. REUSE OF POWER PLANT'S COOLING WATER FOR HEATING GREENHOUSES

The cooling water after the exit from the power plant can be pumped through a plastic pipe in the site where the greenhouses will be installed. The water will be circulated in ½ plastic pipes placed on the ground inside the greenhouses. After the circulation and the heat transfer, the water will be returned and disposed to the sea. If the distance from the power plant to the greenhouses is not greater than 2-3 Km then the temperature loss in the well insulated plastic pipes during the water transport is not higher than 0,3°C. In Table 3 the temperatures of cooling water that can be used for heating greenhouses, are presented, assuming that the heating period is 7 months. In figure 1 the flow diagram of this process is shown.

TABLE 3: Temperatures of cooling water which can be used for heating greenhouses

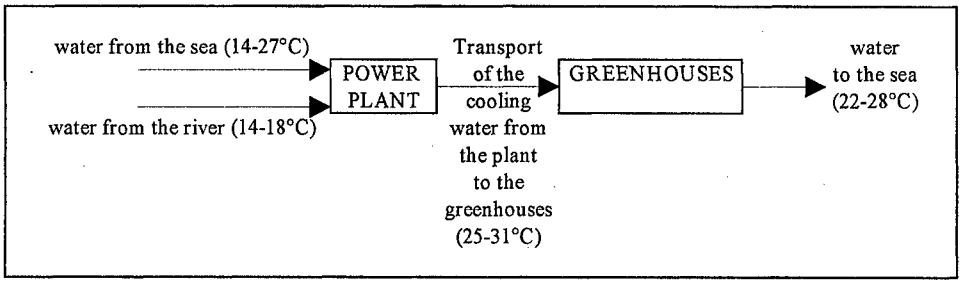
Month	Cooling water from	Cooling water temperatures in the exit of the power plant (°C)
O	SEA	31
N	»	30
D	»	27
J	RIVER	25
F	»	25
M	»	25
A	»	26

In table 4 the minimum biological temperatures for the cultivation of some vegetables in greenhouses in Crete are presented.

TABLE 4: Minimum biological temperatures for the cultivation of some vegetables in greenhouses

	DAY (°C)	NIGHT (°C)
1.Tomato	13	8-10
2.Cucumber	10-14	10-13
3.Green peper	10-12	8-10
4.Egg-plant	10-12	8-10

FIGURE 1: FLOW DIAGRAM FOR THE REUSE OF THE COOLING WATER OF THE POWER PLANT IN HERAKLION FOR HEATING GREENHOUSES



4. ESTIMATION OF SOME PARAMETERS FOR THE HEATING OF THE GREENHOUSES

The following assumptions are made for some estimations

1. The water outlet temperature from the greenhouse is 3°C lower than the water inlet temperature.
2. The desirable temperature during the night inside the greenhouse is 12°C.
3. The air temperature outside the greenhouse is 8°C below the mean air temperature in Heraklion.
4. The heat transfer (KCAL/m) from the plastic pipes inside the greenhouse is estimated from nomographs.
5. The heating needs of a greenhouse (1000 m^2) are given by the equation $Q = 10.000 (T_1-T_2)$, where Q = heating needs (KCAL/h)
   T_1 = mean temperature inside the greenhouse (°C)
   T_2 = mean outside temperature (°C).
6. Heat losses during the transport of the cooling water from the power plant to the greenhouses are negligible.

For a greenhouse 1000 m^2 in a short distance from the power plant for a cold night of January are :

- Air temperature outside the greenhouse	4,3°C
- Air temperature inside the greenhouse	12°C
- Temperature of cooling water from the power plant	25°C
- Water inlet temperature (in the greenhouse)	25°C
- Water outlet temperature (in the greenhouse)	22°C
- Heat transfer from the plastic pipes	17,2 Kcal/m
- Heating needs of a greenhouse (1000 m^2)	77,000 Kcal/h
- Length of 1/2'' plastic pipe placed on the ground of the greenhouse (1000 m^2)	4477 m
- Flow rate of water circulated in the plastic pipes inside the greenhouse (1000 m^2)	25,7 m^3/h

Therefore satisfactory heating is obtained for greenhouses in sites nearby the power plant in Heraklion-Crete. However the length of the plastic pipes and the flow rate of water circulated inside the pipes, are higher than other cases when the water temperature in the pipes is higher.

5. CONCLUSIONS

1. The cooling water from the power plant in Heraklion-Crete can be used for heating greenhouses which can be developed in nearby sites.
2. Although the cooling water temperatures are low, satisfactory heating of the greenhouses can be obtained, due to the fact that the climate of Crete is warm, and the growth of vegetables in greenhouses does not require a lot of heating.
3. The reuse of cooling water from the power plant in agriculture, results in improvement of the degree of efficiency of the plant and in reduction of the thermal pollution of the seawater, where the cooling water is disposed.

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ECOLOGICAL RESEARCH IN THE COASTAL FORESTS OF KASSADRA PENINSULA-GREECE

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ABSTRACT

Along the Mediterranean basin grow forests, which often include a highforest overstory and an understory of maquis (two-story forest). In these forests of the west coast of the Mediterranean, *Pinus halepensis* Mill. is found in abundance. *Quercus coccifera* L., *Pistacia lentiscus* and other species usually form the understory in these forests. In Greece these coastal forests cover the 16,9% of the total forests area of the country. The study of the structure, mixture and regeneration of these forests has a great importance for their protection, conservation and evolution.

Keywords: highforest, overstory, understory, structure, regeneration.

ΟΙΚΟΛΟΓΙΚΗ ΕΡΕΥΝΑ ΣΤΑ ΠΑΡΑΛΙΑΚΑ ΔΑΣΗ ΤΗΣ ΧΕΡΣΟΝΗΣΟΥ ΚΑΣΣΑΝΔΡΑΣ-ΕΛΛΑΣ

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ΠΕΡΙΛΗΨΗ

Κατά μήκος της μεσογειακής λεκάνης υπάρχουν δάση με ανώροφο από υψηλό δάσος και υπόροφο από μακκία βλάστηση (διόροφα δάση). Τα δάση της Χαλεπίου πεύκης επικρατούν στο δυτικό τμήμα της μεσογειακής λεκάνης. Το πουρνάρι, ο σχίνος και άλλα είδη σχηματίζουν συχνά τον υπόροφο. Στην Ελλάδα τα δάση αυτά καλύπτουν το 16,9% της δασικής έκτασης της χώρας. Η μελέτη της δομής, της μίξης και της αναγέννησής τους είναι μεγάλης σημασίας για την προστασία, τη διατήρηση και την εξέλιξή τους.

Λέξεις κλειδιά: υψηλό δάσος, ανόροφος, υπόροφος, δομή, αναγέννηση.

1. INTRODUCTION

Undoubtedly forests and forests areas of our country, which cover the 49% of the total area, compose the backbone of our continental ecosystems. Although the percentage covered by forests is relatively high, the situation of forests is far from the desired one i.e. it is quite far from such a situation which would allow us to characterize them as: stable, ecologically healthy and productive. In a research referring to «The Situation of the European forests» the Greek forests appear without any special problems. However, we all know that Greek forests are burnt and they remain degraded. A small increase of forest area may be attributed to the demographic collapse of the countryside.

It is well-known that forest ecosystems as natural renewable resources are distinguished for their complex functions that they accomplish (productive, sociocultural and environmental) and moreover for their multiple-use (Elefteriadis 1996). However, it is also well-known that although some kind attempts have been made lately for the financial valuation of the «non wood products», they are not taken into consideration by the national accountings.

The proper natural resources management needs a lot of carefully collected data about the inventory and evaluation. The present report is innovating towards this direction. The Greek coastal forests, like this of Kassadra, compose an important part of our continental land in many views. The forests are mainly managed for multiple-use: recreation, aesthetic, and protection. This project started as a research project of the Technological Educational Institution of Drama and with the co-operation of NAGREF/FRI of Thessaloniki. Its aim is to offer knowledge for the silvicultural and the aesthetic management of these forests.

2. STUDY AREA

2.1 Location

The study area is located at the Sani, in the north of the Kassadra peninsula and it's about 60 Km southeast of Thessaloniki. In this area the Forest Service of Kassadra (Forest Direction of Halkidiki) are in charge of these forests as they are state forests. This part of the peninsula is rather hilly. The experimental area is sited in the middle of the slope, 30m above sea level, inclination 20%, exposure N-NE.

2.2 Climate

The study area is about 9 Km (beeline) from the nearest meteorological station, which is located in Kassadria (50m above see level, 40^0 03' geographical width and 23^0 25' geographical length). Therefore, the data taken by the station attribute conditions of the study area very well.

The average annual rainfall comes up to 570mm with a dissimilar distribution of rainfall throughout the year. More specifically we can distinguish two wet periods, the first one late in autumn with the highest rainfall and a second period at the beginning of spring. The driest month is August with a rainfall of 16mm. The average yearly temperature is approximately 16.2^0C considering July as the hottest month for the year (the average is 26.1^0C and the average of the highest temperature is 30.2^0C). On the other hand January is considered as the coldest month of the year (the average is 7.3^0C and the average of the lowest temperature is 4.6^0C).

It is quite obvious, that the ecologically dry period of the year starts in May and ends in September (approximately 5 months). The climate of the study area belongs to the Mediterranean type which is characterized by mild winters and hot dry summers.

2.3 Geology-soil

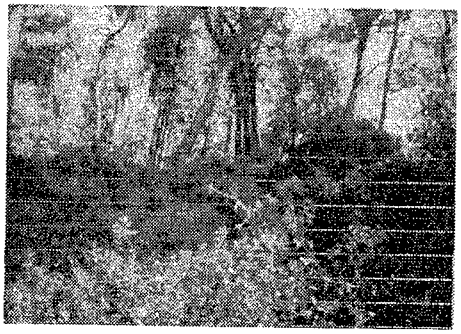
Geologically the Kassadra peninsula belongs to the zone of Axios which was created during the Eocene phase and petrologically, the study area is characterized by a relative homogeneity having as dominant rocks: Marl, Conglomerates, Sand, Marly limestones with connection's material of Marl. The soils of this area belong to renzinas and to brown forests soils which come from marly

limestones with A, C horizons, high pH, rich in $CaCO_3$ (Mavromatis 1973). These soils are often characterized as very clay and even sand-clay.

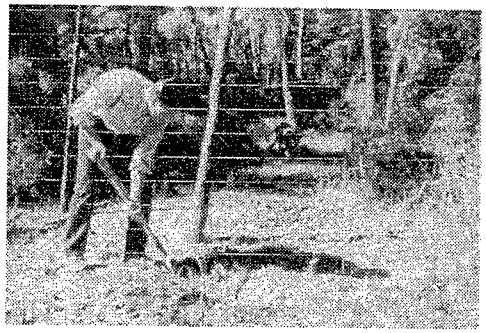
3. MATERIALS AND METHODOLOGY

According to the research aim, some characteristics of the experimental plots were the age of the forest (mature phase) and the site quality (good). Having provided some information by the Kassadra Forest Service and some on the field, it was found that the above mentioned characteristics are satisfied - to a great degree - by Sani area in the north of the peninsula. The area is about 3 ha (210X130m.) and it is divided in a three blocks order (Block I,II,III).

Each block includes four experimental sub-plots sized 40X30m (1200m^2). The first treatment was the control (A)(Pict.1), the second (B1) was the clear-cutting of the understory using mechanical equipments of 30% (3 stripes of 4m), piling upon the spot of the understory. The third treatment (B2) involved the clear-cutting of the understory of about 60% (i.e. 3 stripes of 8m.), while the last treatment involved the third treatment as well as the introduction of native white oak trees (Pict.2).



Pict.1: Control (I-A) of the experimental plot with an overstory of Aleppo pine and an understory of evergreen broadleaves



Pict.2: Treatment (I-B1) with a cut understory, where the width stripe is shown (4m) and the piling in the middle

It should be noted that at the clear-cutting stripes, the present regeneration of pine and oak trees left untouched. At the same time there was a blockage of the regeneration at the uncut stripes of the plots which remained. Also, there was an inventory of the old and the coming (new) regeneration in the stripes of B2 treatment and in plots 1X10m.. The main design of the experimental plots is called «Randomized complete-block design» (Fasoulas 1979).

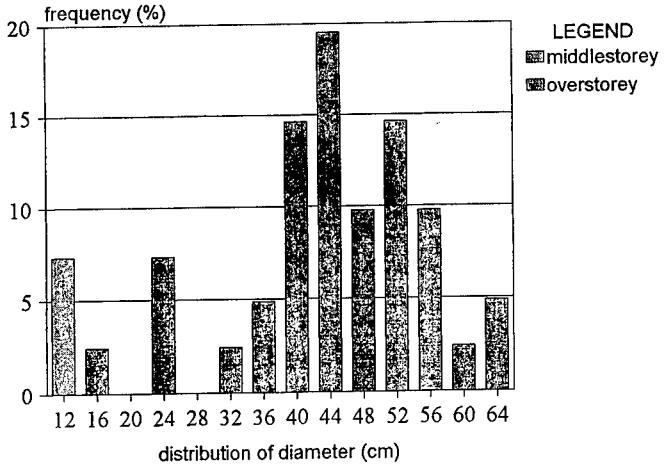
The evaluation of the trees, according to their social and silvicultural status, has been done based on the JUFRO method. The crown density of the main stand (overstory) and secondary stand (understory) was estimated, while the age of the overstory measured on the sample trees directly. The height of the understory was measured on the three control and to six points of one of the diagonals. The last treatment includes the effort to introduce oak under the discontinuous overstory of Aleppo pine. After some oak seeds had been collected from the area and had grown into yearly plants at the nursery, they were planted to the experimental plots in Autumn. The oak planting involves 3 different treatments: care of the plants with watering and weeding, weeding only and finally without any care.

4. RESULTS

4.1 Description of the main stand (overstory)

The average age of the stands is 76 years old (max 115 years, min 32 years and standard deviation 23) as it is resulted from the 15 sample trees. The average cover in the mature stand according to the 3 control plots was found about 43%.

The average number of trees per hectare was calculated to 187 pine trees with a minimum 83 (II-A) and maximum 408 (in I-D). The average breast height diameter (including the bark) is 42cm (11-65cm)(Diagr.1). From the distribution of the trees (Fig.1) it seems that the forest under research consists of a dominant overstory (93% of the trees) with an average breast height diameter of 49cm (including bark) and a middlestory (7% of the trees) with breast height diameter of 12 cm (including bark).



Diag.1.: Distribution of diameters of the pine stand in Sani area

Also, from the tree evaluation, according to JUFRO method, and as far as the social status of the trees is concerned, it was found that 12% of the trees were dominant 73% were normally grown and 6% were suppressed. As concerns the future evolution of the forest, 7% were characterized as «promising», 83% as having a normal evolution and 10% as suppressed. As concerns the economic and silvicultural meaning value of the trees the results showed that 17% of the trees had a great silvicultural value, 68% as normal and 15% with a lower value. The classification of the stems according to economic (excluding the resin-tapping), showed that 17% were valuable, 59% were normal and 24% were of a lower value. Finally, according to the crown length, the trees were distinguished to those with long crowns (10%)(crown length was more than 2/3 of the tree's height), to those with middle crowns (56%), and to those with short crowns (34%).

The average volume of growing stock is 150m^3/Ha. There is also enough natural pine regeneration (I=535 N/Ha, II=1988 N/Ha, III=5556 N/Ha), although there are some difficulties on one hand the accumulated organic matter and on other hand the dense understory. The greatest regeneration density is found on the lower places and more specifically the relationship among them is I:II:III/1:4:10. The average height of the seedlings is the same (5cm) in the three blocks, while that

of the young plants tend to increase at the lower place levels (13cm in I, 21cm in II and 37cm in block III).

4.2 Secondary stand

The secondary stand (understory) mainly consists of Mastic tree (*Pistacia lentiscus*) and kermes oak (*Quercus coccifera*) and it has an average height which is 1.7m (0.1-3.1m).

The average plant cover of the understory at the controls (uncut parts of the forest) was greater than that of the overstory and it was 80-88%. The first year after the treatment (1996) the plant cover of the understory was 33% , while in the second year it was 47% (Table 2). The first year after the treatment a greater tension of plant cover was observed at the lower land levels and the height of the residues which had remained in the forest, was decreased in volume to about a half.

Although the understory is dense, there are scattered small areas in the forest with gaps, covered only by mosses, lichens and dry-dead pine needles. Part of these areas were among the paths which are abandoned by time, and which were used by rasin-collectors and shepherds in the past.

TABLE 2: Statistical parameters of the canopy-cover of the understory before and after its treatment

YEAR OF OBSERVATION	TYPE OF TREATMENT	STATISTICAL PARAMETERS OF CANOPY-COVER (%) OF THE UNDERSTORY	
1st year	Control	average	84
		number of plots	12
		max	95
		min	75
		standard deviation	8
	Treatment	average	33
		number of plots	27
		max	45
		min	15
		standard deviation	8
2nd year	Control	average	84
		number of plots	12
		max	95
		min	75
		standard deviation	8
	Treatment	average	47
		number of plots	27
		max	70
		min	30
		standard deviation	10

4.3 Is mixture possible in these forests?

The above question is easily answered if one thinks that the understory of these stands consists of many species (mastic tree, holm oak). But here the question refers to the overstory and by mixture we mean the present dominant Aleppo pine and the white oak trees (*Quercus pubescens*). The oak which is found here is the characteristic species for the next higher vegetation zone (*Quercetalia pubescentis* Zone), but here it is found sporadically. The question which has to be answered now is how this specie which today is found everywhere in the area as relics or as rootsackers in the understory, can exist as a second species in the overstory. The consequences will be of great importance for a number of reasons which will be mentioned below. But a historical review of the region and a look to the present situation, leads us to the conclusion that in the past the oak was better represented in the plant cover of the area. Today the few forests, equally even one story and pure Aleppo pine forests, don't express the climax of the plant societies in the area. Also, it certainly is more desirable to have a mixed forest even with small scattered oak areas, rather than the

present natural but vulnerable towards fires, pineforest. Specialists often refer to the fact that the present forest is the result of the intense human activities i.e. fire, overexploitation and overgrazing (Dafis 1987).

In this case as we are talking about two silvicultural species with different demands - the white oak tree (*Quercus pubescens*) is more demanding in nutritional elements and it is also more competitive than the pine tree - the mixture with the pine tree is attempted only in the pits. According to the experimental design three different kind of treatments were accompanied by planting.

From the results showed in Table 3 we can see that in the end of the first year after planting a 17-25% loss was found which is attributed more to the quality of the young trees and less to the new site conditions and to the fact that the treatment didn't have any influence. In the end of the second year after planting, the loss percentages were 26-29%. Before this measurement took place there had been a filling of the lost trees with others of the same age. Also, it was observed that new losses were mainly coming from fillings.

TABLE 3: Number of seedlings and planting success percentages (%) for a two-year period of observations.

YEAR	KIND OF TREATMENT	SURVIVAL OF SEEDLINGS	
		NUMBER (n)	PERCENTAGE(%)
1995 (year of establishment)	A*	162	100
	B	168	100
	C	166	100
1996	A	122	75
	B	127	76
	C	138	83
1997	A	116	72
	B	119	71
	C	123	74

* A= watering and cleaning of «other vegetation», B= cutting of «other vegetation», C= without any care

5. CONCLUSIONS-SUGGESTIONS

Generally, the area variability which is observed inside the experimental plot is attributed to a) the improvement of the site to the lower site and b) to previous human intervention like fire, unproper cutting methods e.t.c.. The later factor is attributed 1) to the previous property regime of the area (ex-private) and 2) to the easy accessibility of the area.

According to previous ecological studies the forest type of our study area belongs to the cooler growing space of *Oleo-Ceratonion* Horvat 1976. The phytosociological union *Oleo-lentiscetum aegaeicum* which was located in the peninsula of Sithonia (Konstandinidis 1990) is identical to that one of the experimental plots, as well as to the II stand type of the silvicultural-phytosociological study which was done in Kassandra (Tsitsoni 1991). Also, from the data of the sample trees and on the basis of the Side Index system about the Aleppo pine trees in the area of Arnea, Halkidiki (Gatzogianis 1995), the study area is ranked in the IV site quality. This event makes clear that the forest has been through an intense degrading in the past (fires, grazing e.t.c.).

The problem of unevenness of the distribution of stems and ages, as for example that of fewer stems in the lower-leveled diameters (10-40cm) or that of the accumulation to the higher-leveled (40-52cm), is attributed to a) to the strong stand differentiation and b) to unproper silvicultural measures and c) to uncontrollable factors like illegal cuttings, fires and grazing. So, the

silvicultural shape which is now dominant is the uneven structure and the selective form in small groups, something which is mentioned by others as well (Elefteriadis et.all. 1990).

The better establishment but also the growing of all the categories' regeneration (seedlings, younger plants) in the lower positions are attributed to the better side conditions which dominate there (Tsitsoni 1991, Spanos 1992). The relatively small number of seedlings is easily attributed a) to the unique inventory that was done and b) to the unfavorable of the pine seeds because of the pine-needles and the understory. Regeneration under these conditions is less after fire, when the number of seedlings are some thousands (10-300 thousands). On the other hand the great decrease of regeneration, moving from the seedlings stage to the young plantation stage - independently on the different site quality (3 sites) - should be attributed to the intense competition of the understory which regeneration. According to the above mentioned information, it is made quite clear that natural regeneration of our coastal forests is possible: a) after some appropriate silvicultural treatments and b) by starting from some special (regenerated) places.

Our first fear of a fire in the forest after the cut-understory had been accumulated and piled on the around, was proved to be an extreme, as a year after cutting, their volume fell to half. On the other hand the speed of growing of the pine regeneration and of the oak rootsoots was impressive. An experiment of regeneration with seeds, showed that, although some precautions had been taken (spaying and protection net), the survival and the favor of the oak trees in the forests is not an easy case. Generally, the big volume seeds, the leaves and the wood of the oak tree consist the three main reasons which make the oak tree so value of the «vulnerable».

The problem of regeneration of our coastal forests through the process of their management (i.e. with silvicultural measures) is another challenge for the Greek Silviculture.

ACKNOWLEDGMENTS

We would like to express our gratitude to the Kassandria Forest Service and to the students of Drama's TEI for their help during the establishment of the experimental plots and collection of the data.

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AN ATTEMPT AT WETLAND RESTORATION IN GREECE: THE CASE OF FORMER LAKE KARLA

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ABSTRACT

Former Lake Karla, in the eastern plain of Thessaly, was an example of the long-term sustainable benefits of natural wetland ecosystems. The wetland was compromised by inappropriate land and water use policies in the mid-twentieth century. Canalization, drainage, over-drafting of groundwater and intensive agricultural cultivation dramatically reduced the area's ecological integrity. Wetland restoration is now being planned to retrieve a number of the original benefits. Through the construction of a reservoir, the state and local government hope to provide water storage, aquifer recharge, flood protection, and water quality improvement.

ΜΙΑ ΠΡΟΣΠΑΘΕΙΑ ΑΠΟΚΑΤΑΣΤΑΣΗΣ ΥΓΡΟΤΟΠΩΝ ΣΤΗΝ ΕΛΛΑΔΑ: Η ΠΕΡΙΠΤΩΣΗ ΤΗΣ ΛΙΜΝΗΣ ΚΑΡΛΑΣ

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ΠΕΡΙΛΗΨΗ

Η τέως λίμνη Κάρλα στην Ανατολική Θεσσαλία, αποτελούσε ένα παράδειγμα των θετικών επιπτώσεων από την ύπαρξη των φυσικών οικοσυστημάτων (υγρότοποι). Ο υγρότοπος υποβαθμίστηκε εξαιτίας της ακατάλληλης πολιτικής που εφαρμόστηκε στα μέσα του αιώνα, σχετικά με την διαχείριση των υδάτινων πόρων και των χρήσεων γης στην περιοχή. Τα αποστραγγιστικά έργα, οι διώρυγες καθώς και η υπερεκμετάλλευση των υπογείων νερών, για την εντατική καλλιέργεια, υποβάθμισαν δραματικά την οικολογική αξία της περιοχής. Στην παρούσα φάση προγραμματίζεται η αποκατάσταση του υγροτόπου με σκοπό την μερική επαναφορά του οικοσυστήματος. Το κράτος και η τοπική αυτοδιοίκηση, μέσα από την κατασκευή ενός ταμιευτήρα ευελπιστούν στην επαναπλήρωση του υδροφόρου ορίζοντα, στην αντιπλημμυρική προστασία καθώς και στην βελτίωση της ποιότητας του νερού.

1. BACKGROUND

Lake Karla was the remainder of a former lake, the largest in Greece, covering the greater part of the eastern plain of Thessaly. In ancient times the lake was called Voiviis, and evidence of its existence dates back to Neolithic settlements of 6000 BC. Hundreds of these settlements ring the perimeter of the ancient lake, bearing witness to the fact that the lake supported life throughout history [1]. In its later days eyewitness accounts describe a rich system of reed-beds and shallow waters, small islands and riparian vegetation which supported eels and several species of endemic freshwater fish. On its north-eastern shore, at the foot of Mount Mavrovouni and Mount Pelion, around 1000 fishermen in several villages annually produced up to 1000 tons of freshwater fish which was in high demand on the markets of Larissa and elsewhere [2]. At least 143 species of birds were documented, including migrating and locally breeding waterfowl, as well as raptors. In 1962, during IWRB's mid-winter counts, 430.000 wintering waterfowl were counted on the lake, the highest number ever spotted on any single Mediterranean wetland up until that time [3].

The demise of the lake began in 1932, when flood-protection dikes were built on both sides of the Pineos river. During the period 1949 - 1961, the lake gradually shrunk in size, with a surface area of about 10.000 ha. The lake was shallow, with maximum depths around 5 to 6 meters and averaging only 3 meters. Nevertheless, waste waters of the city of Larissa were drained in to the lake where they were effectively cleaned [4]. In 1962, the remaining lake was entirely drained by constructing a tunnel draining all its water to the Pagasitikos Gulf where it was to flow into the sea at the edge of the city of Volos. The original plan was to replace the brackish waters of the lake with a new reservoir which would be filled with fresh water from Pineos and from rainfall. Unfortunately, only the drainage of the lake was conducted [5]. Bureaucratic intransigence delayed the reservoir construction for over thirty years, allowing environmental conditions to deteriorate and rendering the rehabilitation of the area more difficult and complex.

Expected benefits by cultivating crops were diminished, because only a small percentage of the land gained by drainage could be irrigated due to soil salinity, while most of the needed freshwater is flowing through the tunnel into the sea. On the other hand, much of the area was still flooded in winter because the cross-section of the tunnel was too small. Fisheries were lost. The impact on groundwater and hydrology has caused concern since the water table is steadily dropping in some areas since 1984. Initially most gained land was illegally occupied by politically and financially powerful people, instead of landless farmers. Fishermen had to emigrate to the cities or to the sea. Perhaps the worst immediate effect was pollution by industry in Larissa and by agriculture which rendered much of the freshwater unusable for irrigation and for livestock, which became a nuisance for the city of Volos and a danger for the Pagasitikos Gulf. Such discontent occurred in the Karla and Volos area that people and authorities came to the conclusion that only a restoration of the wetland could bring a satisfactory solution for the use and cleansing of water [2]. Although numerous studies on the construction of a reservoir have been made throughout the period following its drainage, a final decision to restore part of the former lake has only recently been made by the Greek government. The engineering report was completed in 1982, but it took another twelve years for the environmental impact study (EIS) to be commissioned and submitted in December, 1994, with environmental conditions articulated in a final report in May, 1995 [3]. The EIS has been reviewed and amended by the local prefecture and the state accepted the revisions in 1998. The final technical report was completed in 1995 [6], and on this basis, the Greek government requested funds from the European Union's Community Support Funds to proceed with the project.

2. DESCRIPTION AND COST ASSESSMENT OF THE PROPOSED WORKS

The proposed works that would form the Karla complex include: The Karla reservoir, which will flood an area of 3000 ha (minimum) to 4000 ha (maximum); four flood protection ditches that will prevent precipitation runoff from the surrounding hills from flooding the plain; a reservoir spillway, drainage water pumping stations, and irrigation water pumping stations. The original project design did not include pumping stations from the Pineos river. Since some of the water volume to be pumped from the Pineos river was expected to be lost through the karst formations in the northeastern perimeter of the reservoir, the final design of the reservoir was modified to provide extensive water-proofing works at the karst formations. As a result, water losses are estimated to decrease from 85-95 to 10 million cu. m. per year, decreasing correspondingly the quantity of water that would be needed to be pumped from Pineos river, from 172-205 million cubic meters to 97-120 million cubic meters.

According to the official cost estimate of the project presented in the final technical report [6], taking into account the reservoir, the four and pumping and irrigation networks, the cost is estimated at 52,7 billion Greek drachmas. Using the same materials and work quantities specified in the final technical study, a more realistic cost assessment of the unit prices of the items was made for those that were seriously exceeding market prices. This assessment reduces the project cost estimation to 32 billion drachmas. Even if the project is based on this reduced budget, it is likely that a reasonable discount will be offered by contractors.

3. ENVIRONMENTAL CONSIDERATIONS

3.1 Environmental Objectives

While considerable experience exists internationally on the restoration or the construction of wetlands, it is by no means assured that the restoration will be entirely successful, since the criteria by which to judge its success have not yet been defined. Nor is it assured that the expected benefits that have been expressed by various stakeholders will be realized in the short term. The case of former Lake Karla presents particular challenges, due to the severely deteriorated ecological conditions which now prevail, the multiplicity of objectives, the lack of comprehensive scientific assessments, and the need for integrated management planning of the entire watershed of the former lake.
To assess the viability of this project, it would be necessary to have agreement on the main objectives of the reservoir and its associated works. A clear consensus on the main objectives has not yet been established, despite the fact that the technical specifications of the final study clearly describe an irrigation reservoir [7]. While some of the functions stated below may in fact result from the new reservoir, it is difficult, if not impossible, for all of these functions to coexist simultaneously. Furthermore, to maximize the effectiveness of one or the other objective, one may need to follow completely different management strategies.

The following objectives for the restoration have been identified: water storage for irrigation; water storage for drinking water; water storage for domestic or industrial water use (besides drinking water); improvement of water quality of surface water; improvement of water quality of ground water; recharge of the aquifer; flood protection; habitat for fisheries; habitat for wildlife; restoration of scenic value and development of ecotourism; improvement of soil quality; modification of microclimatic extremes in temperature; and mitigation of eutrophication in the Pagasitikos Gulf.

3.2 Water Supply

The sources of water required to fill the reservoir have been identified and quantified: they include rainfall, the winter overflow of the Pineos, runoff from mountainous areas and drainage from the plain of Thessaly through various collectors and drainage ditches. Another source of water that is reported is that in the future, additional flow may be diverted from the Acheloos river via the Pineos and canals. The former lake bed where the new reservoir will be built is mainly composed of clay and silt, and is relatively impermeable in the upper layers [8]. On the other hand, at the borders of the proposed reservoir and surrounding the karst outcrop known as Magoula, there are fissures and other openings characteristic of karst geology. Water losses through these seams are expected to occur, and have been assumed to empty underground into the Aegean Sea to the east. The combination of an impermeable, clay lake bed and karst fissures leading to the open sea imply that the reservoir will not be able to directly recharge the aquifer. Opinions still differ on this issue, and an unequivocal answer simply does not exist. Only a detailed water balance can give the answer, based on site-specific monitoring data collected during a pilot- or full-scale operation of the reservoir.

3.3 Groundwater

It is well-known that there has been a severe problem with groundwater over-drafting for many years. There are reports of drilling wells to 250-300 meters below the surface, as well as of steadily descending water levels since 1984 [3]. It is estimated that the entire water level of the area has dropped 50 meters, and is continuing to drop 1 to 2 meters per year [9]. In addition, the quality of the water is saline. This is most likely caused by irrigation runoff or salt water intrusion from the sea. Such a phenomenon can be expected since the ground elevation at that point is approximately 50 m. a.s.l., while wells have been drilled through to water levels of 100 meters below the surface of the earth. Although slightly saline water can be used for irrigating crops, it is unsuitable for drinking water. In addition, there are high costs associated with drilling the wells and retrieving it from such depths. Many wells are not registered, and are individually owned and operated without any regulation. There are several hundred wells reported to be in the vicinity of the reservoir, but it is likely that the number is higher [3]. Subsidence due to over-drafting of groundwater has already been reported to occur in vicinity of Karla. If it continues for many years it can also cause contamination of the groundwater or eventually lead to exhaustion of the aquifer [10].

3.4 Flooding

The Karla reservoir is expected to absorb the winter flooding episodes which now occur once or twice a year when the water level in the underground tunnel presently draining the basin is overwhelmed. Water will initially be channeled to the reservoir. If the water flow is too great, then part of the water will be diverted through the original drainage tunnel leading to the Pagasitikos Gulf. Another scenario that has been presented is that the water will flow into the reservoir only after the capacity of the tunnel is overwhelmed during winter and spring high water seasons [6]. In the latter case, the water quality of the water draining from the main ditch must be good enough to protect the Pagasitikos Gulf from further pollution. In the event that the capacities of both the tunnel and the reservoir have been reached, an event estimated at intervals of five years, the overflow water is expected to flood an area of 1000 ha outside the reservoir perimeter.

3.5 Water Quality

The main water quality issues that have been identified are sedimentation, nutrients from agricultural use, pesticides and heavy metals, and salinity. *Sedimentation* is expected from the runoff of adjacent

mountainous and Pineos river water. The estimated time for the dead volume to be filled with sediment, according to the design specifications of the reservoir, is 70 years [6]. However, there is evidence that the slopes are in fact more degraded and eroded than what is assumed in this calculation [11]. Thus sedimentation rates may actually be higher, causing clogging of the collecting canals or filling-up of the reservoir at a higher rate. *Nutrients* such as phosphorus and nitrogen are common in agricultural runoff. They cause eutrophic conditions which eventually leads to a drop in dissolved oxygen and the development of algal blooms. These conditions have already developed several times in the Gulf of Pagasitikos, most recently during the early summer of 1997. The sources of nutrients area generally considered to be the tunnel leading to the Gulf which drains water from the agricultural plain of Thessaly. However, municipal sewage from the Volos area may also be a contributor, as could run-off from the denuded slopes of the Pelion mountain range to the east of Volos. There is also a possibility that groundwater itself may be a carrier of nutrients to the Pagasitikos Gulf. In most coastal plain watersheds, groundwater is the primary pathway for water delivery and nutrient loading. In the United States, studies of the US Geological Service have shown that 50 to 80 per cent of streamflow and up to 60 percent of the nutrient loads to coastal watersheds are from groundwater [12]. Nitrate contamination of the groundwater has already been documented, which has led to changes in fertilizer use in cultivation under a program funded by the EU [3]. *Pesticides and heavy metals* which are toxic to plants and microorganisms, are derived from agricultural or industrial waste waters, and are drained from the plain of Thessaly by drainage ditches and runoff, as well as by seeping into the subsurface soil. *Salinity* in the groundwater is due to irrigation or the intrusion of seawater. Saline water derived from groundwater and used for irrigation in Thessaly, further reduces the quality of the soil. Water quality in the reservoir will also be affected by the *substrate*: the substrate is the material forming the bed of the new reservoir. The role of contaminants and salts already on the soil from previous agricultural and animal use has not been adequately addressed. The nature of the substrate is important because it supports many of the living organism in the future wetland; its permeability affects the movement of water through the wetland; chemical and biological (especially microbial) transformations take place within the substrate; and substrates provide storage for many contaminants. Furthermore, the physical and chemical characteristics of soils often change when they are flooded. It is reasonable to assume that using the drainage from agricultural areas would introduce highly polluted water into the reservoir. Solutions that have been suggested range from prohibiting inflow from the drainage ditches altogether, to using this source only during winter and spring when dilution with relatively clean water from Pineos and runoff would lower the pollutant concentration. Another solution proposed in the EIS involves the construction of small, artificial wetlands outside the reservoir for settling and cleansing the water through passive systems such as reedbeds and other wetland vegetation. The EIS also suggests planting reedbeds along the natural borders of the reservoir to filter runoff. Through this buffering, water quality improvement would be achieved by the fringing reeds, not the main lake body. The water would then be re-filtered as it passes through the lakebed, although the extent of this seepage is not known. These methods have been used to improve agricultural runoff and constitute a cost-effective and technically feasible approach to treating runoff. They are inexpensive to build compared to conventional water treatment, and the operation and maintenance expenses are low [13]. By improving the water quality before entering the reservoir, one contributes to the solution of many of the current problems facing the area: the pollution of Pagasitikos Gulf, the deterioration of agricultural soils, the contamination of groundwater, and the shortage of suitable drinking water.

An increase in use of pesticide and fertilizers may constitute an indirect environmental impact of the project, particularly if new land is brought under cultivation by the availability of irrigation water, thereby increasing non-point source pollution. On the other hand, a positive outcome expected from the construction of the new reservoir is the moderation of the microclimate. Elimination of temperature extremes caused by the water body would save adjacent almond cultivation from frost, a

phenomenon occurring three out of every four years due to the loss of the lake's moderating influence.

3.6 Integrated management

The complex environmental problems facing the plain of Thessaly cannot be solved solely with the construction of the Karla reservoir. What is needed is an integrated approach at the level of the entire watershed, an approach which reflects current thinking on the sustainability of water resources. This current thinking has been incorporated into the new EU Water Directive, expected to be issued within 1998. In many parts of Europe and the United States, the approach taken today to deal with flooding episodes or the recharge of aquifers is to mimic natural systems as much as possible. Much work has been done to re-establish the natural flood-plains of river systems and lakes, at considerable cost savings when compared to flood damage and provision of clean water by treating it or by transporting it from long distances [14].

Coordination of multiple stakeholders is crucial to the integrated management of the watershed: the process must be inclusive of all users, involving representatives of industry, agriculture, local development, local government, the scientific and technical community, as well as regulators. There are still many gaps in the assessment of environmental conditions in the watershed, including soil and water quality, point and non-point source pollution, the condition of the water table and the geologic formations which govern the underground flow of water. Once these gaps are filled and environmental monitoring systems are set up, the development of water management plans can proceed.

TABLE 1. Summary of Main Environmental Issues and Proposed Solutions

ENVIRONMENTAL ISSUES	*PROPOSED SOLUTIONS*
Multiple objectives of the reservoir	Identify one primary objective and several secondary ones
Unclear understanding of the hydrology affecting the reservoir	Conduct a complete hydrogeologic study of the watershed; redesign the reservoir parameters to fulfill objectives
End uses of water not linked to water source, water quality, or reservoir design parameters	Conduct a water budget linked to the primary objective, including extreme conditions to designate water levels, water fluctuation, and water quality
Groundwater levels dropping, aquifer is overdrawn	Stop drawing water from areas showing systematic drop in water level since 1984; use alternative water sources
Water quality of reservoir likely to be affected by sedimentation, salinity, nutrients, pesticides and toxics	Install constructed wetlands to clean water using settling and reedbeds before entering the reservoir; change agricultural practices in the watershed
Soil quality is poor in reservoir substrate and in surrounding agricultural land	Conduct a soil quality survey and initiate remedial actions
Pagasitikos Gulf is eutrophic	The Karla tunnel should not be used to drain runoff from agricultural land unless water is first cleansed and filtered in constructed wetlands; change agricultural practices in drainage basin

4. SUMMARY AND CONCLUSIONS

The acute problems of water shortages and poor water quality have created an unprecedented consensus to proceed with the restoration former Lake Karla. Nevertheless, the project as designed seems to hold promises beyond its capacity to deliver. Although it enjoys almost unanimous support from state and local authorities, municipalities, farmers and other local people, the European Union has delayed approval of funding. The main reason is the incompatibility of constructing an irrigation reservoir with the environmental benefits to be realized from wetland restoration. EU subsidies for intensive cotton cultivation are shrinking because of surpluses, and it is considered imprudent to fund irrigation reservoirs which would perpetuate or expand such cultivation in the plain of Thessaly. What needs to be demonstrated in the next phase of project design is the effective management of a complex system of water inflow, storage, and outflow, and of all the land and water uses within the entire catchment basin of the former Lake Karla. Initial emphasis must be on the remediation and rehabilitation of the degraded ecosystems in the area.

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AN OUTLINE OF ENVIRONMENTAL PROBLEMS CAUSED BY THE CONSTRUCTION OF SKIING TRACKS IN PILION AND PINDOS MOUNTAINS

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ABSTRACT

Environmental problems caused by the construction of skiing tracks are a well known issue, especially in the Alps. As in the traditional skiing areas the ecological consequences have been a matter of discussion since many years, new techniques in construction and maintenance methods have been applied to avoid negative ecological consequences. In Greece the problem has been hardly realised or not even been paid any attention at all. The investigated areas suffer from intensive soil erosion, triggered by insufficient construction and maintenance of the skiing tracks.

ΠΕΡΙΒΑΛΛΟΝΤΙΚΕΣ ΕΠΙΠΤΩΣΕΙΣ ΑΠΟ ΤΗΝ ΚΑΤΑΣΚΕΥΗ ΧΙΟΝΟΔΡΟΜΙΚΩΝ ΔΙΑΔΡΟΜΩΝ ΣΤΟ ΠΗΛΙΟ ΚΑΙ ΤΗΝ ΠΙΝΔΟ

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ΠΕΡΙΛΗΨΗ

Τα περιβαλλοντικά προβλήματα από την κατασκευή χιονοδρομικών κέντρων είναι πολύ γνωστά, ιδιαίτερα στην περιοχή των Άλπεων. Καθώς στις παραδοσιακές χιονοδρομικές περιοχές οι οικολογικές συνέπειες έχουν μελετηθεί για πολλά χρόνια, έχουν αναπτυχθεί νέες τεχνικές κατασκευής και συντήρησης, που αποβλέπουν στον περιορισμό των επιπτώσεων στο περιβάλλον. Στην Ελλάδα δεν έχει ακόμη δοθεί προσοχή στο πρόβλημα αυτό. Στις περιοχές που εξετάσθηκαν, παρουσιάζεται σημαντική διάβρωση του εδάφους, εξαιτίας της πλημμελούς κατασκευής και συντήρησης των χιονοδρομικών διαδρόμων.

1. INTRODUCTION

Concerning European touristic and leisure activities skiing is one of the most important factors. Many areas within the Alps are highly dependent on the income from ski-tourism. Meanwhile more than 40.000 ski-lifts and cable cars are in function throughout wintertime and transport capacity is about 1 Mio person/hour (1). These numbers indicate the stress for the natural environment. Parallel to the degradation of the natural (semi-natural) alpine landscape, negative environmental responses have occurred. Some of them are different forms of soil erosion, landslides, flooding and severe destruction of plant cover and soils. Because of these threatening effects, governmental regulations concerning conservation and maintenance of skiing areas exist in order to reduce the man made threats.

2. THE INVESTIGATED SKIING AREAS IN GREECE

Unlike to the socio-economic milieu within the Alps, in Greece skiing is, of course, of minor importance – from economic point of view and related to the affected area. But because of a very different climatic and landscape ecological situation as well as because of obviously missing relevant governmental regulations, the human impact seems to be severe.

2.1. The Chania ski area (Pilion)

The Pilion skiing area is situated southeast of Chania on the northern exposed slopes of Mt. Agriolefkes (1470 m). The area is dominated by schists of the Pelagonian zone, sometimes intercalated with marble. From the geomorphologic point of view the pyramid-like Agriolefkes is marked by smoothed relief. Towards west and east the slopes are remarkable steeper, leading to the deeply incised valleys Mega and Brikonos Rema at the SW side of Mt. Pilion. The smoothening of the slopes is caused by the Pleistocene sediments that cover the underlying relief and sometimes reveal a thickness of more than 1 meter. Together with north-exposed steep walls (cirque-like) they indicate intensive periglacial activity.

2.2. The Metsovo skiing area (Pindos)

From the geomorphologic point of view the skiing areas near Metsovo are very similar to those of Mt. Pilion. The exposition of the investigated skiing tracks is towards NE. The surrounding flat hills and shoulders hardly exceed 1500 m. Towards the southwest steep slopes lead to the adjacent neighbouring valley, towards the north the slopes are smoother and end already at an altitude of about 1.400 m (plain of Politses). The flysch-bedrock is smoothed and mostly covered by a thin sediment layer. At the transition from the slopes to the Politses plain sediment fans are developed. The highest surrounding ridges (1.594 m) exhibit destruction of the soil cover and give evidence of recent frost action.

3. THE ENVIRONMENTAL SETTING

3.1. Vegetation

From the geobotanic point of view the skiing tracks are within the climatic *Fagetalia*-zone (2,3). At more humid places (grooves, gullies) *Populus tremula* and *Populus nigra* can be found, *Pinus sp.* exists on some small spots, too. With increasing altitude above sea level the stem lengths are reduced significantly. In the area of Mt. Agriolefkes the maximum stem lengths are 3 meters only. Many truncated branches and stems indicate the influence of wind and snow upon tree growth. The recent dominating position of *Fagus moesiaca* seems to be a younger adaption to the area. By the end of the

last century [4] the Pilion Mountains above 1.000 m are described as being covered only by shrubbery and bushes (*Fagus moesiaca*). This former forest degradation was coherent with the intensive anthropogenic land use since a long period, especially during the Turkokratia. [3]

3.2. Soils

Due to the specific environmental features of the investigation areas, deeply weathered soils are developed below the beech forest. The profile formula in Pilion is Ah-Bv-Bv/Cv-C and the soil type may be called brown forest soil.
The bedrock of the Metsovo skiing areas consist of flysch (sands and clay). Upon this material a typical soil formula is A-E-Bts-Bs/Cv-C. The Metsovo soil profile may indicate a migration of material downwards (clay and free oxides of iron). An important climatic requirement for these soils is a dry season. The material is translocated during the wet season but the attachment of the particles occurs during the dry period [5]. Thus the higher precipitation of the Pindos Mountains is indicated.

3.3. Climate

The climatic conditions of the investigated areas are mainly controlled by the altitude, the striking of the mountain ranges as well as by the specific features of the Aegean and Adriatic climate. From the ecological point of view, the following features are of major importance:

- Precipitation (amount, annual distribution, heavy rainfall)
- Dryness (intensity, period)
- Temperatures (average, maximum, minimum)
- Wind (speed, direction)
- Snowfall (period, amount)
- Snow-cover (period)
- Frost action

Within the highest areas of Mt. Pilion precipitation of at least 1000 mm has to be supposed [6]. But according to the annual precipitation of the neighbouring meteorological station Pouri (500 m a.s.l.), which shows 920 mm, we may assume that within the highest Pilion Mts rainfall should exceed the 1000 mm mark significantly.

The annual distribution of rainfall reveals a maximum in December (at Morna), [7] respectively in October (Pouri). A second maximum is measured in June (Morna) and in May (Pouri). Whereas the maximum coincides with activities of the polar front, the May and June precipitation maximum already mirrors the increasing convectional processes.

The high amount of precipitation in the Pilion area, compared to Eastern Thessaly (Larisa, 522 mm), is due to the activity of the east Mediterranean branch of the polar front as well as to the barrier-effect by the Pilion mountain range. During wintertime this specific situation causes remarkable precipitation in Pilion with 2-3 m of snow. The duration of snow-cover is not recorded. Due to personal information and observation a snow cover from December until end of March is possible, even beyond this period snowfall is not unusual.

From the second investigated area more exact meteorological data exist. The mean annual precipitation at Metsovo is 1486 mm (period 1951-90). In November (195 mm) and December (190 mm) precipitation has its monthly maximum. Until May precipitation is declining gradually (May: 113

mm). In June (65 mm) the value indicates the start of summer. An overview of the 24-hour values of precipitation in Epirus reveals that in Metsovo the high values of the lower areas are less. But a maximum of 70 mm/24h is still remarkable.

Snowfall is recorded in Metsovo on 28,4 days [8]. Snowfall is possible from October until May. Only within the period form December to March, 24,1 days with snowfall are registered. The precipitation dynamics in Metsovo are highly dependent on the position of the Pindos mountains towards the weather side.

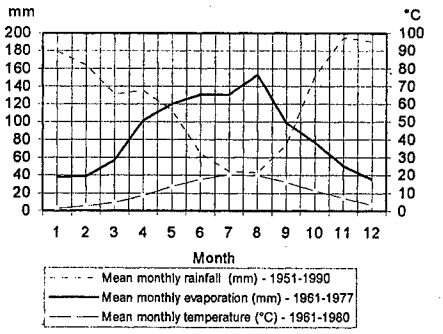
The winter climate is marked by the low temperatures, too. Analogous to the values of Mt. Ossa [9] we may assume mean temperatures above 1200 m in Pilion below 0°C. Although the border of solifluction in Greek mountains is supposed to be at about 1800 m [9,10], the temperatures below zero indicate a possible influence of frost respectively frost action in the higher Pilion areas. This assumption is confirmed by the record of mean 13,2 days with temperatures below zero in Metsovo (1165 m).

During summertime the chance of convectional events (thunderstorms) in Pilion increases and because of the Pilion acting as a barrier local clouds or even a widespread cloud cover develops. Thus, the rather humid North-Aegean air brings humidity to the Aegean side (NE) of the Pilion peninsula.

These climatic differences are reflected in a contrasting development of vegetation between NE and SW side of Mt. Pilion, where the SW, exposed to the Pagasitikos gulf, reveals significant drier elements [3]. Because of the greater distance to the sea the exposition-inclined situation is different in Metsovo, but both skiing areas are within the same climatic vegetation belt.

Measurements concerning wind action are missing in both areas. Due to the exposed position of the skiing areas, ecological relevant wind action has, however, to be taken into account.

TABLE 1: Mean monthly rainfall, evaporation and temperatures in Metsovo (1165 m)



Concerning the ecological situation of the vegetation, duration and intensity of dryness is of relevance. Although the Mediterranean dryness of the lower areas, expressed by Cs-climate allocation [11] or expressed in the relevant climate-diagrams [3] does not exist within the Greek mountains (indicated by vegetation, too), we may suppose local dryness because of high radiation, high soil temperatures and rather low relative humidity. This results in drying out of the soils and in a rise of evaporation (cf. Table 1). The evaporation maximum in Metsovo is 153,1 mm (August) highly contrasts the amount of precipitation (43,2 mm). These measures indicate the possibility of a severe local

dryness of boundary layer climate and soils. On the NE side of the Politses plain (only a few km away from the skiing areas), where the lee-position towards the weather is more significant and the soil cover has been eroded due to pasturing, geomorphologic features evidence desertification phenomena.

The summer soil temperature records in Metsovo (25 and 50 cm) show similar values as the air temperatures, starting with September soil temperatures are even higher. Mean relative humidity measures 64 % in Metsovo (87 % in January). Field recordings in the Pilion skiing areas (22./23.9.1996) reveal an average 10 % lower relative humidity than in the neighbouring beech forest (50–54 % versus 63 %).

4. LANDSCAPE ECOLOGICAL MODIFICATIONS WITHIN THE SKIING TRACKS

In Chania as well as in Metsovo severe modifications of the ecosystem, triggered by the construction of the skiing areas, are visible. After deforestation the skiing tracks were levelled by a caterpillar. Using this method no attention had been paid to ecological aspects, especially concerning a preservation of the soil cover, and the soil layers were almost completely removed. By this way of construction the natural capacity of water storage by soil and plant cover has been destroyed. Thus the amount of surface water flow increased enormously. The destructive effects of increasing surface water is well known from alpine skiing areas [12,13]. Within the investigated areas the human impact has lead to severe soil erosion (cf. Photo 1). Although some measures were taken to prevent soil erosion, these measures rather accelerate the phenomenon.

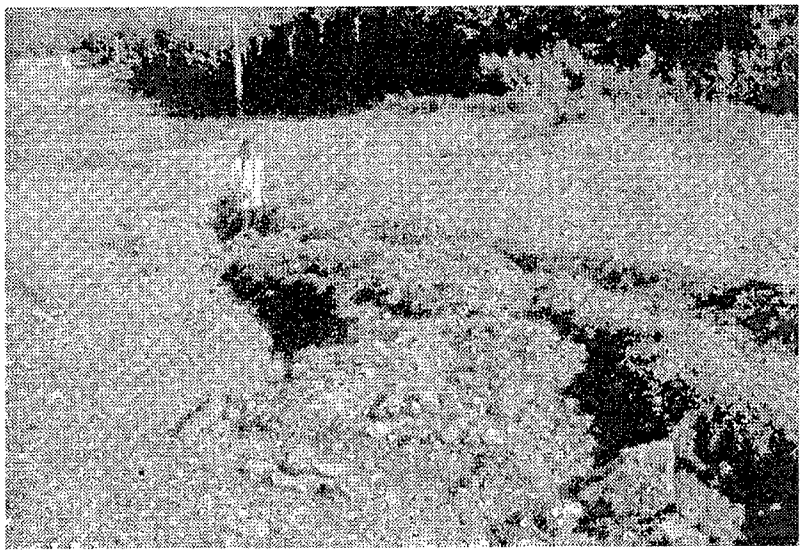


Photo 1: Linear erosion phenomena within the skiing tracks of Pilion. The gullies are cut up to 80 cm into the surface. The plant cover is mainly missing.

All skiing tracks are covered with different geomorphologic witnesses of erosion. Micro-terraces and sickle-shaped cascades of relative height of 10 cm and more are widespread and are eroded by backward erosion. The front of the terraces runs mostly parallel to grasses, that control the rapidity of

erosion. Linear erosion phenomena with lengths from a few cm until metres and depths until 150 cm(!) occur upon the most recent constructed skiing tracks. Within this forms cracking of the soil appears. Thus further erosion is prepared. Erosion niches and small accumulation areas of dm^2-dimensions testify the lability of the surface.

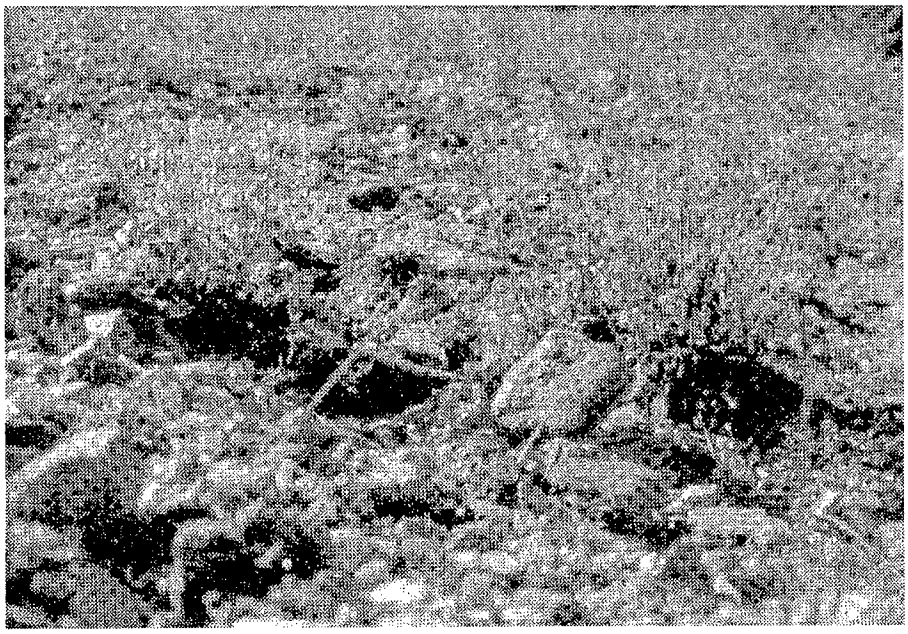


Photo 2.: The surface of the skiing tracks is dominated by parent material. In some areas *Inula sp.* is growing and controlling micromorphologic erosion

In both research areas within the middle slope linear erosion starts to become severe, while within the upper slope only elements of micro erosion exist. Where no replanting has taken place (almost everywhere) the grass cover usually lies below 10 %. In Pilion *Inula sp.* is widespread. This plant usually grows in stony areas of the alpine zone [14] and prevents other plants from coming up. Sometimes *Rubus fruticosus* grows in between. The immigration of *Inula sp.* proves the ecological changes.

Although some artificial replanting with herbs has been done in Metsovo, soil erosion could not be prevented sufficiently. Because of the destruction of the original soil cover a replanting with herbs which are non adopted to the habitat seems – regarding prevention of soil erosion - to be completely insufficient. Additionally, pasturing of sheep, goats and cows diminishes the regrowing potential of the herbs to an absolute minimum. Only upon the skiing tracks of Mt. Pilion about 150 sheep and goats are pastured. Pasturing season lasts from the end of April until the end of October. Usually sheep are pastured first because goats are rather unselective in their eating habits. This temporaryly agricultural use prevents regrowing of plants, regeneration of soil and thus indirectly supports the destruction of the ecosystem, too.

5. THE FUTURE OF THE SKIING AREAS

The previous knowledge about and observations of the skiing areas in Chania and Metsovo indicate a harmful development of the skiing tracks, due to improper construction of the tracks as well as because of missing protective measures. Due to the massive loss of the soil cover and rather intensive pasturing further intensification of soil erosion is most probable. It has to be assumed that even in case of realisation of immediate ecological stabilising measures the skiing areas will remain an aesthetic and ecological scar for decades.

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CHOOSING THE BEST SAMPLE SIZE FOR PREDICTING SAWTIMBER HEIGHT OF FIR TREES FOR HARVESTING DESIGN

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ABSTRACT

The quality that goes to the making of a best sample size is the acceptable sampling precision, through the minimum sample size. That does not detract at all from the sample value. Contrary, this criterion contribute substantially to sampling cost reduction. The sampling design that the paper deals with is a technique for definition of the best sample size for regression analysis. A pilot sample of 64 fir trees provided us with a regression equation. This equation is needed to predict the mean of the sawtimber height as a function of the diameter at breast height of the trees. The requirements for the values of the independent variable were calculated with respect to the maximum width of the confidence interval of the mean of the dependent variable. Four relative frequency distributions were used. In conclusion the most efficient sampling design was the design makes use of the uniform frequency distribution and selected by using the relative efficiency of the distributions.

ΕΠΙΛΟΓΗ ΤΟΥ ΚΑΛΥΤΕΡΟΥ ΜΕΓΕΘΟΥΣ ΔΕΙΓΜΑΤΟΣ ΓΙΑ ΤΗΝ ΠΡΟΒΛΕΨΗ ΤΟΥ ΥΨΟΥΣ ΚΟΡΜΩΝ ΠΡΟΣ ΠΡΙΣΗ ΔΕΝΤΡΩΝ ΕΛΑΤΗΣ ΓΙΑ ΣΧΕΔΙΑΣΜΟ ΣΥΓΚΟΜΙΔΗΣ

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ΠΕΡΙΛΗΨΗ

Η ορθή επιλογή του κατάλληλου μεγέθους του δείγματος βασίζεται στην αποδεκτή δειγματοληπτική ακρίβεια μέσω του ελάχιστου μεγέθους του δείγματος. Η ελαχιστοποίηση αυτή οδηγεί στην μείωση του δειγματοληπτικού κόστους. Η εργασία αυτή ασχολείται με την πρόταση δειγματοληπτικού σχεδίου για τον καθορισμό του καλύτερου μεγέθους δείγματος το οποίο θα χρησιμοποιηθεί σε ανάλυση παλινδρόμησης. Χρησιμοποιήθηκε ένα πιλοτικό δείγμα 64 δέντρων ελάτης και καταρτίστηκε μια εξίσωση παλινδρόμησης. Η εξίσωση αυτή χρησιμοποιήθηκε για να προβλέψει το μέσο ύψος πριστής ξυλείας σαν συνάρτηση της στηθιαίας διαμέτρου των δέντρων. Οι απαιτήσεις σε αριθμό δέντρων των τιμών της ανεξάρτητης μεταβλητής υπολογίστηκαν λαμβάνοντας υπ΄ όψη το μέγιστο πλάτος του διαστήματος εμπιστοσύνης της εξαρτημένης μεταβλητής. Τέσσερις σχετικές κατανομές συχνοτήτων χρησιμοποιήθηκαν. Συμπερασματικά, το αποτελεσματικότερο σχέδιο ήταν αυτό το οποίο κάνει χρήση της ομοιόμορφης κατανομής συχνοτήτων.

1. INTRODUCTION

The knowledge of sawtimber height of a number of trees helps foresters to calculate sawtimber volume that is a measure of a particular wood quantity, but very important for wood industries. This wood quantity have to be obtained from a forest following rules relating to avoidance degradation of the environment.

Sawtimber height can be estimated from relationships between sawtimber height as dependent variable and diameter at breast height as independent. These relationships are the results from a regression analysis. In forestry, regression techniques are applied in every field of research. The most typical question that arises is how many observations do we need and what will be the precision. For a regression analysis, a planned sampling is very important. Suggestions for choosing the best sample size that is going to be used in a regression analysis through a planned sampling, has been given from Demaerschalk and Kozak (1974, 1975), Marshall and Demaerschalk (1986), Corona and Ferrara (1990, 1991), Philip (1994), Diamantopoulou and Matis (1995), and Matis and Diamantopoulou (1995). In the statistical sense, a sample is a representative part of a whole population. In sampling theory there is a number of ways to choose a sample. In this paper, an attempt was made to propose the best sample size for predicting sawtimber height of fir trees that is going to be used in a regression analysis. The procedure of choosing this sample size makes use of the theoretical support that Demaerschalk and Kozak (1974, 1975) have given earlier for a simple linear regression equation. This procedure makes use of the relative frequency distribution of the observations over the range of the independent variable.

2. METHODS

A pilot sample of n=64 fir trees was collected from the University forest at Pertouli, Greece, to study the relationship between sawtimber height (H_{20}) and diameter at breast height (d). It was fitted a large number of multiple and nonlinear regression equations (Diamantopoulou 1996) and the best was selected by using the standard error of estimate (SE) criterion. The value of SE of the best equation it was used for sample size determination.

From the scatter of the (H_{20}) against (d), it's clear that there is not enough evidence that a linear model holds. There are many possible distributions that one can use, but four of them are considered worthy of study. In the first frequency distribution $S_1(X)$, more observations are collected towards the boundaries of the range (R_X) of the independent variable X. In the second frequency distribution $S_2(X)$, more observations are collected in the mean of X and fewer as values of X goes further away from the mean. The third frequency distribution $S_3(X)$, is the uniform distribution with equal number of observations for every X value and in the fourth distribution $S_4(X)$, more observations are collected in the minimum value of X and fewer observations are collected as values of X goes from the minimum to the maximum value.

The mean $\overline{X}_j$ of the four frequency distributions $S_j(X)$, where j=1,2,3,4, is calculated from:

$$\overline{X}_j = \sum_{i=1}^{k+1} (X_i S_j(X_i)) \qquad (1)$$

where X_i is the i^{th} value of the independent variable, i=1,...,10,
$S_i(X_i)$ is the j^{th} relative frequency for the i^{th} value of the independent variable,
k is the number of the equal intervals that X has been divided to.

The variance of the distribution, V_j, is computed as:

$$V_j = \sum_{i=1}^{k+1} ((X_i - \overline{X}_j)^2 S_j(X_i)) \quad (2)$$

According to Demaerschalk and Kozak (1974), sample size **N** is given from the relationship:

$$N = \frac{4t^2_{(n-3;\alpha/2)} SE^2 (1 + \frac{(X_i - \overline{X}_j)^2}{V_j})}{W_i^2} \quad (3)$$

where $t_{(n-3;\alpha/2)}$ is the t-value for n-3 degrees of freedom and level of statistical significance α,

W_i is the required maximum width of the confidence interval of the mean of the dependent variable,

SE is the standard error of estimate of the theoretical sawtimber height values.

The width of the confidence interval of the mean of the dependent variable for a given value of the independent variable and probability of (1-α) is defined as:

$$w_i = 2t_{(n-3;\alpha/2)} SE \sqrt{\frac{1 + \frac{(X_i - \overline{X}_j)^2}{V_j}}{n}} \quad (4)$$

The required sample size **N** was selected according to the most demanding value of X. This value, X_i is the one for which the ratio w_i/W_i is maximum.

All different relative frequency distributions that have been used, will require different sample sizes to obtain the same prediction. The evaluation of the effectiveness of $S_j(X)$ in relate to $S_k(X)$ can be done with the relative efficiency of the distributions ($RE_{j,k}$):

$$RE_{j,k} = \frac{1 + \frac{(X_k - \overline{X}_k)^2}{V_k}}{1 + \frac{(X_j - \overline{X}_j)^2}{V_j}} 100 \quad (5)$$

where X_k, X_j are the most demanding values of X, using $S_k(X)$ and $S_j(X)$, respectively,

$\overline{X}_k$, $\overline{X}_j$ are the means of $S_k(X)$ and $S_j(X)$, respectively,

V_k, V_j are the variances of $S_k(X)$ and $S_j(X)$, respectively.

3. RESULTS AND DISCUSSION

The nonlinear equation:

$$H_{20} = 1.3 + \frac{27.97}{1 + e^{(6.12d)}} \quad (6)$$

was found to be the most appropriate to the available data set with the smallest value of SE=3.19. The graphical representation of the predicted values through the equation (6) and the observations of sawtimber height for each diameter value is shown in Figure 1.

From the pilot sample was calculated the range of the independent variable (X=d):

$$R_X = X_{max} - X_{min} = 0.87m - 0.30m = 0.57m \quad (7)$$

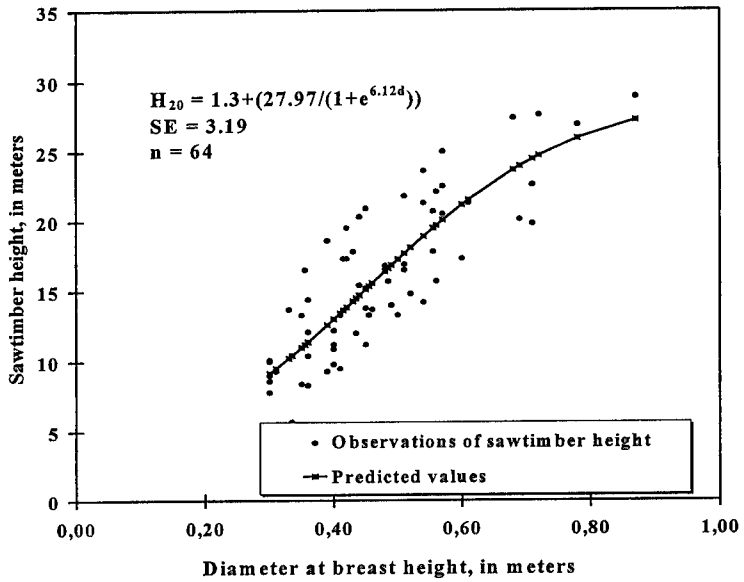


Figure 1. Relationship between sawtimber height and diameter at breast height.

Relative frequencies, at k=9 regular intervals of X, with k+1=10 values, in all different frequency distributions are given in TABLE 1.

TABLE 1. Relative frequencies at k regular intervals of X in all different frequency distributions.

k+1=10 values of the independent variable X	Relative frequencies at k=9 regular intervals of X in all different frequency distributions			
	$S_1(X)$	$S_2(X)$	$S_3(X)$	$S_4(X)$
X_{min}	0.17	0.03	0.10	0.182
$X_{min} + (R_X / k)$	0.13	0.07	0.10	0.164
$X_{min} + (2R_X / k)$	0.10	0.10	0.10	0.146
$X_{min} + (3R_X / k)$	0.07	0.13	0.10	0.127
$X_{min} + (4R_X / k)$	0.03	0.17	0.10	0.109
$X_{max} - (4R_X / k)$	0.03	0.17	0.10	0.091
$X_{max} - (3R_X / k)$	0.07	0.13	0.10	0.073
$X_{max} - (2R_X / k)$	0.01	0.10	0.10	0.054
$X_{max} - (R_X / k)$	0.13	0.07	0.10	0.036
X_{max}	0.17	0.03	0.10	0.018
Sum	1.00	1.00	1.00	1.000

From the relationships (1) and (2), means and variances for all frequency distributions were resulted and are given in TABLE 2.

The required maximum width (W_i) was selected to be the 10% of the confidence interval of the mean of the sawtimber height equals to 1.576.

TABLE 2. Means and variances for the frequency distributions.

	Frequency distributions $S_j(X)$			
	j=1	j=2	j=3	j=4
Mean	0.5850	0.5850	0.5850	0.4896
Variance	0.0467	0.0195	0.0331	0.0240

The widths (w_i) of the confidence intervals of the mean of the sawtimber height for given X_i' s and for all different frequency distributions were resulted from the relationship (4). The most demanding value of the diameter at breast height was selected according to the ratio w_i/W_i . Finally the required sample size for each different value of X was resulted from the relationship number (3). Widths (w_i), ratios w_i/W_i and required sample sizes for each different value of the diameter at breast height, are given in TABLE 3.

TABLE 3. Widths (w_i), ratios w_i/W_i and required sample sizes for each different value of the diameter at breast height (N), and for each different frequency distribution ($S_j(X)$).

	Frequency distributions											
	$S_1(X)$			$S_2(X)$			$S_3(X)$			$S_4(X)$		
X_i values	w_i	w_i/W_i	N	w_i	w_i/W_i	N	w_i	w_i/W_i	N	w_i	w_i/W_i	N
0.300	2.59	1.64	172	3.55	2.26	326	2.90	1.84	217	2.47	1.57	157
0.363	2.24	1.42	129	2.94	1.86	222	2.47	1.56	157	2.02	1.28	105
0.427	1.94	1.23	97	2.36	1.50	144	2.07	1.31	110	1.69	1.07	73
0.490	1.71	1.08	75	1.89	1.20	92	1.76	1.12	80	1.56	0.99	63
0.553	1.58	1.00	64	1.60	1.02	66	1.59	1.01	65	1.69	1.07	73
0.617	1.58	1.00	64	1.60	1.02	66	1.59	1.01	65	2.02	1.28	105
0.680	1.71	1.08	75	1.89	1.20	92	1.76	1.12	80	2.48	1.57	158
0.743	1.94	1.23	97	2.36	1.50	144	2.07	1.31	110	3.00	1.90	231
0.807	2.24	1.42	129	2.94	1.86	222	2.47	1.56	157	3.56	2.26	324
0.870	2.59	1.64	172	3.55	2.26	326	2.90	1.84	217	4.14	2.63	442

For the same sampling precision, the most demanding values of X using $S_1(X)$, are X_1=0.3m and X_{10}= 0.870m, with required sample size equals to 172 fir trees. Using $S_2(X)$, the required sample size is 326 trees, for the same values. Using the uniform distribution, the sample size required is 217 fir trees for the same values, as well, and using $S_4(X)$, the required sample size is 442 trees for the most demanding value of X equals to 0.870 meters. The distribution of the required sample sizes for each different value of diameter at breast height and for each frequency distribution, are shown in Figure 2.

It's not false to say that the distribution $S_1(X)$ with more observations towards the boundaries of the range (R_X) of the independent variable X, is the most efficient distribution, since it requires the smallest number of observations (n=172), with the same sampling precision. The second efficient distribution $S_3(X)$ is the uniform distribution with required sample equals to 217 observations. $S_2(X)$ and $S_4(X)$ could be qualified as inefficient sample designs as they require 326 and 442 observations for the same sampling precision, respectively.

The relative efficiency of distributions, was calculated from the relationship (5) and are given in TABLE 4. It is clear that $S_1(X)$ is 189% more efficient than $S_2(X)$, 126% than $S_3(X)$ and 257%

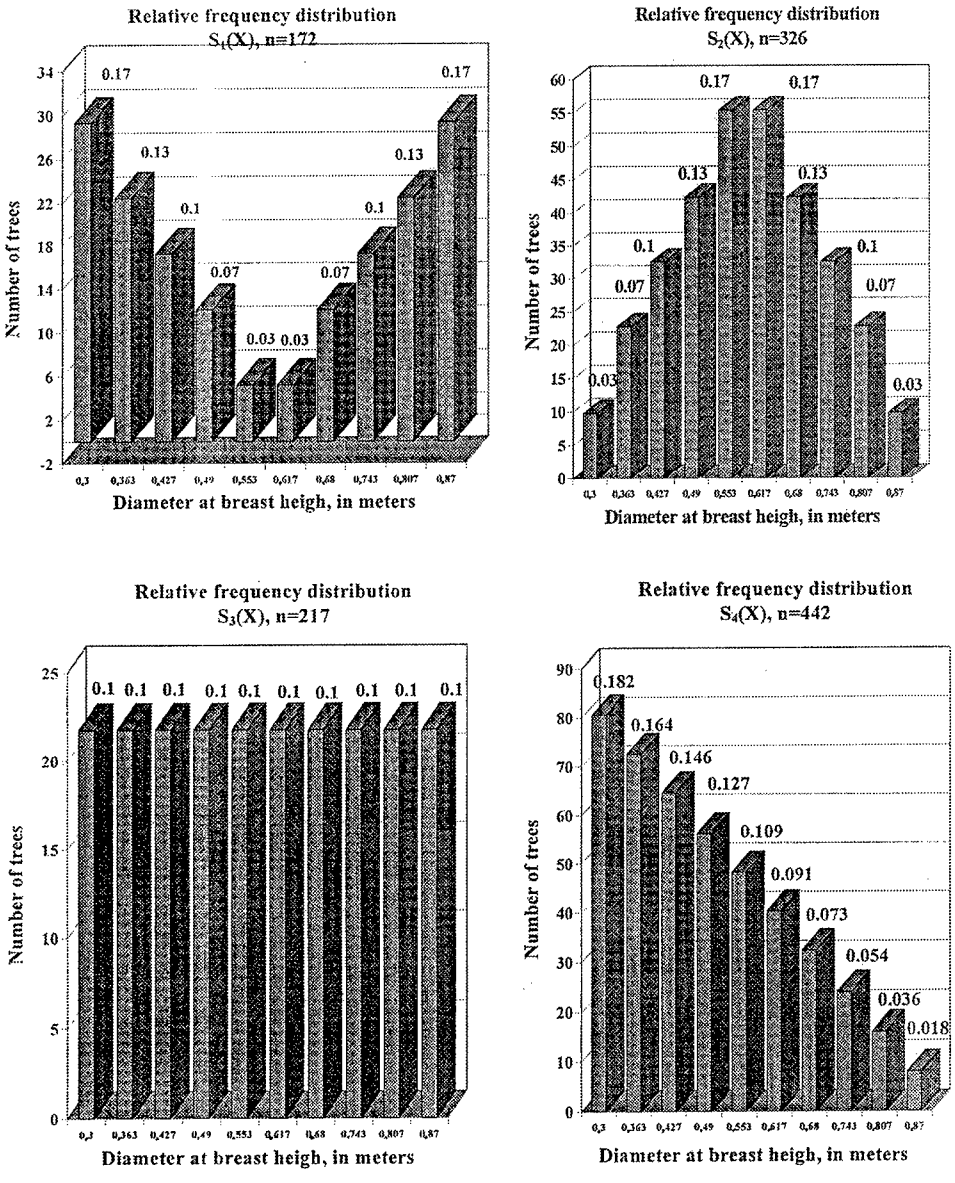


Figure 2. Relative frequency distributions $S_j(X)$ for each value of the independent variable.

more efficient than $S_4(X)$. For example, $RE_{2,4}$ = 136%, means that $S_2(X)$ is 136% more efficient than $S_4(X)$. In other words, we need 1.36 times more observations using S4(X) than by using $S_2(X)$.

TABLE 4. Relative efficiency of distributions of the observations.

k	$RE_{j,k}$ (%)			
	$RE_{1,k}$	$RE_{2,k}$	$RE_{3,k}$	$RE_{4,k}$
1	100	53	79	39
2	189	100	150	74
3	126	67	100	49
4	257	136	203	100

The graphical representation of the relative efficiency of distributions of the observations, are shown in Figure 3.

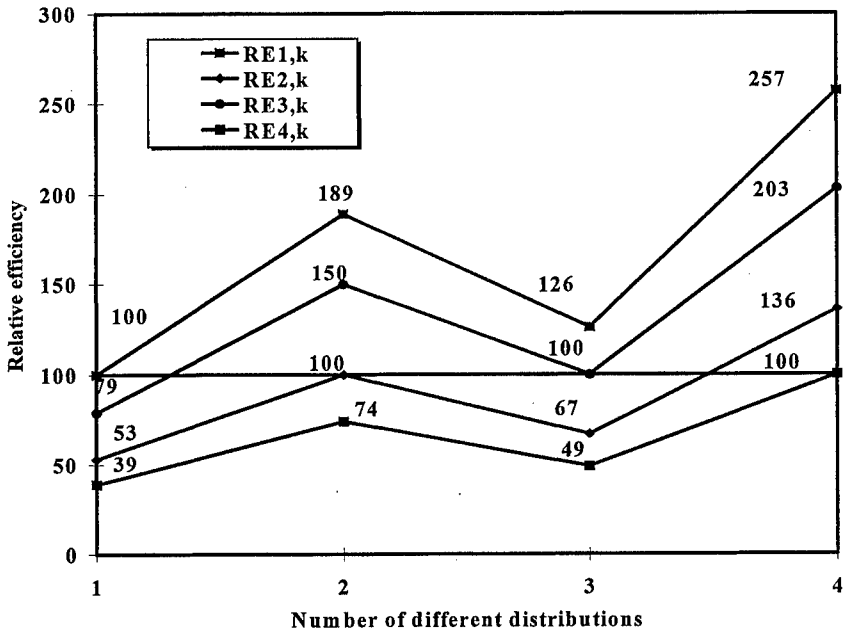


Figure 3. Relative efficiency of distributions of the observations

4. CONCLUSIONS

When there is not enough evidence that a linear regression model can describe properly the relationship between an independent and a dependent variable, then four frequency distributions are considered worthy of study, in problems taken from the nature: $S_1(X)$, with more observations collected towards the boundaries of the range R_X of the independent variable X, $S_2(X)$, with more observations collected in the mean of X and fewer as values of X goes further away from the mean, $S_3(X)$, with equal number of observations for each X value and $S_4(X)$, with more observations

collected in the minimum value of X and fewer observations collected as values of X goes from the minimum to the maximum value.

$S_1(X)$ is the most efficient distribution, since requires the smallest number of observations (n=172), with the same sampling precision. The second efficient distribution $S_3(X)$ is the uniform distribution with required sample equals to 217 observations. $S_2(X)$ and $S_4(X)$ could be qualified as inefficient sample designs as they require 326 and 442 observations for the same sampling precision, respectively.

In forests, the most common frequency distributions are very alike to $S_2(X)$ and $S_4(X)$. So if one selects the most efficient distribution $S_1(X)$, probably there were not enough trees to obtain observations towards the boundaries of the range of the independent variable. So it is more safe to propose a uniform distribution, that is 150% more efficient than $S_2(X)$ and 203% more efficient than $S_4(X)$.

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INVESTIGATING Pb AND Cu TOLERANCE OF TWO PLANT POPULATIONS

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ABSTRACT

Pb and Cu tolerance of germinating seeds of various populations of two plant species *Chamaenerion angustifolium* and *Buddleia davidii* was investigated. Seeds were germinated in petri dishes moistened with aqueous solutions of Pb and Cu at concentrations of 0, 10, 50, 100 and 500 ppm and 0, 12.5, 25, 50 and 100 ppm respectively. There was no significantly statistical difference between populations of both species except for *Buddleia* from site F in Cu at 0 ppm which showed reduced germination than the other populations. Neither species germinated in Pb at 500 ppm. In Cu *Chamaenerion* did not germinate at 50 and 100 ppm, and *Buddleia* at 25, 50 and 100 ppm.

ΕΡΕΥΝΩΝΤΑΣ ΔΥΟ ΠΛΗΘΥΣΜΟΥΣ ΦΥΤΩΝ ΓΙΑ ΑΝΘΕΚΤΙΚΟΤΗΤΑ ΣΕ Pb ΚΑΙ Cu

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ΠΕΡΙΛΗΨΗ

Εξετάστηκε η ύπαρξη ανθεκτικότητας μεταξύ διαφόρων πληθυσμών *Chamaenerion angustifolium* και *Buddleia davidii* ως προς την ικανότητα βλάστησης σπόρων σε μόλυβδο και χαλκό. Η βλάστηση των σπόρων έγινε σε τρυβλία petri υπό τις συγκεντρώσεις 0, 10, 50, 100 και 500 ppm και 0, 12.5, 25, 50 και 100 ppm σε μόλυβδο και χαλκό αντίστοιχα. Δεν υπήρξαν στατιστικά σημαντικές διαφορές μεταξύ των πληθυσμών *Chamaenerion* και *Buddleia* εκτός από έναν πληθυσμό *Buddleia* σε συγκέντρωση 0 ppm χαλκού. Οι πληθυσμοί των *Chamaenerion* και *Buddleia* δεν βλάστησαν σε συγκέντρωση 500 ppm μολύβδου. Οι πληθυσμοί *Chamaenerion* δεν βλάστησαν στις συγκεντρώσεις 50 και 100 ppm χαλκού ενώ οι πληθυσμοί *Buddleia* δεν βλάστησαν στις συγκεντρώσεις 25, 50 και 100 ppm χαλκού.

1. INTRODUCTION

To date most heavy metal contaminated sites in the UK are dealt with mainly by containment, cover systems, excavation and removal to landfill or a combination of the above [1]. These conventional methods, are expensive and contaminants either remain on site or are transferred to another site; thus the problem of contamination remains unsolved [2]. In the UK legislation concerning contaminated land has become more stringent and the transport of contaminants to licensed landfills is becoming more expensive. Therefore there is increasing interest in in-situ technologies that are relatively inexpensive, treat, destroy or stabilise contamination, to minimise future liabilities [3]. Phytoremediation is an emerging method for reclaiming contaminated land which uses plants to remove, accumulate, or render harmless soil, water and waste contaminants. It is of interest because it is a relatively inexpensive in-situ method; potentially aesthetically pleasing and perceived by the public as a benign technology [4]. Until now, research into phytoremediation has mainly concentrated upon using small hyperaccumulating herbaceous plants, which effectively accumulate heavy metals. These species have evolved physiological mechanisms enabling them to survive at high concentrations of metals. Typical hyperaccumulators include *Alyssum* sp., *Cardaminopsis halleri, Thlaspi caerulescens, Thlaspi cepaeifolium* (Cruciferae), *Silene vulgaris*, and *Minuartia verna* (Caryophyllaceae) [5]. Some metal tolerant but non hyperaccumulating grasses used to provide a stabilising cover for contaminated land includes *Agrostis tenuis* 'Goginan', *Festuca rubra* 'Merlin', and *Agrostis tenuis* 'Parys' [6]. Unfortunately, most of these plants produce a small biomass, which limits the total amount of heavy metals that can be removed from the soil. Moreover, the conventional technology available for harvesting crop-plants is not suitable for harvesting such low biomass plants. Another source of hyperaccumulation is breeding or engineering plants to tolerate metal concentrations around 1-3%, such as with *Brassica juncea* [7], [8]. A third approach is to utilise native or naturalised tall growing herbaceous or woody species that tolerate and / or accumulate heavy metals at moderately high concentrations to overcome the aforementioned problems of low-biomass. Such species would provide a functional yet aesthetically pleasing and dynamic landscape and a habitat for native fauna. We are currently investigating the metal tolerance / accumulation of two such species to assess their suitability as part of a clean up technology.

Due to their frequent occurrence on contaminated land, the metals studied in this research are lead and copper. Lead is one of the most widely dispersed contaminants; it remains in the environment for many years, and there is no known innocuous form into which it can be converted [9]. On the other hand copper is produced in larger amounts than any other heavy metal [10]. Both lead and copper form persistent chelates with organic matter leading to high retention times in soils. Retention times are higher for lead than copper due to vegetative uptake of the latter [11]. High concentrations or daily intakes (via breathing, eating, drinking or skin contact) of both metals may cause hazards to health [12], [13]. The two plant species we have chosen to study are *Chamaenerion angustifolium* (Onagraceae) a native tall herbaceous perennial, and *Buddleia davidii* (Loganiaceae) a naturalised shrub. Both species are frequent colonisers of lightly contaminated industrial land in Britain. The frequent occurrence of a species on metal contaminated soil suggests it may be metal tolerant. Metal tolerance further implies the presence of a specialised physiology which is the result of a constitutional tolerance within the species or differentiation of that species into a metal tolerant populations [14]. Both species are ubiquitous, have massive seed production of small readily dispersed seed which enables them to spread and establish on sites not yet colonised by other plant species. The fecundity of these two species also suggests that there are opportunities for natural

selection to develop populations with some tolerance / accumulation to lead or copper. The overall objectives of the research are to:

1. Identify and collect populations from sites contaminated with Pb and Cu in Northern Britain.

2. Determine the response of these populations in both germinating seedlings and vegetative plants to various concentrations of Pb and Cu.

3. Determine the impact of defoliation (due to harvesting) on established plants of these species.

In this paper preliminary findings are presented on the germination of seed of different populations of these two species at a range of metal concentrations (objectives 1 and 2 above).

2. MATERIALS AND METHODS

2.1 Materials

Samples of seeds of *Chamaenerion angustifolium* (Onagraceae) and *Buddleia davidii* (Loganiaceae) were taken from three populations, from three contaminated sites. The research commenced by identifying sites contaminated with Pb and Cu across the industrial conurbation of Northern Britain which also support populations of *Chamaenerion* and *Buddleia*. This work involved extensive discussions with individuals and agencies involved in contaminated land restoration. In addition, one sample, was taken from a population that was presumed to be growing on a non contaminated site. The latter was used as a contrast to contaminated site populations. A summary of the location and levels of contamination of the collection sites are given in Table 2.1. ICRCL threshold values for lead and copper which are dependant on landscape end use are included in the table for reference [15]. Seeds were collected by harvesting mature inflorescences from plants chosen at random across the sites. Following collection, seeds were stored according to the method by Hendry and Grime [16] slightly altered to suit the nature of the seed and thus make handling more convenient. The collected seed was left to air dry in the paper envelopes in the laboratory on a bench for two weeks before cleaning. Seed was cleaned by passing through a series of sieves, followed by air blowing in an air current to remove the chaff. The cleaned seed was placed into sealed polythene bags in darkness at a temperature of 5°C. Seed is non-dormant and viability was measured by conducting a simple germination test. The information obtained by the germination test helped inform design subsequent experiments. Seeds of *Thlaspi caerulescens* and *Brassica juncea* (Brassicaceae) two species known to be highly tolerant of lead or copper, were also included in the experiment as a control. Soil samples were taken from all sites, adjacent to the areas from which *Chamaenerion* and *Buddleia* were harvested to determine soil metal concentrations. Prior discussions with governmental agencies had confirmed that all sites (excluding Site A and Site E) possessed elevated levels of lead or copper or both. Soil Analyses (see Table 2.1) confirmed this.

2.2 Method

Each treatment (population X metal concentration) consisted of 5 petri dishes (replicates) each containing 20 seeds. The concentrations used for each metal were 0, 10, 50, 100 and 500 ppm lead and 0, 12.5, 25, 50, and 100 ppm copper. Lead was applied as an aqueous solution of $Pb(NO_3)_2$ and copper was applied as an aqueous solution of $CuSO_4 \cdot 5H_2O$. Seeds were uniformly spread across a 9cm petri dish lined with three layers of Whatman No 1 filter paper moistened with 10 ml of the appropriate metal solution. The petri dishes were placed in a growth chamber in a completely randomised design. The growth chamber was maintained at 24°C (16h day) / 20°C (8h night).

Germination was recorded when the radicle had clearly emerged through the seed-coat and after two days observation showed signs of elongation. Seeds that did not progress beyond initial protrusion were scored separately. In the analyses presented in this paper only data for seeds that showed radicle extension beyond preliminary protrusion is used. The seeds were recorded daily for a period of twenty-one days. Seeds that germinated were removed from the petri dishes. Seeds that exhibited any sign of fungal or bacterial infection were removed and the filter paper and water renewed. Petri dishes were re-randomised daily post counting. Final germination percentages used in data analyses were corrected prior to use to take into account the previously determined percentage germination of the different populations.

TABLE 2.1: Site location and description, from which *Chamaenerion* and *Buddleia* were collected.

Location of *Chamaenerion* Populations		**Metal Concentrations (ppm)**			
		Total		**Threshold values***	
		Pb	**Cu**	**Pb**	**Cu**
Site A	Is an opening in a urban woodland in Sheffield and is regarded as uncontaminated.	103-648	20-68	Domestic gardens and allotments 500 ppm. Parks, playing fields, and open space 2000 ppm.	Any uses where plants are to be grown 130 ppm.
Site B	Is an abandoned scrapyard, in the 'heart' of an industrial area in Sheffield, that once received tippings from the iron and steel industry such as ash, clinker, and slag.	665-2440	424-811		
Site C	Is a derelict site in Rotherham that, once received tippings from the iron and steel industry forming slag heaps which are still obvious.	272-839	216-473		
Site D	Is a site in Knowsley adjacent to a Cu metal refinery that is still in use.	77-172	253-1346		
Location of *Buddleia* Populations		**Metal Concentrations (ppm)**			
		Total		**Threshold values***	
		Pb	**Cu**	**Pb**	**Cu**
Site E	Is an area within the Botanical Gardens of Sheffield containing self seeded *Buddleia* and is considered as uncontaminated.	452-634	132-179	Domestic gardens and allotments 500 ppm. Parks, playing fields, and open space 2000 ppm.	Any uses where plants are to be grown 130 ppm.
Site B	Same site as described for *Chamaenerion.*	665-2440	424-811		
Site F	Is a temporary Carpark in Sheffield within an area of heavy industry.	Results pending			
Site G	Is a site in Liverpool adjacent to a gasworks that is still in use.	701-1797	103-299		

* If all sample values are below the ICRCL threshold concentrations then the site may be regarded as uncontaminated from a hazard perspective. Above these concentrations, remedial action will be required or the form of development changed [17].

2.3 Statistical Analysis

Data was subjected to ANOVA using SPSS (version 7.5) Statistical Software. The results of the post hoc tests (Tukey's) conducted at a significance level $p = 0.05$ are given in Table 2.2. The data presented are the mean germination percentage for each population and metal concentration. Values followed by the same letter are not statistically different at ($p = 0.05$).

TABLE 2.2 : Germination percentages for *Chamaenerion* and *Buddleia* populations and two contrast species at a range of Pb and Cu concentrations.

Chamaenerion angustifolium					
ppm Pb	**0**	**10**	**50**	**100**	**500**
Site A	97.20 a*	95.00 a	97.60 a	97.40 a	0.00 b
Site B	92.40 a	98.00 a	91.80 a	99.40 a	0.00 b
Site C	96.40 a	97.00 a	99.20 a	98.20 a	0.00 b
Site D	98.20 a	98.60 a	97.00 a	94.40 a	0.00 b
Buddleia davidii					
ppm Pb	**0**	**10**	**50**	**100**	**500**
Site E	99.20 a	97.60 a	97.40 a	100.00 a	0.00 b
Site B	100.00 a	100.00 a	99.20 a	100.00 a	0.00 b
Site F	100.00 a	93.60 a	99.00 a	99.00 a	0.00 b
Site G	98.40 a	94.80 a	94.40 a	94.60 a	0.00 b
Thlaspi caerulescens					
ppm Pb	**0**	**10**	**50**	**100**	**500**
	97.60 ab	97.60 ab	99.20 a	90.80 b	0.00 c
Brassica juncea					
ppm Pb	**0**	**10**	**50**	**100**	**500**
	100.00 a	100.00 a	98.00 a	100.00 a	99.00 a
Chamaenerion angustifolium					
ppm Cu	**0**	**12.5**	**25**	**50**	**100**
Site A	95.00 a*	95.20 a	97.60 a	0.00 b	0.00 b
Site B	98.20 a	94.00 a	97.20 a	0.00 b	0.00 b
Site C	98.40 a	98.40 a	96.00 a	0.00 b	0.00 b
Site D	94.00 a	90.20 a	97.20 a	0.00 b	0.00 b
Buddleia davidii					
ppm Cu	**0**	**12.5**	**25**	**50**	**100**
Site E	98.40 a	100.00 a	0.00 c	0.00 c	0.00 c
Site B	98.40 a	98.40 a	0.00 c	0.00 c	0.00 c
Site F	92.40 b	100.00 a	0.00 c	0.00 c	0.00 c
Site G	99.20 a	100.00 a	0.00 c	0.00 c	0.00 c
Thlaspi caerulescens					
ppm Cu	**0**	**12.5**	**25**	**50**	**100**
	100.00 a	100.00 a	100.00 a	0.00 b	0.00 b
Brassica juncea					
ppm Cu	**0**	**12.5**	**25**	**50**	**100**
	100.00 a	100.00 a	100.00 a	100.00 a	0.00 b

* For each metal, means within a given metal and species followed by the same letter across concentrations are not statistically significantly different at ($p = 0.05$).

3. RESULTS

3.1 *Chamaenerion angustifolium*

The results of the analyses showed that there was no statistically significant difference at ($p = 0.05$) between the various populations of *Chamaenerion* at any of the lead or copper concentrations examined. However there was a statistically significant difference at ($p = 0.05$) between the various

concentrations for both metals. *Chamaenerion* germinated but did not progress beyond initial radicle protrusion in lead at 500 ppm. There was no statistically significant difference observed between mean germination percentages at the other concentrations. Similarly *Chamaenerion* germinated but did not progress beyond initial radicle protrusion in copper at 50 and 100 ppm. There was no statistically significant difference observed between germination percentages at the other concentrations.

3.2 *Buddleia davidii*

The results of the analyses showed that there was no statistically significant difference at ($p = 0.05$) between the various populations of *Buddleia* at any of the lead concentrations examined. However there was a statistically significant difference between the various populations of *Buddleia* for copper at 0 ppm. *Buddleia* from site F presented a lower germination percentage than the other populations. There was no statistically significant difference between populations of *Buddleia* at any of the other concentrations of copper.

There was a statistically significant difference at ($p = 0.05$) between the various concentrations of both metals. *Buddleia* germinated but did not progress beyond initial radicle protrusion in lead at 500 ppm. There was no statistically significant difference observed between mean germination percentages at the other lead concentrations. Similarly *Buddleia* germinated but did not progress beyond initial radicle protrusion in copper at 25, 50 and 100 ppm. There was no statistically significant difference observed between germination percentages at the other concentrations.

3.3 *Thlaspi caerulescens*

Thlaspi germinated but did not progress beyond initial radicle protrusion in lead at 500 ppm, even though it is a known Pb accumulator and Zn hyperaccumulator [18]. *Thlaspi* presented the highest percentage germination for lead at 50 ppm but there was no statistically significant difference between the concentrations 0, 10, and 50 ppm, nor between the concentrations 0, 10, and 100 ppm. *Thlaspi* germinated but did not progress beyond initial radicle protrusion in copper at 50 and 100 ppm. There was no statistically significant difference observed between germination percentages at the other concentrations.

3.4 *Brassica juncea*

There were no statistically significant difference at ($p = 0.05$) between the various lead concentrations. There was however a statistically significant difference at ($p = 0.05$) between 0, 12.5, 25, 50 ppm and 100 ppm copper. *Brassica* germinated but did not progress beyond initial radicle protrusion in copper at 100 ppm.

4. DISCUSSION

Both populations of *Chamaenerion* and *Buddleia* were able to germinate under relatively high concentrations of lead and copper suggesting they possess some tolerance to these metals. Seed germination eventually ceased as the concentration of heavy metals solutions increased to a threshold value. Mhatre and Chaphekar [19] have mentioned similar effects of mercury at 100 and 1000 ppm inhibiting germination of various plant species. Hsu and Chou [20] found that germination percentages of *Miscanthus* spp. decreased as concentrations of lead, mercury, copper or cadmium increased. There were no obvious differences between the various populations of *Chamaenerion* and *Buddleia* in their ability to germinate under various concentrations of lead and copper. This could be due to a number of factors; both species may contain genes for tolerance in all populations or the sites regarded as uncontaminated (site A and E) from which both "control"

populations were collected may have been colonised by adjacent metal tolerant populations or have incorporated genes conferring metal tolerance. Both species are effectively wind dispersed. Alternatively differences between the experimental populations may exist but were hidden within the large jumps between the concentrations used in this experiment. More detailed research is currently in train to examine germination over a range of intermediate concentrations not examined in the preliminary experiment. Experiments are also in progress to investigate whether population differences are manifested by vegetative plants in response to soil metal gradients as opposed to germinating seed in aqueous culture. Tolerance of germinating seed to lead and copper did however vary between the species. *Chamaenerion* and *Buddleia* show similar tolerance to lead, neither progressed beyond initial radicle protrusion at 500 ppm lead. Tolerance to copper is greater in *Chamaenerion* than in *Buddleia*; *Buddleia* was unable to progress beyond initial radicle protrusion at a lower copper concentration than *Chamaenerion*. These results are unexpected given that both species appear to be equally abundant on metal contaminated sites. Future work on the growth of vegetative plants across metal gradients may provide an explanation for differences between physiological tolerance and observed ecological distribution.

5. ACKNOWLEDGEMENTS

I would like to thank the State Scholarship Foundation of Hellas for funding the research; the Unit of Comparative Plant Ecology, and Analytical Services Unit of the University of Sheffield; Dr AJM Baker for his advice; Ms J Russell for her assistance with SPSS; the support staff of the Department of Landscape; Mr Nick Gibbins, for his constant technical support and assistance. Finally I would like to thank my family for their unlimited support.

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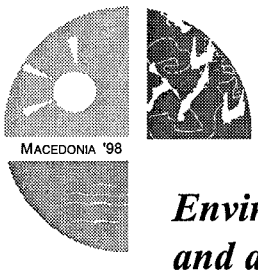
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Environmental law, policy and decision making

INTERNATIONAL LAW AND CONTROL OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH HAZARDS

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ABSTRACT

With the increased globalization of the world economy, occupational and environmental problems have taken on a multi-national and international dimension. The control of these health hazards requires both the harmonization of national legislation, standards, and practices--and international agreements, with mechanisms for enforcement and verification. Areas discussed include (1) the international trade of hazardous products, (2) international trade of equipment and plant, (3) the transfer of technological know-how, (4) international trade of hazardous waste, (5) trans-boundary migration of pollution, and (6) multi-national contributions to pollution affecting the global commons.

ΔΙΕΘΝΗΣ ΝΟΜΟΘΕΣΙΑ ΚΑΙ ΕΛΕΓΧΟΣ ΕΡΓΑΣΙΑΚΩΝ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΙΚΩΝ ΚΙΝΔΥΝΩΝ ΥΓΕΙΑΣ

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ΠΕΡΙΛΗΨΗ

Με την διεθνοποίηση της παγκόσμιας οικονομίας, εργασιακά και περιβαλλοντικά προβλήματα έχουν πάρει πολυεθνικό χαρακτήρα. Ο έλεγχος διαφόρων κινδύνων υγείας απαιτεί εναρμόνηση της εθνικής νομοθεσίας, εφαρμογές μέτρων και διεθνείς συμφωνίες με κατάλληλους μηχανισμούς εφαρμογής και επιβεβαίωσης. Τα θέματα που αναλύονται περιλαμβάνουν 1) διεθνές εμπόριο επικινδύνων προιόντων 2) διεθνές εμπόριο εξοπλισμού εργοστασίων 3) μεταφορά τεχνολογίας 4) διεθνές εμπόριο επικινδύνων αποβλήτων 5) μεταφορά ρυπαντών από μιά χώρα στην άλλη και 6) πολυεθνική συνεισφορά ρύπανσης.

1. INTRODUCTION

With the increased globalization of the world economy, occupational and environmental health problems have taken on a multi-national and international dimension. Legal mechanisms for controlling occupational and environmental health hazards include both the harmonization of national legislation, standards, and practices--and international agreements, with mechanisms for enforcement and verification. So-called "voluntary agreements" and legally unenforceable codes of conduct are also important, even if they are motivated partly by a desire to avoid legal regulation.

The international aspects of occupational and environmental health have taken on new importance because (1) environment, and worker health and safety, are seen as inter-related [1] and are becoming more important in all countries (2) continued inequities have adverse political and social consequences, (3) different levels of protection are viewed as subsidies or barriers to trade, depending on one's point of view [2], and (4) without harmonization and international agreement, inequities and disparities will continue. Efforts at achieving international agreement on environment and workplace health and safety have been spearheaded by the European Union (EU), the Organization for Economic Cooperation and Development (OECD), the United Nations (UN), the World Health Organization (WHO), and the International Labour Organization (IL0)--and through side agreements (addressing environmental and labor standards) to the North American Free Trade Agreement (NAFTA) and to a lessor extent in the General Agreement on Tariffs and Trade (GATT) overseen by the World Trade Organization (WTO). In addition, voluntary efforts have been lead by the United Nations, the International Standards Organization (ISO), and the Coalition for Environmentally Responsible Economies (CERES).

The international implications of occupational and environmental health hazards may be different for (1) the international trade of hazardous products, such as pesticides, (2) international trade of equipment and plant, (3) the transfer of technological know-how with consequential location of donor-designed plant in recipient countries, (4) international trade of hazardous waste, (5) trans-boundary migration of pollution, creating for example acid rain, and (6) multi-national contributions to pollution affecting the international commons, such as damage to the ozone layer and global warming.

The purpose of this article is not to review the more than 150 multilateral agreements on environmental issues on the United Nations Environment Program's (UNEP's) Register, of which approximately 100 were concluded after 1970 [3], but rather to analyze each problem area in terms of (1) the technologies, activities and actors which need to be influenced, (2) the most effective approach to ameliorating the problems within the current legal frameworks, and (3) identifying options for better success in the future.

2. HARMONIZATION OF HEALTH, SAFETY AND ENVIRONMENTAL STANDARDS

Before an examination of individual problem areas, it is useful to review the principal international programs that are attempting to harmonize health, safety, and environmental standards. There are many different kinds of standards, both voluntary guidelines and binding regulations [4]. Some pertain to the safety of products which are used domestically, but which could also be exported. Product standards address product content, labelling, packaging and recycling. European Union (EU) directives on Classification, Packaging, and Labelling of Dangerous Substances (revising the original Directive 67/548/EEC), Marketing and Use of Dangerous Substances (revising the original Directive 76/769/EEC), phasing-out PCBs, recycling packaging waste, and road transport of

hazardous materials are constantly being updated. Those products that are exported and present threats to environment, health, and safety in the receiving countries are addressed in the next section. Other standards refer more to the way products are made or used in industrial or agricultural applications, i.e., process standards. These standards serve to regulate hazards from manufacturing, production, and industrial or agricultural use. Included are occupational safety and health regulations; pesticide application; and effluents, emissions, and waste from energy systems, extraction industries, manufacturing, and agriculture.

Standards may differ in different countries and thus theoretically affect international trade through the imposition of different economic burdens on products destined for export. The World Trade Organization (WTO) is charged with harmonizing the rules of trade to create a more uniform trade environment. WTO tends to view environmental standards which are more stringent than international standards (including both mandatory standards and those of the international voluntary standard-setting organizations) as non-tariff trade barriers under the GATT, while others view inadequate regulation as a subsidy to production on the backs of a lax country's workers or an exploited local environment [2]. WTO members can challenge (and have challenged) environmental standards related to product safety (especially food, plant and animal products) they consider barriers to trade. As a result of the Uruguay Round of negotiations on the GATT, process regulations which affect the final product and are more stringent than international standards may also be deemed to constitute a non-trade barrier. The tendency toward adopting the least stringent or burdensome restrictions in the harmonization of environmental, health, and safety standards implicit in the GATT may be somewhat muted or even countervailed in NAFTA by the side agreements on environment and labor.

ILO conventions on occupational health and safety, and those workplace initiatives contained in European Union (EU) directives are attempts to harmonize worker protection regulation. Parallel efforts exist in the EU for environmental regulation [5]. However, EU directives create bare-bones principles and a general framework for environmental and worker protection. The details of the national legislation are not really harmonized, although a common basic framework and principles do "reduce the likelihood of erratic deviations" in the national laws of EU or OECD member states [4]. Nations are generally free to adopt specific approaches suitable to their general needs and philosophies, and enforcement of standards remains a serious limitation of achieving stated legislative goals.

The most famous EU Directive (82/501/EEC) on the Major Accident Hazards of Certain Industrial Activities, the so-called "Seveso Directive", requires member states to ensure that all manufacturers prove to a "competent authority" that major hazards have been identified in their industrial activities, that appropriate safety measures--including emergency plans--have been adopted, and that information, training and safety equipment have been provided to on-site employees [6]. A revised version of the Seveso Directive came into effect in February 1997 (96/82/EEC). It strengthens the original provisions and coverage of accident-prevention activities, as well as broadens the types of installations which must comply with it.

The OECD has made significant strides in promoting international environmental cooperation. In 1978 the OECD instituted a special Program on the Control of Chemicals under the auspices of its Environmental Program. The chemical control program was designed to harmonize the regulatory efforts of OECD members, to prevent the creation of technical barriers to trade, and to avoid duplication of effort and cost in chemical testing among member nations. As a result, the OECD issued guidelines for (1) assessing the risks of chemicals, including the encouragement of monitoring

at all stages of chemical development, use and disposal, (2) good laboratory practice, and (3) information exchange, requiring notification and consent prior to export of banned or severely restricted use or handling of chemicals [7].

International harmonization of effluent, emission, and waste treatment/disposal standards have been discussed by the OECD, but no binding instrument has emerged. The OECD has responsibility for the Screening Information Data Sets (SIDS), an international voluntary testing program launched in 1989 which is aimed at developing a base set of health/environmental toxicity, exposure and fate data on high-production volume commercial chemicals, and which spreads the cost of testing amongst industrialized countries. The International Program for Chemical Safety (IPCS), funded by the ILO, UNEP, and WHO, is charged with overseeing completion of action items identified in Agenda 21 at the UN Conference on Environment and Development held in Brazil (the Earth Summit). Difficulty exists in achieving international consensus in IPCS's Chemical Classification System for human toxicity criteria for exposures by inhalation encountered in transportation, the workplace, environment, and consumer use. In the meanwhile, the European Chemicals Bureau (ECB) was established in 1993 by a decision of the European Commission following a proposal by the Joint Research Centre (JRC) and the European Commission's Directorate General XI (Environment, Nuclear Safety and Civil Protection). The ECB is a unit of the Environment Institute of the JRC, located in Ispra, Italy. Work areas of the ECB include classification and labelling of dangerous substances, new chemicals, testing methods, existing chemicals, and the import and export of dangerous substances. Stemming from Council Directive 67/548/EEC, the European Inventory of Existing Chemical Substances (EINECS) containing over 100,000 substances was published in 1990.

Such UN Conventions as the Basel Convention on waste trade and the Montreal Protocol on chlorofluorocarbons (CFCs) affecting the global commons, are discussed in subsequent sections.

International conventions become binding on signatory states only after their ratification and implementation, and they are binding on individuals after incorporation into national law. Enforcement and verification of compliance at both the national and individual firm level are obviously crucial if harmonization is to be more than a "paper tiger". Officials or agencies that negotiate agreements are not always those authorized to implement them, governments change, and there may be inadequate regulatory infrastructure [8].

In attempts to get polluters to take environmental standards and guidelines more seriously, the UN Commission on Crime Prevention and Criminal Justice adopted a resolution in 1994 calling for increased use of criminal law to prosecute environmental crimes. The 34-nation Council of Europe published a draft convention that would require member states to protect the environment through criminal sanctions.

In contrast, the International Standards Organization (ISO) has been concentrating on certifying companies for compliance with voluntary environmental management standards. ISO 14000 includes principles, systems and supporting techniques an organization should consider when setting up an Environmental Management System (EMS). Core elements of an EMS are included in the ISO draft 14001 standard as part of the broader ISO 14000 series. These standards address management systems and are not environmental performance standards [9]. To some extent, inconsistencies in regulatory requirements among nations and the difficulty in achieving harmonization of national performance standards prompted this response--which can be described as a commitment toward achieving compliance with environmental requirements, though not one which is strictly enforceable. An earlier standard, ISO 9000, requires company commitment to quality assurance for product

development, production, installation, and service. The U.S., in particular, has been arguing, unsuccessfully thus far, for including job health and safety considerations in the ISO 9000 standard [10]. The trade unions in Europe are especially apprehensive about the possible expansion of the ISO 9000 voluntary approach to incorporate occupational health and safety concerns [11]. In Europe, the EU Eco-Management & Audit Scheme (EMAS) has emerged as a voluntary third-party certification system (similar to ISO 14000) along with the EU's legal requirements (Council Regulation 1836/93/EEC).

In 1994, the United Nations Environment Programme (UNEP) issued a Code of Ethics on the International Trade in Chemicals as a "voluntary" guide to standards of conduct in chemical production and management. The code's three sections address (1) a commitment to improved health, safety and environmental protection, (2) a commitment to testing and assessment, quality assurance, classification, packaging and labelling, information exchange, education and training, and advertising and marketing, (3) periodic monitoring and follow-up of the parties' voluntary compliance, including UNEP's role in reporting progress on the code's implementation. (See also the later discussion of the CERES principles in the context of a single company agreeing to adhere to the same standards in all countries in which it operates.)

3. INTERNATIONAL TRADE OF HAZARDOUS PRODUCTS

Although the United States does not have a comprehensive system for disseminating information on hazardous exports, some attempts have been made to establish notification schemes under existing laws [12]. At present, seven U.S. federal statutes forbid the export of certain banned or significantly restricted substances unless the recipient country has been notified of the regulatory status of the substance in the United States. These statutes apply to toxic substances in general, pesticides, pharmaceuticals, consumer products, flammable fabrics, and waste. The EU has regulations requiring notification (to any recipient country) by member countries exporting chemicals that are banned or severely restricted in the European Union (1734/88/EEC; 428/89/EEC; 2455/92/EEC). Council Regulation 793/93/EEC on the "Evaluation and Control of the Risks of Existing Substances" requires reporting to the European Chemicals Bureau by manufacturers and importers in the EU of some 3900 high production volume chemicals (1000 tonnes annually) on the EINCS inventory before June 4, 1995 and thereafter additional reports for some 10,000 substances manufactured or imported in quantities between 10 and 1000 tonnes per year. The reporting is facilitated by an electronic reporting system using the Harmonized Electronic Data Set (HEDSET). Individual firm HEDSET reports are collected in the International Uniform Chemical Information Database (IUCLID). The HEDSET reporting program can also be used to submit data to the OECD Existing Chemicals Programme.

Safeguards that are based on notification systems alone assume that the recipient countries would fulfill their implied responsibility to ensure that technology is transferred with minimum risk to the health of their citizenry and environment. This applies to both the importation of products, plant and equipment, and to blueprints for manufacturing, energy facilities, and transportation systems that might be indiscriminately used to construct systems inappropriate for the recipient country.

Going a step beyond mere notification, a panel of the UN Commission on Sustainable Development, set up by the UN General Assembly to monitor implementation of Agenda 21, expressed a "strong sentiment" for a right-to-know policy of Prior Informed Consent (PIC), to be required before shipments of hazardous materials could be received from exporting countries. This sentiment has ripened into the International Code of Conduct on the Distribution and Use of Pesticides by the

Food and Agricultural Organization (FAO) of the UN and the London Guidelines for the Exchange of Information on Chemicals in International Trade by the United Nations Environment Programme (UNEP). The procedures for Prior Informed Consent are presently voluntary, but as we go to press, there is serious discussion by the FAO/UNEP Joint Programme on the Implementation of PIC of the creation of a legally-binding instrument for the application of PIC for certain hazardous chemicals and pesticides in international trade.

Whether under notification schemes alone, or with prior informed consent, in order to fulfill its responsibility to its citizens in practice, each recipient country would need to develop or have access to appropriate information systems/data bases, corresponding to those developed or accessed by donor countries or international organizations, that can facilitate the assessment of the efficacy, health, and environmental effects of various technologies in light of the national demographics and unique environment of the recipient country. In order to make full use of these information systems, capability in technology assessment (TA) is of course essential. In addition, the information systems in the recipient countries must be flexible and capable of keeping pace with rapid growth rates in developing countries. But more is needed. The undertaking of technology options analysis (TOA) to identify alternate inputs; final products; and manufacturing, industrial, and agricultural processes; and transportation, and energy systems is also essential. Identifying superior technologies that *could be* adopted or developed, rather than doing "damage control" by performing assessment on existing technologies in use, is a necessary pro-active approach and one not currently required by national or international regulations [13].

The OECD has adopted an initiative on the code of conduct concerning the export of hazardous chemicals. The voluntary code urges exporting countries to adopt standards for exported products to parallel those for domestically-used products. UNEP has established the Global Environmental Monitoring Systems (GEMS), the International Referral Service (IRS), and the International Registry of Potentially Toxic Chemicals (IRPTC) to facilitate uniformity and compliance.

4. INTERNATIONAL TRADE OF EQUIPMENT AND PLANT

Directives 89/392/EEC and 91/368/EEC restrict the free movement of machinery and personal protective equipment, respectively, that do not comply with health and safety requirements affecting workers, consumers and animals (see especially the annexes to these directives which set out the basic health and safety requirements regarding the design and construction of machinery) [14]. These essential requirements theoretically cover all the types of risks to which workers may be exposed at the different stages of the machine's life, i.e., its installation, operation, adjustment, maintenance, cleaning, repairs and transport. Conforming machinery bears the "EC" mark. For certain machines regarded as particularly dangerous, third party certification is compulsory in the absence of harmonized standards before the machine can be marketed. Notably missing in these provisions in practice, however, are ergonomic requirements for machinery and equipment, and technology-based restrictions for industrial production technology that uses or produces harmful chemicals. Although the export of non-conforming technology may be policed in the context of EU trade, it has been suggested that the importing country--especially a non-EU country--is in the best position to restrict undesirable trade through its ministries of commerce, industry and trade [12]. Besides, since equipment and machinery may be used in ways unanticipated by the original supplier or exporting country, the importing country should exercise scrutiny [15]. Information on possible adverse effects from those technologies is essential for proper policing by the importing country. The Advisory Committee to the UNEP Environmental Technology Assessment (EnTA) Programme is currently considering the feasibility of developing non-binding guidelines to the UNEP Governing

Council, especially where the technology involves the production or use of harmful chemicals [16]. The guidelines would address what information on environmental impacts the exporters of technology should provide to importers.

In order to ensure that production technologies imported into a country meet a minimum degree of environmental performance, it could be required that joint ventures or foreign-owned companies meet the same environmental controls as "at home". This is the practice already required by the OECD Council Acts for waste management. (See discussion of the CERES principles below.)

5. THE TRANSFER OF TECHNOLOGICAL KNOW-HOW

Even guidelines on the export of hazardous products, equipment, and plant would not be adequate for preventing the local construction of dangerous production facilities and manufacturing of hazardous products. The Union Carbide plant in Bhopal designed after a corresponding plant in Institute, West Virginia is a notorious example. Here the transfer of *technical knowledge* embodied in plant design is not easily amenable to strict control. Voluntary promises of multi-national corporations who, being signatories to the CERES Principles, agree to operate plants according to more strict home-based regulatory standards may help. [The CERES Principles (formerly the Valdez Principles) is an industry-endorsed model corporate code of environmental conduct drawn up by the non-profit membership organization, the Coalition for Environmentally Responsible Economies]. International conventions on equivalency in waste treatment practices may also help, but neither is likely to be a good substitute for recipient country scrutiny and planning, backed up by requisite capability in technology assessment and knowledge of the risks of alternate technologies [12].

6. INTERNATIONAL TRADE OF HAZARDOUS WASTE

The transfer of hazardous waste is now covered by the 1989 Basel Convention on the Control of Transboundary Movement of Hazardous Waste and Their Disposal (90/170/EEC) and by a regulation addressing its implementation (259/93/EEC). Trans-boundary movement and disposal of hazardous and "other" waste is prohibited unless there is written consent by all countries involved, including transit countries. Further, the exporting nation must be certain that wastes will be managed by the receiving country in an environmentally sound manner. However, the lack of enforcement and verification mechanisms, and inadequate provisions for responsibility and liability for inappropriate disposal of wastes, are major weaknesses [17]. Only 64 out of the 107 countries who signed the 1989 convention have ratified it. In 1994, these 64 countries agreed on a total ban of exports of hazardous waste to countries outside the OECD by 1998, even those wastes destined for "recycling". Although the decision reached in 1994 is not binding, violation of this voluntary agreement on the part of any of the signatories would be greeted by strong international criticism and condemnation.

7. TRANS-BOUNDARY MIGRATION OF POLLUTION

Many (mostly industrialized) countries are expressing concern over the gases SO_2 and NO_X that cause acid rain. While most industrialized nations at the UN Stockholm Conference on the Human Environment in 1972 formerly endorsed the proposition that states have an obligation to control pollution that causes damage to a foreign environment [18], and while the OECD adopted a Council Recommendation on Transfrontier Pollution, actual controls result from national restrictions on those emissions and many bilateral and multilateral agreements. The same is true for shared water systems, like lakes and rivers, and coastal zones. (See also discussion of the pollution of the

Mediterranean in the next section.) Having problems with one's neighbors over pollution serves to provide pressure for regulatory action. This pressure is missing with pollution that disperses into the stratosphere and affects the international commons. However, in 1994, the Geneva-based UN Economic Commission for Europe re-negotiated a 1985 convention on SO_2, which had had some success in forcing a reduction of emissions. The new protocol obliges parties (from 33 countries) to reduce emissions, taking each country's capabilities into account.

Aside from SO_2 and NO_X, other transfrontier environmental problems have been recognized. In the revised Seveso Directive, specific acknowledgement of the inter-country consequences of sudden and accidental releases of chemicals is made. Further, with the advent of concern for bioengineered organisms, there are Council Directives on both contained use of genetically-modified micro-organisms (90/219/EEC) and on deliberate [field] release of genetically-modified organisms (90/220/EEC). Because of the possible multiplication and migration of potentially pathogenic/harmful organisms, neighboring countries as well as other countries have expressed concern.

8. PROBLEMS AFFECTING THE INTERNATIONAL COMMONS

Both greenhouse warming and the destruction of stratospheric ozone are environmental effects that go beyond transfrontier pollution resulting, for example, in the formation of acid rain or the contamination on another nation's rivers. It is an international version of the tragedy of the commons. Two UN resolutions, the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol on Substances That Deplete the Ozone Layer (addressing chlorofluorocarbons) and the International Climate Convention address these problems, but here, as with other international attempts, enforcement and verification mechanisms are sorely lacking. The EU environment ministers agreed in 1994 to phase out hydrochlorofluorocarbons (HCFC's) and methyl bromides faster than the timetable called for in the November 1992 Copenhagen Amendments to the Montreal Protocol. The EU issued a regulation incorporating stricter controls (Regulation 3093/94/EEC replacing Regulation 594/91/EEC on Substances that Deplete the Ozone Layer). In September 1995, representatives of the 149 countries that ratified the 1987 Montreal Protocol drafted a series of recommendations for strengthening the protocol, and in December conference participants agreed to phase out methyl bromide by 2010 and HCFC's by 2020. Ironically, HCFC's which are less damaging to the ozone layer, present more risk for workers who handle them. Thus, the implementation of environmental protection mechanisms and workplace safeguards continues to lack coordination.

Concern for the pollution of the Mediterranean, the largest non-oceanic body of water, has also given rise to a number of directives (77/585/EEC; 81/420/EEC; 83/101/EEC; and 84/132/EEC). The Directive for the North Sea (84/358/EEC) is also relevant. The Mediterranean Action Plan brings together the Mediterranean basin countries in an attempt to address their mutual concerns.

9. HARMONIZATION, ENFORCEMENT, AND RELINQUISHMENT OF NATIONAL AUTONOMY

In 1972, the OECD adopted its "Recommendations on Guiding Principles Concerning the International Aspects of Environmental Policies." These incorporated the "polluter pays" principle and the principle of non-discriminatory (i.e., internationally uniform) application of national standards. It took until 1993, following the United Nations Conference on Environment and Development (UNCED) in 1992, for OECD to follow up with its "Procedural Guidelines on

Integrating Trade and Environmental Policies" which address the need for transparent standards, international consultation and cooperation, and the arbitration of disputes [4]. Harmonization of regulatory requirements, enforcement mechanisms, and actual practices remain a major problem. Nations are extremely reluctant to give up national authority (sovereignty) in health, safety, and environmental matters to either international organizations or to international tribunals for the resolutions of conflicts. Even if the International Court of Justice does hear a dispute, it has no power to enforce its findings or recommendations, through either injunctive or compensatory relief [19]. This is in sharp contrast to the trends occurring in the globalization of trade. Standardization of technologies and trade practices are more often seen as conferring a net benefit on exporting countries.

10. USING TRADE TO IMPROVE OCCUPATIONAL AND ENVIRONMENTAL HEALTH

Although there has been much concern voiced over the health, safety, and environmental consequences of technology transfer and globalization of the world economy, trade practices could actually improve the long-term prospects if judicious policies were developed. An industrialized nation could give *preferential treatment* to environmentally-superior and inherently safer technologies destined for export. Ironically, a superior technology, designed in an advanced country, could actually be deployed *first* in a less-developed receiving country, perfected there, and eventually compete with the older, less-desirable technologies in both the donor and recipient countries. The receiving country could have an equity share in subsequent sales both back to the exporting country and to other developing countries. In this way, trade could be used to improve, rather than compromise, health, safety and the environment. Of course this result would require a deliberate *industrial policy for the environment*, not laissez faire trade practices. Such a policy should not be construed to constitute a trade barrier, but rather a quality enhancement in the exported technology.

International financing institutions, such as the World Bank, can also influence environmentally-superior development by establishing strict environmental guidelines for lending and by monitoring projects as they are implemented [13]. The record of international lending institutions to date, however, has not been impressive.

11. CONCLUSION

The international control of occupational and environmental health hazards is seen to require a variety of instruments and approaches, depending on whether the problems are (1) the international trade of hazardous products, (2) international trade of equipment and plant, (3) the transfer of technological know-how with consequential location of donor-designed plant in recipient countries, (4) international trade of hazardous waste, (5) trans-boundary migration of pollution, or (6) multi-national contributions to pollution affecting the international commons. What all these problems have in common is that the solutions lie in the appropriate national and international regulation of specific products; manufacturing, agricultural, transportation and energy systems; extraction industries; and the service sector,--and in influencing corporate management of occupational and environmental hazards, as well as consumption patterns for goods and services. Commerce and trade, and health, safety, and environment are inter-linked and solutions must address those linkages. Regulation of hazardous technologies is not sufficient. Environmental, worker health and safety, development, and trade policies must be integrated wherever possible.

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THE MULTIPLICITY OF SOURCES OF GREEK ENVIRONMENTAL LAW AND THE INTEGRATION OF THE RELEVANT POLICY

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ABSTRACT

The corpus of greek environmental legislation derives from multiple sources. Most of these sources are of supranational character. This point has influenced in several ways the integration of greek environmental policy. In this paper we examine the influence on the clarity of the goals and the relation of greek environmental policy with the unique peculiarities of greek environment and greek society.

Η ΠΟΛΛΑΠΛΟΤΗΤΑ ΠΗΓΩΝ ΤΗΣ ΕΛΛΗΝΙΚΗΣ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗΣ ΝΟΜΟΘΕΣΙΑΣ ΚΑΙ Η ΟΛΟΚΛΗΡΩΣΗ ΤΗΣ ΣΧΕΤΙΚΗΣ ΠΟΛΙΤΙΚΗΣ

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ΠΕΡΙΛΗΨΗ

Η ελληνική περιβαλλοντική νομοθεσία προέρχεται από πολλαπλές πηγές, οι περισσότερες από τις οποίες είναι υπερεθνικού χαρακτήρα. Αυτό το χαρακτηριστικό έχει επηρεάσει με διάφορους τρόπους την ολοκλήρωση της ελληνικής περιβαλλοντικής πολιτικής. Στη παρούσα εργασία εξετάζουμε τις επιπτώσεις στη σαφήνεια τών στόχων και στη σχέση της ελληνικής περιβαλλοντικής πολιτικής με τις ιδιαιτερότητες του ελληνικού περιβάλλοντος και της ελληνικής κοινωνίας.

1. INTRODUCTION

The sources of the corpus of legislation on any sector of state intervention characterize the nature, the form, and the cohesiveness of the relevant public policy, since legislation is not only a major element, but also the most binding instrument of any policy. In most countries national legislation on the sector of environmental protection is more or less influenced by the goals, activities and measures set by international law or by the law of regional organizations with relevant activities (supranational sources of legislation). This feature is by no means condemning and it fits the nature of most environmental problems which «have no boundaries».

In this paper we focus on the interaction of the supranational sources of greek environmental legislation with what we call "national environmental policy". First, we make a brief review of the time periods during which supranational environmental law entered the corpus of greek legislation (2.0). The next two paragraphs deal with raising two questions that in our opinion create an extensive field for empirical research: a) the way supranational sources are incorporated to what we call "national environmental policy (par. 3.0), and b) the adaptation of the goals and measures set by the supranational sources to the unique peculiarities of the greek environment and the greek society (par. 4.0).

2. THE SUPRANATIONAL SOURCES OF GREEK ENVIRONMENTAL LEGISLATION

In the short history of greek environmental legislation we can distinguish three time-periods according to influence of supranational sources on it. This influence depended on major events and activities happening both in the international and the national level.

2.1. The period 1945-1970

In the years after the IWW, several international organizations took initiatives in environmental issues. Some of these initiatives were of binding character, taking the form of international conventions[1], new organizations[2] and specialized programs[3].

Greece was an eager participant in all of these international initiatives, signing and ratifying the international conventions and participating in the new organizations and programs. It also signed several bilateral or multilateral agreements with neighboring countries, in issues concerning mainly the management of transboundary natural resources[4].

However, the relevant legislative activities of the greek state during that period are characterized by the protection of the environment with *only indirect means*[5]. Most of these laws are still presently in force, although with amendments. Every one of these sectors of legislative intervention was formulated and materialized from quite different authorities, in order to fulfil quite different needs. Of course their philosophy and goals never converged.

2.2. The decade of 1970's

The decade of the 1970's is considered to be of heightened international environmental awareness. The major event was the Stockholm Conference in 1972, which was the starting point for a series of important initiatives in the level of international and regional organizations in that decade[6]. Therefore, by mid-1970, there was a plethora of international forums where the environmental issues were treated and any state willing to start relevant activities, had a range of options from which to draw standards, support and experience (Jacobson, 1983).

In the beginning of 70's the military government of Greece took a number of initiatives which are considered to have established the **first greek environmental policy agenda**. Some of these initiatives were the declaration of 1970 as «Year for the Protection of Nature», the embodiment of the «environment» in the Long-term Development Program (1970-1985) as an independent sector, several administrative changes, etc. It is supported that this first registration of the environment in the policy agenda owes a lot to **international pressure**. It is the case of intra-level cross fertilization between states according to Hogwood and Peters (Spanu, 1995b).

Besides, the special provision in the new Constitution of 1975 about the obligation of the state to protect the natural and cultural environment (article 24 par. 1)[7] and the enactment of Law 360/1976 "On Spatial Planning and the Environment", are considered to be the first **policy output** of greek environmental policy.

At the same time Greece ratified several international conventions for the protection of the environment, which were used as a standard for the construction of greek environmental legislation. On specific issues, these international conventions are the **only** legislation available in our country. Outstanding examples of that case are the Ramsar Convention for the protection of Wetlands, or the Bern Convention on the Conservation of the Wildlife and the Natural Environment of Europe.

2.3. The period from 1980 to present

During the last 18 years, the greek state proceeded in a series of activities that have created a significant amount of environmental legislation and have led to the "growing up" of the protection of the environment in our country (Papadimitriou, 1995). It is calculated that up to 1990, there were more than 800 environmental laws and administrative orders (Stevis, 1992).

The sources and causes of this legislation are twofold: Firstly greek governments try to face the national environmental problems (esp. measures to fight the problem of air pollution in Athens[8], planning laws to face the human settlement and urban planning problems[9]). Besides, they try to construct the necessary legal and institutional framework for the protection of the environment (Framework Law 1650 "On the Protection of the Environment", creation of new administrative structures[10]).

However, the fact that has characterized most than anything else the development of greek environmental legislation of the period is the process of harmonization with the **European Community Law**. This process has enriched the body of greek legislation with more that 200 complete and well-processed environmental directives and a plethora of regulations and guidelines for parallel activities. Of course international soft and hard law produced during these years is still an important source for greek legislation.

3. QUESTIONS ON THE COHESION AND THE INTEGRATION OF GREEK ENVIRONMENTAL POLICY

As it is obvious from the short review made above, greek environmental policy derives from multiple sources, most of which are of supranational character. We can notice the initiatives of the greek state for the protection of environmental goods are in the most cases ex post reactions to ad hoc problems (air pollution, human settlement, sewage, waste problems, etc.). An important part of greek environmental legislation came from the international obligations of Greece and its participation to the European Union.

In fact, this characteristic has benefited a lot the content and the completeness of the relevant regulations and obviously fits the nature of environmental problems. Our criticism here does not concern the character of supranational sources. It concerns their interaction with what we call "national environmental policy". The starting point of our discussion is the fact most researchers agree that greek environmental policy has a **fragmented character**[11]. This finding is based on two elements:

a) There is no clear **policy framework**, with cectain goals and program of action. Law 1650/1986, which consists the current legal framework for the protection of the environment, ignores three major sectors of environmental management: sea pollution, cultural and manmade environment and the protection of forests and no care has ever been taken for their incorporation into the general environmental policy. Also the "programs for the protection of the environment" which were foreseen by Law 360/1976 never worked.
b) There is a **plethora of administrative agencies** with environmental responsibilities and luck of a permanent and strong mechanism for their **co-ordination** (see C.E.C. 1993). This situation has resulted the diffusion of activities and the fragmentation of decisions and action in many points of the administrative structure. Competent ministries refuse to yield decisive responsibilities to YPEHODE, which according to law 1650/86 is the main responsible for the formation of environmental policy. This resistance creates and perpetuates further fragmentation both in the **formation** and in the **implementation** of sectoral environmental policies.

The further result of this situation is that as we have proved elsewhere (Dalacu, 1997), what we call "national environmental policy" consists of **a sum of "policies for the protection of environmental goods"** (e.g. air pollution policy, policy for the protection of sea pollution, pesticides policy etc). This sum of policies has failed so far to form an integrated and comprehensive environmental policy.

The obvious question from this finding is: "How does this fragmented and multi-scattered policy system absorb rules, measures and policies coming from multiple supranational sources?"

Possible answers to this question are not simple, and they deserve comprehensive empirical work. Part of that work has already started in the Department of Environmental Studies in the University of the Aegean. The focus of study is the allocation of responsibilities and action during the whole process of the policy process: participation in the decision – making process of supranational bodies, implementation and evaluation of policies, accounting to supranational organs.

So far, the literature review has already shown that, as it was expected, the implementation of our country's supranational obligations follows the fragmentation of national environmental responsibilities and actions. Ministries responsible for one sector of environmental protection are also responsible for implementing the supranational obligations concerning the same sector. After the disuse of interministerial committees foreseen by law 1104/80, there is no institutionalized and known co-ordination framework, even for the formation of greek stances on european issues. Moreover, it has been stated that the public agencies charged with the implementation of supranational policies face them as something *foreign,* external and irrelevant with their pure responsibilities (Makridimitris Passas, 1994).

4. THE NEED FOR ADAPTATION OF SUPRANATIONAL PROVISIONS TO INTERNAL PECULIARITIES

The fact that greek environmental policy comes from supranational sources poses also the question of the way this legislation is specified and adapted to the unique features of greek environment and greek society. In order to examine closer this question, we can use Hofferbert's conceptual frame-

work of the policy process with policy decisions as the dependent variable (Sabatier, 1991). The whole approach is named the "Funnel of Causality", from the diagrammatic picture it gives.

As indicated in Figure 1, policy decisions are seen as a direct and indirect function of five driving forces: historical-geographic conditions, socioeconomic conditions, mass political behavior, governmental institutions and elite behavior. The facts happening in any one of those levels inherit characteristics or results -positive or negative- to the next level of political incidents and so on. The chain of direct and indirect effects continues until they acquire the form of a policy output.

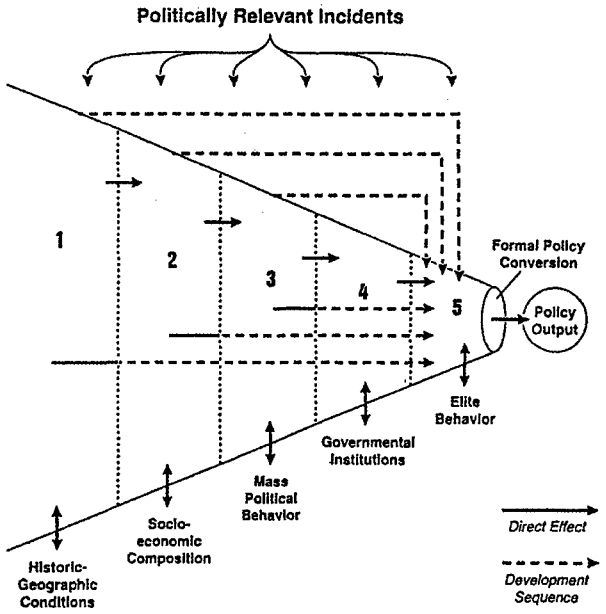


Figure 1. Hofferbert's Model for Comparative Study of Policy Formation
(Source: Sabatier A., 1991)

The driving forces leading to a policy decision in supranational level, are obviously those of the level they concern (international, regional, european and so on). This means that the funnel of causality is based on a quite broad **scale** of problems, data and conditions that have caused policy decisions. Usually supranational policy decisions are the **lowest common denominator** of the interests of the countries participating in the decision-making process (Palaiologou, 1994).

When a policy decision based on the rationale of the "lowest common denominator" needs to be implemented in one country the driving forces that have caused it are of a quite different scale. The difference on scale is not only quantitative, but also qualitative. Each society creates quite different

functions on the five levels of the funnel of causality: Historic-Geographic conditions, Socioeconomic Composition and Mass Political Behavior, Government Institutions and Elite Behavior.

This fact proves the need for **adaptation** of supranational environmental decisions. The adaptation concerns:

a) The unique peculiarities of greek **natural and manmade environment**: Although the environmental problems are not restricted to the national boundaries, it is generally accepted that the greek environment has special features that should be taken into account in any environmental management effort. Some of these features are: the insular nature of most greek territory; the plethora of endemic species; the big variety of natural ecosystems; the extensive existence of archeological treasures, etc. In addition, the intensity and the range of environmental problems in Greece are unique. Most analysts agree that the most important environmental problems in Greece are the urban air pollution and wastes which are considered to be «national problems», since they affect greek cities where more than 60% of the greek population lives. Other problems are soil degradation, fires, dangers on biodiversity (Stevis, 1992, O.E.C.D., 1983).

b) the **societal and cultural features of greek society**. Most policies are intended to rule the **behavior** of groups of people or of a whole society. In order to rule behavior, one should first study and take account of the existing **patterns of behavior** towards the specific issues. Usually the patterns of behavior are an expression of existing attitudes, values, habitus, or even of informal social institutions (Barbour, 1980) of the specific groups towards the specific issues or goods.

The issue of adaptation may seem quite obvious, but we believe it should be examined further, since there is evidence that it has not received the proper attention during the implementation of supranational policies and legislation from the greek state.

An example that reflects this disregard is the process of harmonization to european directives. Most of the Ministerial Decisions issued during that process are just translations of the relevant directives. While almost all the directives of the European Union have a standard provision that the member states can take stricter measures from those of the directive, Greece has made use of this provision only once, during the harmonization with directive 76/160 on the quality of bathing water (Palaiologou, 1994).

5. DISCUSSION

International or transnational co-operation is a necessary precondition for environmental protection. The products of this co-operation, in the form either of soft or of hard law have influenced in various ways greek environmental policy. First of all they have played a very important role in the process of agenda setting and policy formulation. International and european law also compose a large part of greek environmental legislation.

Nevertheless, our obligations to international organizations or the European Union seem to remain unknown to greek citizens and their representatives. For example, it has been proved that the provisions of european law are only rarely invoked in the process of parliamentary questioning in Greek Parliament (Hlepas, 1994). Also, in some cases Greece has failed to comply with its supranational obligations, as is the delay in the production of any national plan on sustainable development, according to the provisions of Rio Convention. (Fousekis, Lekakis, 1997).

In this paper we have focused on two issues that have obstructed supranational sources to play the best of their role. One is the fragmentation, which characterize both the formation and implementation of environmental policies in Greece. The second is the absence of serious care for the adaptation of supranational law to the unique peculiarities of the greek natural and manmade environment and the societal and cultural features of greek society.

The issues that were mentioned in this paper rather raised a field of scientific hypotheses and empirical research, than gave certain answers. Our strong belief is that they deserve serious attention both from researchers and from policy-makers, since the facing of the relevant problems would contribute to the efficiency of the efforts for environmental protection in Greece.

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[1] e.g. London convention on «Prevention of Pollution of the Sea by Oil» (1954/1962)

[2] e.g.IUCN in 1948, WWF in 1961, IMCO in 1954, Directorate for Environmental Affairs in the OECD in 1970, etc.
[3] e.g. World Weather Watch in 1967, Man and Biospher in 1970.
[4] N. D. 4012/1959, N.D. 4410/1964, A.N. 55/1967
[5] In 1932 the first Planning Law appeared, which was restricted to the basic level of physical planning, without any mention to land use or regional planning. We also had legislation for Antiquities (1932), National Parks (1937), Sewage (1965), pesticides (1967), etc..
[6] e.g. Barcelona Convention for the «Protection of the Mediterranean Sea against Pollution» (1976), Geneva Convention on «Long-Range Transboundary Air Pollution» (1979), Berne Convention on the «Conservation of the Wildlife of Europe's Natural Environment» (1979), etc.
[7] We should mention here, the relevant and unique jurisprudence of the Greek Counsil of the State, based on the constitutional provision (see decisions 3047, 3048/80, 262/82), which has directed the sources of environmental policy and the action of the State in a wider sense of environmental protection .
[8] e.g.. regulation of the quality of fossil fuels; implementation of emergency measures; traffic regulation
[9] Laws 947/1979 and 1337/1983
[10] Establishment of YHOP, in 1980, and YPEHODE in 1985
[11] see Spanu 1995a, Dalacu 1997, Fousekis, Lekakis, 1997

THE INTERNATIONAL LEGAL REGIME FOR THE PROTECTION AND RESTORATION OF THE OZONE LAYER

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ABSTRACT

The International Legal Regime for the Protection of the Ozone Layer is one of the most completed global attempts aiming to protect and restore a globally common good. Target of this study is to present, in general lines, the attempt. Moreover it aims to show, on the one hand its difficulties and particularities and on the other the principles and the factors trough which the international community could deal with similar problems.

ΤΟ ΔΙΕΘΝΕΣ ΝΟΜΙΚΟ ΚΑΘΕΣΤΩΣ ΓΙΑ ΤΗΝ ΠΡΟΣΤΑΣΙΑ ΚΑΙ ΑΠΟΚΑΤΑΣΤΑΣΗ ΤΟΥ ΣΤΡΩΜΑΤΟΣ ΤΟΥ ΟΖΟΝΤΟΣ

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ΠΕΡΙΛΗΨΗ

Το Διεθνές Νομικό Καθεστώς γιά την Προστασία του Στρώματος του Οζοντος αποτελεί μία από τις πιό ολοκληρωμένες προσπάθειες, σε παγκόσμιο επίπεδο, να προστατευθεί και να αποκατασταθεί ένα αγαθό παγκοσμίως κοινό. Στόχος της εργασίας αυτής είναι να παρουσιάσει στις γενικές της γραμμές την προσπάθεια αυτή και να καταδείξει τόσο τις δυσκολίες και τις ιδιαιτερότητες, όσο και το πλαίσιο αρχών και παραγόντων μέσω των οποίων μπορεί η παγκόσμια κοινότητα να διαχειρισθεί παρόμοια ή ανάλογα προβλήματα.

1. INTRODUCTION

Ozone is a "natural atmospheric constituent" [1]. The 90% of this element is part of the stratosphere [2]. It's main function is to absorb a great deal of Ultraviolet Radiation, before this radiation reaches the earth's surface, creating this way a shield for humans, other animals and plants. Moreover it has an important role in keeping temperature onto earth's surface at a normal level [3]} and contributes to the stability of the climate structure [4].

In conclusion we realise that ozone is crucial for maintaining life on earth (at least in the form we know it so far).

2. GLOBALLY COMMON GOODS OR INTERNATIONAL COMMONS

2.1 Theoretical approach

Ozone layer falls in a category of goods that international community started to talk about, only the last thirty years. Traditionally the prevailing attitude was the one saying that such goods are unlimited and have endless capacity of absorbing and decomposing wastes and emissions. The last decades, though, the above impression changed and issues such as protection and restoration of those goods emerged.

Ozone layer is viewed as a good of common concern or as international or global common [5]. Such a status has a double result:
First, its alteration insults the rights "of the community of states as a whole" [6], because anywhere in the atmosphere, means everywhere in the atmosphere.
Second, all states have a legal interest in protecting it [7].

It's true that although the depletion of the ozone layer was due to activities (production and consumption of Ozone Depleting Substances) of certain countries, nobody could say which particular activity was responsible for which part of the depletion. Moreover it was possible for every country to contribute to the depletion any moment, by starting such activities.

From all the above we conclude that only with common action by all states the problem could be faced: the ones which contributed to the depletion should bind themselves to stop all the disturbing activities; the others who didn't contribute yet should bind themselves not to get involved in such activities in the future. On both cases present and future interests are affected, economic and developmental ones [8].

With goods like ozone layer there are great dangers [9]. Since it's a globally common good its depletion affects everybody and not only the one that causes the depletion. The meaning is that in short-terms the benefit of the acting country is much greater comparing to the damage allocated. In long-terms, though, if the destructive action is amplified and multiplied, the globally common good becomes useless for all.

Additionally, if **some** countries, carrying destructive activities, terminate or minimise them, then ozone depletion would be limited and **all** countries would benefit. Such a way of thinking would result , for the countries, in continuing their destructive activities wishing to benefit by the restrictions of the rest. If such a behaviour is followed by the most of the countries, then no limitation of the destructive activities would occur and nobody would benefit. On the contrary this attitude would probably result in irreversible consequences.

All the possible problems and dangers mentioned above, were reinforced by the scientific uncertainty that covered the causes, the consequences and the scale of the Ozone depletion.

International community decided to base its action on a set of "new", for the time, principles:

- The precautionary principle [10].
- The sustainable development principle [11].
- The balance of interests between developed and developing countries principle.
- The broad co-operation principle.

3. THE DEPLETION OF THE OZONE LAYER

3.1 The problem

Ozone is an unstable gas created and destroyed by solar radiation [12]. It's also destroyed naturally by natural compounds containing oxygen, nitrogen, chlorine, bromine and hydrogen [13]. It was in the '70s when two scientists from the USA, F.S.Rowland and M.Molina, pointed out the highly destructive action of a number of human-produced gases, the halocarbons. In these gases are included chlorofluorocarbons (CFCs), bromofluorocarbons and Halons.

These chemicals are very inert, so they don't react in the lower atmosphere and they don't cause any pollution. But the truth is that they are transported to the stratosphere and they react there with high-energy photons from sunlight and they released chlorine or bromine atoms. These atoms are involved in a catalytic circle and can destroy about 100.000 ozone molecules before they are washed back to the troposphere [14]. The above ozone-destructive process is much stronger and fatal over the Antarctic continent because of the unique weather conditions that prevail in the atmosphere there. The ozone decline is so great that became known with the term "ozone hole". The different conditions over the Arctic is the reason for which the destruction is not so great there [15], though the last years extreme declines occurred [16].

3.2 The ODS (Ozone Depleting Substances) and their uses

Substances	Uses
Halons	Fire Extinguishing
Methyl Chloroform ($C_2H_3Cl_3$)	Solvent
Carbon Tetrachloride (CCl_4)	Solvent, raw material for CFC_{11} production
CFCs	Refrigerators fluids, propellants in aerosol cans, blowing agents for foams, solvents, sterilants
HCFCs	CFCs substitution
Methyl Bromide (MBr)	Fumigant in agriculture and storage

3.3 The consequences of the ozone depletion

1. Contribution to the increase of the solar UV radiation that reaches the earth's surface [17].
2. Contribution to the change of the atmospheric temperature and so to the climate change [18].

The first of the above, has effects on:

- Human and animal health (increase of: skin cancer cases, eyes problems cases and infectious diseases cases, damages to DNA, suppression of the body's immune system [19]).
- Terrestrial plants (effects on plants growth, biodiversity, plants productivity) [20].

- Biogeochemical circles [21].
- Synthetic materials [22].
- Photochemistry of the troposphere [23].

4. THE INTERNATIONAL LEGAL REGIME FOR THE PROTECTION OF THE OZONE LAYER

4.1 The history

1957: Scientists started observing and measuring stratospheric ozone from a station in Antarctica.
1974: Stolarski and Cicerone focus on the possible destructive behaviour of chlorine for stratospheric ozone. Rowland and Molina combine the CFCs behaviour in the stratosphere with the ozone destruction. They focus on sprays, the media spread the news and the pressure for controls grows.
1977: The "World Plan on Action on the Ozone Layer" was adopted under UNEP.
1981: UNEP establishes the Ad Hoc Working Group of Legal and Technical Experts for the Elaboration of a Global Framework Convention for the Protection of the Ozone Layer.
1985: The Global Framework Convention for the Protection of the Ozone Layer was adopted in Vienna. It doesn't include any controls on ozone depleting substances but sets the frame for future controls and the members were binded in adopting such measures with a protocol.
In 1985 British scientists "discovered" the ozone hole over Antarctica and an american satellite confirm the observation. It's the first time that there are proofs about severe ozone depletion, but there is no proof for the connection between CFCs and ozone depletion, yet.
1987: In the 16th of September the Montreal Protocol on Substances that Deplete the Ozone Layer, was signed.
1988: In the 15th of March the most important report for the connection between CFCs and ozone depletion was published. It's the report of the "Ozone Trend Panel" which concludes that CFCs are responsible for the "ozone hole" over Antarctica [24].

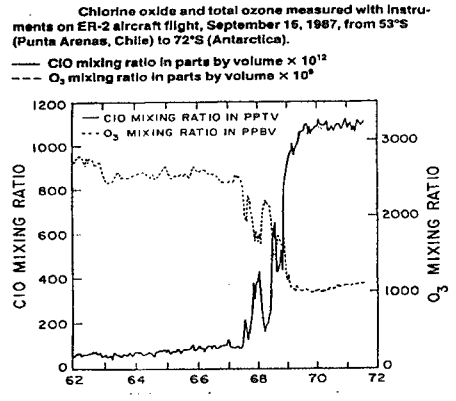


Figure 1. [25]

The same year another report was published concerning the bromine substances.
1990: The Protocol was amended in London
1991: An Interim Multilateral Fund was established. It had a three-year budget and its purpose was to provide financial and technical assistance to developing countries-parties to the regime, for supporting the implementation of its controls.
1992: The Protocol was amended for the second time in Copenhagen, so that the phase-out schedules speed-up and the Multilateral Fund became permanent.
1995: The members adopted the phase-out schedule for the developing countries which were exempted for ten years from the protocols restrictions.
1997: The members met in Montreal and amended the protocol again.

In every amendment and adjustment the regime was becoming stricter for the controlled substances and new substances were added to the already controlled.

4.2 The regime's restrictions

The restrictions focus on two areas:
First the production and consumption of ozone depleting substances. The final target is the complete phase-out of them and their replacement, in the first place, with transitional substitutes and, finally, with ozone friendly processes and alternatives.

TABLE 1. The phase-out schedule for developed countries

Substances (basis)	Montreal 1987 London 1990	Copenhagen 1992	Vienna 1995	Montreal 1997
CFCs 11,12,113,114 115 (1986) Annex A,I	1/7/1989: freeze 1/1/1995: -50% 1/1/1997 -85% 1/1/2000: -100%	1/1/1994: -75% 1/1/1996: -100%		
Halons 1211, 1301 2402 (1986) Annex A,II	1/1/1992: freeze 1/1/1995: -50% 1/1/2000: -100%	1/1/1992: freeze 1.1.1994: -100%		
10 new CFCs (1986) Annex B,I	1/1/1993: -20% 1/1/1997: -85% 1/1/2000: -100%	1/1/1993: -20% 1/1/1994: -75% 1/1/1996: -100%		
Carbon Tetrachloride (1989) Annex B,II	1/1/1995: -85% 1/1/2000: -100%	1/1/1995: -85% 1/1/1998: -100%		
Methyl Chloroform (1989) Annex B,III	1/1/1993: freeze 1/1/1995: -30% 1/1/2000: -70% 1/1/2005: -100%	1/1/1993: freeze 1/1/1994: -50% 1/1/1996: -100%		
34 HCFCs (1989+3,1% of CFCs consumption in 1989)* Annex C,I		1/1/1996: freeze 1/1/2005: -35% 1/1/2010: -65% 1/1/2015: -90% 1/1/2020: -99,5% 1/1/2003: -100%	* The 3,1% reduced to 2,3% (article 2F§1(α) Annex II)	
34 HBFCs Annex C,II		1/1/1996: -100%		
Methyl Bromide (1991) Annex E		1/1/1995: freeze	1/12001:-25% 1/12005:-50% 1/1/2010: - 100% (article 2H)	1/1/1999:- 25% 1/1/2001:-50% 1/1/2003:-70% 1/1/2005:-100% (article 2H§2-4)

Second the trade of ozone depleting substances, products and technology, as a motive for countries to bind themselves by the regime.
The regime has also used two other techniques in order to become attractive for the developing countries:

- It gave a ten-year grace period for member-countries with very-very low consumption of controlled substances.
- It recognised the difficulties that developing countries might face by trying to comply with the regime restrictions and established The Multilateral Fund for financial assistance.

TABLE 2. The phase-out schedule for developing countries

Substances (basis)	Vienna 1995	Montreal 1997
CFC $_{11,12,113,114,115}$ (the average consumption and production 1995-97) Annex A,I	1/1/1999: freeze 1/1/2005:-50% 1/1/2007: -85% 1/1/2010: -100%	
Halons 1211, 1301, 2402 (1995-97) Annex A,II	1/1/2002: freeze 1/1/2005: -50% 1/1/2010: -100%	
10 new CFCs (1998-2000) Annex B,I	1/1/2003: -20% 1/1/2007: -85% 1/1/2010: -100%	
Carbon Tetrachloride (1998-2000) Annex B,II	1/1/2005: -85% 1/1/2010: -100%	
Methyl Chloroform (1998-2000) Annex B,III	1/1/2003: freeze 1/1/2005: -30% 1/1/2010: -70%	
34 HCFCs (2015) Annex C,I	1/1/2016:freeze 1/1/2040: -100%	
34 HBFCs (2015) Annex C,II	1/1/1996: - 100%	
Methyl Bromide (1995-98) Annex E	1/1/2002: freeze (quantities for quarantine and pre-shipment applications are exempted)	1/1/2005: -20% 1/1/2015: -100% (article 5§8 ter,d,iv)

4.3 Range of the regime

The member- states of the Vienna Convention and the Montreal Protocol are 163, but it's much smaller the number of the countries that have ratified the London and the Copenhagen amendments.

5. THE MAIN FACTORS CONTRIBUTING TO THE OZONE PROTECTION REGIME

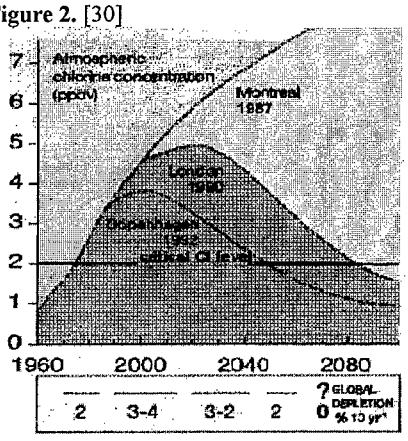
- Science. It has been said that "Vienna Convention and its Montreal Protocol provide a dramatic example of science in the service of human kind" [26]. It was science that managed to persuade decision makers to deal with a possible threat and not with a fact.
- The excellent co-operation of the two UN bodies, UNEP and WMO, that put the whole process under their auspices.
- The strong movement created by the NGOs.
- The strong leadership by a group of countries which played the role of the locomotive in the beginning of the process.
- The manageable financial scale of the problem.
- The special provisions for the developing countries.
- The rather simple and not particularly expensive substitution process of the ozone depleting substances.

6. THE RESULTS OF THE REGIME TILL NOW

6.1 From an environmental point of view

– The total ODS production and consumption has noticeably been decreased.
– The CFCs emissions in the atmosphere have been declined by 34% from 1988 till 1992 [27]. In general, the increasing rate of the ODS concentration in the atmosphere has been declined [28].
– If all the regime restrictions and provisions will be strictly implemented by the member states, then the ozone layer will reach at the pre 70s acceptable levels by 2050 or even later [29].

Figure 2. [30]



6.2 From a legal point of view

The ozone protection regime was one of the first legal "products" setting or reassuring, the main principles (mentioned above 2.1) on which the International Environmental Law should develop.

All these principles have been implemented through several provisions of the regime, such as:

- The Multilateral Fund provision (article 10).
- The transfer of technology provisions (art. 10A).
- The trade restrictions provisions (art.4).
- The ODS phase-out provisions (art.2).

7. CONCLUSIONS

The International Legal Regime for the Protection of the Ozone Layer has been one of the most successful examples of how we can attempt to protect and restore a globally common good.

The almost 20 years of ongoing efforts prove that only with a highly cross-scientific approach, common action and full acknowledgement that environmental policy costs, international community has serious hopes to assure a sustainable future for the coming generations.

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INDUSTRIAL ACTIVITY AND ENVIRONMENTAL POLICY IN THE EU. A LEGISLATIVE APPROACH

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ABSTRACT

The new Council Directive 96/61/EC concerning the integrated pollution prevention and control (IPPC) is one of the most recent environmental tools of new European Policy for industrial pollution abatement. In the present work, the basic requirements and aims of the Directive are analyzed, the current licensing procedure existing in certain EU member states is presented and the results of a preliminary research financed by the EU, concerning the successful implementation of the IPPC Directive in Greece are presented. In addition, alternatives on the organization of the Greek competent authorities and of the permitting system, which will unify and update the whole legislative situation of environmental permitting in Greece, are proposed.

ΒΙΟΜΗΧΑΝΙΚΗ ΔΡΑΣΤΗΡΙΟΤΗΤΑ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗ ΠΟΛΙΤΙΚΗ ΣΤΗΝ ΕΕ. ΝΟΜΟΘΕΤΙΚΗ ΑΝΤΙΜΕΤΩΠΙΣΗ

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ΠΕΡΙΛΗΨΗ

Το πλέον σύγχρονο εργαλείο άσκησης περιβαλλοντικής πολιτικής στην ΕΕ είναι η νέα Οδηγία 96/61/σχετικά με την Ολοκληρωμένη Πρόληψη και Έλεγχο της Ρύπανσης (IPPC). Στην παρούσα εργασία παρουσιάζονται οι βασικές αρχές που διέπουν τη νέα Οδηγία και το σύστημα αδειοδότησης που ισχύει σε Κράτη-Μέλη της ΕΕ. Παρουσιάζονται επίσης τα αποτελέσματα ειδικής μελέτης στον Ελληνικό χώρο, αναλύονται οι αναμενόμενες επιπτώσεις από την εφαρμογή της Οδηγίας στην Ελλάδα και προτείνονται εναλλακτικές δυνατότητες οργάνωσης της εφαρμογής της.

1. INTRODUCTION

In order to tackle pollution problems resulting from industrial activities most effectively, the European Community has adopted the implementation of an integrated system of pollution prevention and control. An integrated system of pollution prevention and control regards the environment as a whole and aims to solve the problem of pollution by preventing the creation of polluting substances. Wherever it is not possible to do so, the integrated system of pollution prevention and control aims to minimize the risk of harm to the environment from industrial and other relevant activities. The system of Integrated Pollution Prevention and Control is now adopted by Directive 96/61/EC, which will introduce the principles for the integrated permits for certain highly polluting industries. The level of effort required to prevent or reduce pollution will be based on **Best Available Techniques** (BAT). The Directive also establishes the relationship between **emission limit values** (ELV) set using BAT and **environmental quality standards** [1].

The system of integrated pollution prevention and control takes into account the effects of substances, or of industrial activities on the three environmental media, air, soil and water in the framework of the procedure of granting permits [2]. In this manner it goes beyond the traditional approach to control the emissions in the environmental medium in which they are released (for example, air), but also addresses the potential of those emissions to cross over into other environmental media and cause harm to waters and soil [3].

Greece should take all the necessary measures in order to harmonize the national environmental policy with the provisions laid down by the Directive, from the date of implementation (October 1999). For example, the Directive requires that industrial permits must set emission limit values based on what is achievable through the use of the Best Available Techniques. The concept of BAT is defined as «the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable to, generally reduce emissions and the impact on the environment as a whole»[1].

The determination of BAT for the industrial sectors covered by the Directive will take place at EC level. The selected BAT will be available to the Member States through a Central Data Base and each Member State will be responsible for the dissemination of information within the State[4].

2. EXISTING SITUATION IN MEMBER STATES

Until now the EC legislation approach concerning the industrial pollution prevention was basically oriented towards the three environmental media separately. The framework law is the 76/464/EC Directive which concerns with the pollution caused by dangerous substances and their discharge into aquatic systems and the 84/360/EC Directive which concerns the atmospheric pollution caused by industrial units. A comparison of the three industry Directives (76/464/EC, 84/360/EC and 96/61/EC) is presented in Table 1, and the fundamental characteristics of the licensing procedure of certain Member States are briefly described below [5]:

France

Pollution control is based on a technical/economic approach which consists of using the best available anti-pollution techniques not entailing excessive cost. Classified installations are inspected not by the prefect but by a separate inspection service (DRIRE) before an application for a permit is made.There are no specific requirements for BAT use. In several cases BATNEEC are enforced.

National Laws and Decrees designate the emission limit values for air pollutants and waste disposal as well as the environmental quality standards.The licensing is based on EC Directives that are enforced on national level. The criteria concerning the permitting procedure are based on the EQS, the emission limit values and on the major accident hazard notifications. The responsible bodies for the licensing are the relevant Ministries and the Secretariat General for Environment.

TABLE 1. Comparison of some administrative requirements between Directives 76/464/EC, 84/360/EC and 96/61/EC (IPPC)

Administrative procedure	Instrument	Directive 76/464/EC	IPPC Directive	Directive 84/360/EC
PERMIT	Renewal frequency	4 yrs	periodically	none
	Level of control determined by:	Toxicity of the substance	Best Available Techniques	Best Available Techniques not Entailing Excessive Costs
	Control method	ELV or EQO	ELV and EQO	ELV and quality limit value
MONITORING	Single substance	yes	yes	yes
	Group/sum parameters	very limited	yes	yes
	Toxicity of emission	No	yes	No
AUTHORITIES ISSUING PERMIT		Permit for aquatic environment only	Coordinated permit covering all media	Permit for air environment only

Germany

Pollution control in the Federal Republic of Germany has traditionally been media oriented. In the mid-eighties, some elements of integrated pollution control have been introduced into German legislation and emphasis is continuing to be placed on integrated environmental technologies. Cooperation among different competent authorities already takes place in the context of the Federal Air Quality Control Act (BImSchG). The German Basic Law contains some constitutional principles related to the protection of the environment. The application of BAT is based on various decrees such as: Federal Emission Control Act 1974, Ordinance on Large Combustion Plants, Federal Water Management, Technical Instruction on Air Quality.The Federal Immission Control Act stipulates the quality standards for the atmosphere. Environmental Quality Standards for water are established by the Federal States and are not binding. ELVs are based on the precautionary principle and hence on the decision concerning the choice of the BAT. The implementation of the federal environmental protection laws is a responsibility of each Federal State. For the permitting procedure, the emission limit values and the EQS are taken into account.

United Kingdom

The Environmental Protection Act of 1990 set up a system of integrated pollution control. Most importantly the Act requires best available techniques to be used to first of all prevent, and only when that is not practicable, minimize the release of substances to the environment. The 1990 Environmental Protection Act (EPA) introduced two regimes of pollution control, the Integrated Pollution Control (IPC) for large scale, multimedia polluters and the Local Authority Air Pollution Control (LAAPC) for air emissions from small units. BAT are based on the Environmental Protection Act of 1990 and on the Environmental Protection Regulations of 1991. The 1990 Environment Protection Act gives the Secretary of State the power to set environmental quality objectives or standards for any medium in any area. There are no regulations on a national level that concern the emission limit values. Indicative ELVs are set out in BATNEEC and IPC guidelines.The 1991 Environmental Protection Regulations, lay out the procedure that has to be abided by, in the application for, and the delivery of, an authorization under the Environmental Protection Act.

Spain

The regional authorities are responsible for the enforcement of legislation that concern air emissions and wastes, while the national authorities for internal waters. There no specific provisions for BAT use. Nevertheless, the techniques must be harmonized with the existing limit values and environmental quality standards. The emission limit values are determined by sectoral national laws and European regulations. The responsible bodies are the Ministries and the regional authorities. Regional legislation is in line with national legislation.

Italy

The protection of the environment is provided for in articles 9 and 32 of the 1947 Italian Constitution. The Clean Air Law offers guidelines for air pollution control and prevention. The Water Pollution Control Law regulates the discharge of industrial and municipal effluent into surface and groundwater. Atmospheric emissions from industrial sources are regulated under the 1988 Industrial Air Pollution Law. The regions have to observe national emission limits and guidelines. The decrees DM 12/07/1990 and DM 01/02/1991 provide information on the BAT use. Under the Water Pollution Control Law, the regions are required to prepare and administer water purification plans with consideration for, inter alia, wastewater treatment. Ambient quality standards are defined at the national level but may be rendered more stringent locally in the case of sensitive ecosystems and heavily polluted areas. The Decree DM 12/07/1990 imposes limitations on the emissions of atmospheric pollutants from existing industrial plants while the DM 01/02/1991 establishes limits on emissions of atmospheric pollutants from new industrial plants. Separate permits are required for emissions/discharges to different media. Permits are issued on a case-by-case basis. The provincial authorities are responsible for licensing.

The Netherlands

Pollution control in the Netherlands has traditionally been sectoral. Most laws and regulations focus on one environmental medium alone. In 1980 the Environmental Protection Act came in force laying down the basis for more general provisions concerning, among other things, advisory bodies, planning and the issuing of permits. The Dutch Constitution stipulates that Government care concerns the habitable quality of the country and the protection of the environment. The two framework laws are the Environmental Management Act (EMA) and the Surface Water Pollution Act. In Chapter 8 of the EMA, general rules are given concerning BAT. The permitting procedure is based on the ALARA principle. This means that the pollution caused by an installation must be as low as reasonably achievable. BAT concepts are described and elaborated in governmental policy

documents and recommendations of the Coordination Committee on the Implementation of the Surface Water Pollution Act. Chapter 5 of the EMA lays out the rules concerning EQS. EQS are thoroughly laid down in National Policy Documents on Water Management and in the Rhine Action Program. The Ministry of Housing, Spatial Planning and the Environment sets out binding national emission standards. Under the Surface Water Pollution Act, maximum emission standards for designated substances are established. According to the 1993 Environmental Management Act, industrial plants are required to obtain a permit to be allowed to operate or even before constructing the installation. Because there are no national BAT requirements, BAT principles are applied on a case-by-case basis at the permitting stage.

Greece

The basic environmental law is the 1650/86. This law introduces the obligation to obtain an approval of Environmental conditions as well as an approval for site allocation. In Greece, the use of BAT is not obligatory. In 69269/5387/90 Decree, the potential use of BATNEEC is referred. Greece complies with the relevant environmental quality Directives promulgated by the European Union in the various media concerned. In particular, various Regional Decisions have been issued concerning the quality of water receivers. The European Community Directives are followed as far as the air emissions is concerned. The production of wastewater is regulated by a series of Regional Decisions. The disposal of solid wastes is governed by Ministerial Decisions that comply with the EC Directives. The Ministry of Development has to provide a permit in each industrial unit prior to its establishment and operation according to the recent Law 2516/8-8-97. The main steps of the licensing procedure is: 1) site allocation of the unit, 2) approval of environmental conditions, 3) operation permit, 4) other permits (e.g wastewater and solid wastes). For the disposal of wastewater and solid wastes a permit of the relevant Regional Service is necessary.

From the aforementioned it can be concluded that a variety of controlling pollution procedures exists in the Member States. Nevertheless, a general trend towards integrated pollution control systems can be noticed.

3. EFFECTS FROM THE IMPLEMENTATION OF THE DIRECTIVE

The Directive aims to prevent or minimize industrial pollution. Therefore, the production and processing sectors will be the sectors affected the most along with energy production and to a lesser extent waste management sectors. Administrative systems are also concerned, since the Directive requires the coordination and unification of the permitting procedures, as far as environmental issues are concerned. This is essential due to the existence of many laws and of complicated and time consuming procedures for environmental licensing. The procedure provided by the Directive should not result in a more complicated and time consuming procedure due to the increased bureaucracy of today. On the contrary it should develop in a short term and efficient procedure which will unify and update the whole procedure of industrial environmental permitting [3,6].

The Directive concentrates on those industrial activities with the greatest pollution potential. The types of industrial installations covered by the Directive are listed in Annex I of the Directive [1]. Additionally in Annex I, the Directive sets threshold values referring to production capacities or outputs, by which smaller scale installations are excluded. Even though, the types of industrial installations covered by the Directive are localized in the north of the EU, it is estimated that 200-300 industrial units covered by the Directive exist in Greece [6]. However the Community plans the development of a complementary framework Directive concerning pollution from smaller installations. It is now proposed that IPPC should be applied to Small and Medium sized enterprises

-SMEs in accordance with the Fifth Action Program on the Environment, thus extending the principle to the majority of industrial plants in EU. Within the European Union these installations account for 66% of total employment. It is now recognized that they are a key factor for generating growth and employment opportunities in the European Union. In addition these enterprises face an increasingly complex legal, fiscal and administrative environment [3,7].

It must be noted that the Directive foresees the capability of derogations from the requirements set by the use of best available techniques, in certain regions where the local environmental quality is very good, with the assumption that the emissions will not have unacceptable effects on the environment. As a result it may be possible to set different standards in certain cases and certain regions compared to those set for heavily industrialized regions. In analogous situations it may be appropriate to introduce deviations from the emission limits presuming that environmental quality standards are assured, the pollution caused is negligible and the conditions of transboundary pollution and in general global pollution will be maintained [1,2].

4. PERMIT APPLICATIONS ACCORDING TO THE NEW DIRECTIVE

Member States shall take all the necessary measures to ensure that the application for a permit to the competent authority shall include a description (Article 6) of:

- the installation and its activities
- the raw and auxiliary materials, other substances and the energy used in or generated by the installation
- the sources of emissions from the installation
- the conditions of the site of the installation
- the nature and quantities of foreseeable emissions from the installation into each medium as well as the identification of significant effects of the emissions on the environment
- the proposed technology and other techniques for preventing or, where that is not possible, reducing emissions from the installation
- where necessary, measures for the prevention and recovery of waste generated by the installation
- further measures planned to comply with the general principles of the basic obligations of the operator as provided in Article 3.
- measures planned to monitor emissions into the environment.

The information contained in an application for permit will be available to the public for specific comments before the competent authority reaches it's decision. The results of monitoring of releases as previously mentioned, must be also made available to the public [1].

5. ALTERNATIVES FOR THE IMPLEMENTATION OF THE DIRECTIVE IN GREECE PERMITTING PROCEDURE - ORGANIZATION OF COMPETENT AUTHORITIES

The principal factors in the existing permitting procedure are the following [6]:

- Legislation
- Competent authorities and jurisdictions of authorities granting permits. Procedure of submission of information, review procedure by the competent authorities and availability to the public
- Content of environmental term statements
- Types of licenses

All these factors were examined in the conducted research and alternative solutions may be proposed with the aim to simplify the procedures and determine an integrated permitting procedure (one stop shop) [6].

Proposals concerning Legislation

Under today's legislation the operating permit is issued according to the provisions laid down by the Ministry of Development (Law 2516/8-8-97). Part of the permitting procedure covering environmental aspects is governed by the Law 1650/86and the Ministerial Decision 69269/5387/90.

The following possibilities exist for the adaptation of the legislation:

- Modification of Ministerial Decision 69269/5387/90, in order to separate the industries covered by the IPPC Directive from the others.
- Accession into the recent bill of law by the Ministry of Development.
- Drafting of a new bill relating all issues.

The third solution is preferred. A new bill should be drafted relating the provisions of Law 2516/8-8-97 laid down by the Ministry of Development with the provisions of Law 1650/86 of Ministerial Decision 69269/5387/90, unifying the relative procedures of other licenses. The bill most probably should have the form of a Presidential Decree coordinating the whole procedure. On the basis of the «one stop shop» concept, applications shall be submitted to the Ministry of Development and forwarded to the Ministry of Environment, in the case the whole procedure remains at a central level. For better results a decentralization of the procedure will be most effective.

Proposals for the responsible authorities which will realize the permitting procedure and grant permits

Up today the responsible authorities were the Department of Industries of the Ministry of Environment, the Central Services of the Ministry of Development, and the Prefecture Administration, mainly the Prefecture Council, the Environmental Bureau and the Directorates of Health and Industry.

The alternative solutions are:

- The whole procedure to be realized at a Central level.
- Part of the procedure to be realized at a Prefecture level.

The second solution is preferred for decentralization reasons. In reality though problems may arise due to the lack of staff executives and relative experience. Specifically, it is suggested that the procedure for the approval of Environmental conditions should be realized at a central level (possibly within the operational frame of the authority responsible for the information exchange or the Focal Center). Thus, after a sufficient time interval, set according to the Prefecture administration's capabilities, a gradual decentralization may be effected.

Proposal of a permitting procedure.

Based on all mentioned previously, the integrated permitting procedure required by the Directive may have the structure shown in Figure 1. For the existing installations the system could be modified in order to become more efficient, by preserving the basic lines, and by providing economic assistance, based on the fact that a financial burden will occur during the adaptation period [6]. Specifically, the applications will be submitted to the competent authority of the Ministry of Development, determined as the «one stop shop», along with the rest of the required supporting documents for the granting of the operating permit. The applications for the approval of Environmental conditions, in order to save time, could be submitted directly to the competent authority of the Ministry of Environment, and later on to the Prefecture Administration. All necessary other permits and approvals (i.e. effluent discharge, solid waste disposal, risk analysis etc.) should be submitted with the application .

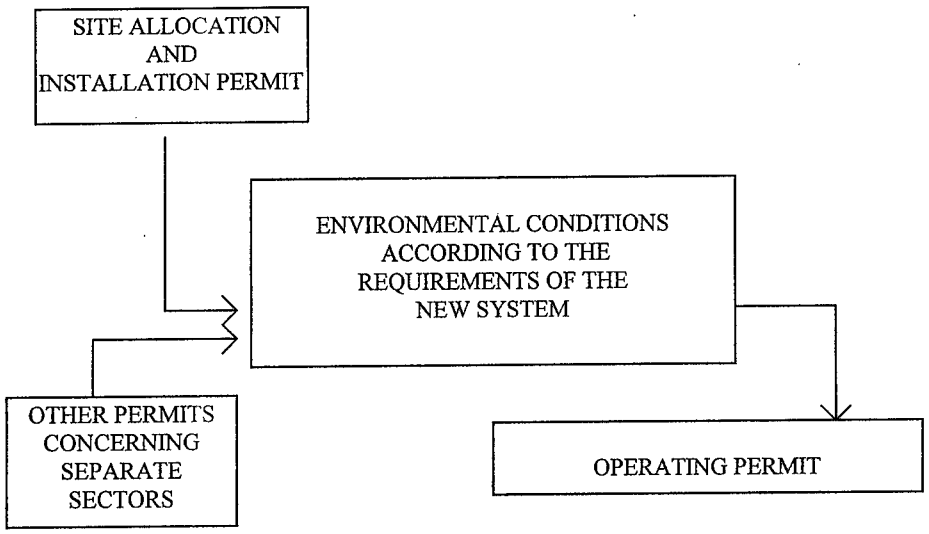


Figure 1 . The proposed permitting system according to the requirements of the new directive (only for units covered by IPPC)

6. CONCLUSIONS

Under IPPC Directive, control over emissions from industrial installations in the EU will take into account the effects on all environmental media. A high level of environmental protection would be maintained and improved, mainly since the use of BATs will be applied. The new Directive is a typical example of simplification, consolidation and updating of existing Community legislation. It gives an opportunity to get away from the old approach legislation for the individual environmental media and will and will make some existing single medium legislation redundant and will lead to its repeal. Reaching an adequate coordination and balance between environmental and industrial policies is an important and attainable issue. Legal, economic and technical means and tools to achieve it, do exist

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COMPARATIVE PRESENTATION OF PACKAGING POLICIES IN EU MEMBER STATES AND IMPLEMENTATION IN GREECE

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ABSTRACT

This paper aims at the assessment of the policies implemented in France and Germany concerning packaging waste through the conduction of a SWOT analysis in order to use this experience as a learning opportunity for the Greek context in terms of providing guidelines for sustainable policy planning and implementation. The German policy is difficult to be implemented in Greece, mainly due to the opposition of the majority of the key actors and the high implementation cost. The French policy is more flexible, realistic and compatible with the existing initiatives. Nevertheless, modifications are essential in terms of determination of quantitative objectives by law and not through contractual agreements. Both EC policies demonstrate the inadequacy of the regulatory approach and the need for the use of economic and communicative instruments.

ΣΥΓΚΡΙΤΙΚΗ ΠΑΡΟΥΣΙΑΣΗ ΤΗΣ ΠΟΛΙΤΙΚΗΣ ΓΙΑ ΤΑ ΥΛΙΚΑ ΣΥΣΚΕΥΣΙΑΣ ΣΕ ΧΩΡΕΣ ΤΗΣ ΕΥΡΩΠΑΙΚΗΣ ΕΝΩΣΗΣ ΚΑΙ ΕΦΑΡΜΟΓΗ ΣΤΗΝ ΕΛΛΑΔΑ

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ΠΕΡΙΛΗΨΗ

Στην παρούσα εργασία παρουσιάζεται η ανάλυση της πολιτικής που εφαρμόζεται στην Γαλλία και τη Γερμανία σχετικά με τα υλικά συσκευασίας με σκοπό την εκτίμηση της πιθανής εφαρμογής τους στην Ελληνική πραγματικότητα. Η πολιτική της Γερμανίας είναι δύσκολο να εφαρμοστεί στην Ελλάδα λόγω κυρίως των αντιδράσεων που υπάρχουν και του υψηλού κόστους που απαιτείται για την εφαρμογή της. Η πολιτικής της Γαλλίας είναι πιο ρεαλιστική και συμβατή με τις υπάρχουσες πρωτοβουλίες. Παρόλαυτα τροποποιήσεις είναι απαραίτητες για την εφαρμογή τους στην Ελληνική πολιτική. Οι δύο κοινοτικές πολιτικές δείχνουν την ανεπάρκεια της νομοθετικής προσέγγισης σαν μοναδικό εργαλείο άσκησης πολιτικής και την ανάγκη ταυτόχρονης χρήσης άλλων εργαλείων.

1. INTRODUCTION

The worldwide crisis in the disposal of solid waste, in the context of which packaging appeared as a primary waste flow, was the main triggering element which led to the adoption of the 94/62 EC Directive. Aiming at environmental protection and harmonization of national measures, the Directive imposes provisions concerning sound packaging waste management which should have been incorporated in all Member States before June 1996.

Faced with an increasing amount of packaging waste and a complex network of actors involved in the packaging chain, Greece is currently at the stage of policy planning. Incorporation of the Directive has been delayed for more than a year, thus posing pressure on the competent public authorities to act as fast as possible towards this direction. The Committee responsible for the formulation of the new policy, consisting of representatives of some of the actors, anticipates problems, mainly due to the existing conflict of interests. The majority of the actors participating in the Committee tends to favor the French policy, with or without modifications, while the state actors consider certain elements of the German policy more appropriate for the Greek setting. The situation as described calls for an immediate and integrated solution.

2. METHODOLOGY

The aim of this paper is to contribute to the formulation of a sustainable policy for the country, consistent with the EC Directive, and taking into consideration the experience gained both in Germany and France. These two policies will be presented and their strengths and weaknesses will be assessed. Then, the situation in Greece will be examined, starting from the general context, to the administrative structure and the instruments used for environmental policy. Following, the packaging problem and the instruments used in this field will be examined. The next step includes the identification of all the actors involved in the packaging chain, their stakes, expectations and initiatives. Finally, a SWOT analysis of both the German and the French system will be conducted, in order to assess the strengths, weaknesses, opportunities and threats that would arise from the selection of either of the two policies as appropriate for the Greek setting.

3. POLICIES FOR PACKAGING WASTE IN EUROPE

3.1 The German Policy

Rise of public environmental awareness, increasing amounts of packaging waste and exceptionally high landfill costs were the basic triggering elements for the implementation of a strict and concrete policy in Germany. In June 1991 the "Ordinance on the Avoidance of Packaging Waste" passed the Bundestag. Prevention is the primary target of the Decree, followed by reuse and recycling. Incineration was originally not considered as an acceptable waste recovery method. The Ordinance determined high recycling targets, which eventually caused serious implications [1].

The Law introduced strict producer responsibility by imposing a take-back requirement to producers and retailers for the packaging they place on the market. This obligation can be avoided if the producer/retailer participates in an established system for the collection and recovery of the used packaging. Towards this end, the Duales System Deutschland (DSD) was founded by the industry and the retailers in order to create a parallel to the existing municipal waste management system concerning packaging waste. Companies pay a license fee to DSD in order to participate in the scheme and use the "Green Dot" on their products. Products bearing this logo can be disposed off by the retailers and the consumers in the DSD collection bins [2].

The whole policy involved high implementation cost, imposed unrealistic recycling rates resulting to waste exports, thus almost leading the system to bankruptcy.

The German Government, by creating a government mandated recycling system administered and run by a private entity, illustrates both the strengths and weaknesses of government intervention in markets. The whole policy proved effective in terms of encouraging companies to reduce the volume of their packaging materials and has prompted industry to work on the development of creative packaging alternatives. The policy was also effective in promoting public participation and satisfying collection of the targeted materials. The development of advanced recycling technologies and the promotion of research are benefits deriving from the policy implementation. Nevertheless, these achievements resulted to a significant financial cost and an uncertain impact on the environment.

The main lessons for policymakers in other countries deducted by the German experience are:

- government policies cannot erase technical and economical realities, they can only influence them or be broken by them. By imposing unrealistic goals regarding plastic material recycling, the system was almost led to bankruptcy.
- when setting recycling rates it is crucial to keep in mind the importance of maintaining a national marketplace
- the use of instruments (regulatory, economic and communicative) aiming to stimulate demand for recycled products created by industry input, is necessary in order to achieve a balanced approach
- recycling should be considered as a part of the solution to the packaging problem, not a panacea
- coordination between the Federal Government and the local authorities in setting policy objectives and using economic instruments is crucial in order to avoid unexpected side effects.

3.2 The French Policy

The French policy was the response to the increasing amounts of packaging waste and the reaction towards the German system, which was perceived by the French industry as a threat. In April 1992 the Decree No. 92-377 on packaging in which the holders are households, was published (Lalonde Decree), based mainly on negotiations with the industry. According to the Decree, packaging waste should be "valorized", namely recycled or incinerated with energy recovery. Producers and importers of packaging are obliged to cater for the disposal of the packaging waste they have put on the market either on an individual basis or through deposit systems or by using the services of an accredited by the Government company.

The Local Authorities (Communes) maintain competence in the packaging waste management. In July 1992 Act No. 92-646 was published, encouraging valorization through the establishment of a landfill tax. Furthermore, the Act determined that, as of 1 July 2002, only the dumping of final waste will be allowed. Finally, the Act provided for the introduction of departmental waste elimination plans, aiming at the coordination between Communes in their household waste management plans.

In order to comply with the legislation, the French industry established a private company, Eco-Emballages [3]. On 12 November 1992, the company was accredited in the sense of the Lalonde Decree through an Interministerial Decision and was awarded a six years operation license, having as primary target to reach 75% of recovery of household packaging waste by the year 2002. The Eco-Emballages system operates in the following way: Industries pay a participation fee in order to get the right to put the "Point Eco-Emballages" on their packaging. Eco-Emballages provides financial support through contracts to the communes in order to help them install and implement collection and sorting systems. The Associations for the five basic targeted materials provide also a take back recycling guarantee at a minimum price.

Overall, the French policy can be characterized as flexible and realistic, actually been designed by the industrial sector. By defining a long term objective, it leaves room for maneuvering to all the actors involved. This consists a strength but also a threat to the system, since the absence of intermediary objectives does not allow accurate evaluation of the implementation of the policy. Local authorities maintain responsibility of local waste management and have supervised freedom on the valorization technique to be selected. Departmental plans ensure coordination between Communes'waste plans. As far as prevention is concerned, an inadequate use of instruments can be observed, which is not in compliance with the provisions of the 94/62 EC Directive. The introduction of the landfill tax can be considered as an incentive to reduce packaging, yet it cannot, without parallel use of other, mainly economic, instruments promote prevention efficiently.

The French policy does not foster recycling, and the current recycling rate is around 10%. Therefore, the EU objectives are unlikely to be attained. Incineration with energy recovery seems to be the most favored solution. According to estimations by ADEME , this valorization technique will be the dominant one by the year 2002, representing 60 to 65% of total valorization. The overall valorization target of 75% is unlikely to be reached by the year 2002, even if an acceleration is being achieved in building waste treatment facilities. The expected increase of the contribution fees from the companies towards Eco-Emballages by an average of 3 centimes per packaging unit, will not be adequate to cover the necessary expenses. Nevertheless, the target set by the EC Directive, concerning a minimum of 50% recovery of packaging waste by the year 2001, is quite possible to be attained [4].

4. CASE STUDY -GREECE

Greece is a country facing a growing problem in the field of waste and packaging waste management, both due to the increasing amounts of packaging waste and to the inadequacy of the current practices to sustainably cope with them. Packaging waste management in the 3 500 islands is in fact absent at the time and calls for an immediate solution. Furthermore, the delay of the transposition of the 94/62 EC Directive in national law for more than a year, poses an additional problem. The absence of a monitoring system on the amounts of municipal and packaging waste generated in the country is an essential missing prerequisite for the adoption of an appropriate policy. The country has four levels of administration, with a relative vertical structure, which nevertheless leaves room to the more than 6 000 Municipalities and Communes to develop their own initiative [5]. The latter have, by law, exclusive competence in the local waste management. At the moment, new legislation is promoted by the Ministry of the Interior, concerning a reformulation of the administrative structure through the merge of small Communes to Municipalities, causing serious opposition by the Local Authorities affected.

As far as the use of instruments is concerned, Greece is a country which traditionally uses legislation as the main instrument to achieve environmental goals. The existing legislation in the field of the environment is strict and detailed, consistent with the EC provisions and mainly EC driven. It provides a solid basis for the further formulation of legislation dealing with packaging waste, which is currently absent. Monitoring and control of the implementation of the existing legislation is relatively weak, therefore the new packaging waste legislation should contain relative provisions.

The use of economic instruments is usually sectoral and isolated, while in the field of packaging waste the use of such instruments can be characterized as at least inadequate. Communicative instruments are more common, and have proved quite effective when implemented. Actions towards the solution of the packaging problem have remained, until recently, at a voluntary level. Nevertheless, the industry has developed its own initiative by forming associations which cooperate and finance Local

Authorities in order to develop recycling schemes. The outcomes of these initiatives can be considered as satisfying, yet they lack an integrated character [6,7].

The Ministry of the Environment has created, already since 1994, a committee consisting of the main actors in the packaging chain, having as a task to formulate a new policy for packaging waste, consistent with the requirements of the EC Directive. The committee has not yet reached a final position, while the negotiations until now indicate a preference by almost all the private actors of the French policy. State actors favor the German system, particularly the provisions for strict producer responsibility and promotion of recycling and recovery objectives including intermediary targets.

A stakeholder analysis concludes that the Ministries, the industrial associations, the retailers, the Ecological Recycling Company and the Municipalities which have already introduced a recycling scheme, are the key players whose expectations should be taken into consideration in the policy formulation and implementation. The Municipalities with no recycling or waste recovery scheme, the retailers and the Ecological Recycling Company are the actors from which major dangers or opportunities can arise, due to the fact that they maintain high power, while their stance towards the new policy is highly unpredictable. The outcome of the conflict between the Ministry of Interior and the Communes will decisively affect the attitude of the latter towards the selected policy in this field. At this stage a concrete policy has to be selected, consistent with the provisions of the EC Directive and taking into consideration the Greek reality and the experience already gained in other Member States both as a learning opportunity and as a guide towards sustainable solutions.

5. SWOT ANALYSIS OF THE EU SYSTEMS IF APPLIED IN GREECE

If the German system was applied in Greece, the main strengths, weaknesses, opportunities and threats deriving from its implementation are presented in Table 1.

TABLE 1. SWOT Analysis of the German System, if applied in Greece

STRENGTHS	WEAKNESSES
• "instrumental" fit - regulatory approach common in the two countries • preference for recycling: -favored in Greece -consistent with EC Directive • creation of work opportunities - recycling schemes are labor-intensive	• high cost of introduction and maintenance of a parallel system • cost of high recycling targets • Greek context alienated from reuse systems • recycling not feasible in certain territories • inadequate flexibility to deal with diversity of local differences
OPPORTUNITIES	**THREATS**
• change of philosophy-disposal part of product life cycle • potential motivation towards prevention • specific & intermediary targets facilitate monitoring and control • Local Authorities are relieved from the management of significant waste amounts	• opposition by the majority of key actors • merge of Municipalities against the system • merge of NGO's with Municipalities against the policy • significant alterations to public every day practices: -non acceptability -high communication costs • problems in integration of existing schemes with the new system

The opposition by the majority of the Greek key actors constitutes the major threat of the German policy, actually eliminating the possibility to effectively introduce this policy in the Greek context.

This opposition derives from the expected high cost of the system, the limitation to the competence of Local Authorities and the adverse publicity provoked by the 1993 crisis. Nevertheless, strengths and opportunities of this system such as the establishment of specific and intermediary objectives and the preference for recycling should be taken into consideration during the planning of the new policy.

Going further to the examination of the potential implementation of the French system in Greece, the SWOT analysis presented in Table 2 indicates the key points which have to be addressed. The French system provides flexibility in terms of allowing industry to gradually adapt, thus avoiding distortions to the operation of the market. Furthermore, Greece and France have a similar administration system with a large number of Local Authorities which have competence in waste management. The French policy anticipates the disparities and differences between the Communes, by giving them freedom of choice in selecting the form and the content of a possible contractual agreement with the accredited body. Furthermore, the acceptability of this policy by the majority of the key actors in combination with the reasonable costs of implementing the system, and the compatibility of the existing initiatives which are based on the French model, constitute factors which make this policy more adaptable to the Greek setting. Nevertheless, this system is not without weaknesses and threats, calling for modifications, either by introducing elements of the German system, or by introducing new ones, in order to enhance effectiveness.

TABLE 2. SWOT Analysis of the French System, if applied in Greece

STRENGTHS	WEAKNESSES
• acceptability by the majority of key actors • no competence limitation to the Local Authorities • flexibility, through contracts, anticipate better the diversity of problems at local level • easier incorporation due to existing compatible infrastructure • long term targets provide space for gradual adaptation • the landfill tax motivates prevention & provides additional funds	• French targets not in consistence with EC Directive • absence of intermediary targets hinders effective evaluation and control • Greek context not familiar with incineration • discrimination between household/non household waste in not in consistence with the EC Directive
OPPORTUNITIES	**THREATS**
• extensive involvement of industry in policy planning: - solution based on consensus - setting realistic targets • economic viability of the system • • opportunity for gradual expansion • departmental plans ensure coordination, providing opportunities for cooperation and experience exchange between Local Authorities • low contribution fees: - wider participation - minimization of free rider syndrome - compatible with SME's capabilities • incineration potential solution for specific areas	• extensive involvement of industry in policy planning: - actual exclusion of other actors - downward dispensation of targets - flexibility does not ensure achievement of EC targets • recovery and recycling targets not set by law • system of regularly renewed contracts causes periods of inertia • prevention not foster adequately • low contribution fees: - no opportunity for ambitious planning - do not foster achievement of high environmental goals

Overall, the two SWOT analyses clearly indicate the reality that policies are not models for export, they are opportunities to learn through the experience gained, either by introducing elements of these policies which have proven to be effective and are at the same time adaptable to the national setting, or by avoiding mistakes.

6. DISCUSSION

Three issues constitute the necessary prerequisites which have to be addressed before the selection of either of the two policies:
- a monitoring system for the waste and packaging waste quantities generated has to be established, following the fundamental principle : "If you cannot measure it, you cannot manage it."
- the administrative reformulation of the country has to be completed as soon as possible. As long as the solution is still pending, tensions will exist and a clear view on the needs of the new administrative units cannot be achieved.
- the policy should be introduced by a Parliamentary Law and not by a Ministerial Decision. The latter would provide space for re-negotiations and modifications according to political criteria.

As far as the policy-planning procedure is concerned, expansion of the participants in the Committee responsible for the new policy is imperative in order to include the Universities, the SME's and the Municipalities with no waste recovery scheme. Furthermore, the Committee should have a permanent character, being responsible also for monitoring the implementation of the new policy.

As far as the most appropriate system is concerned, it becomes obvious that the policies examined were established at a different time, for a different purpose and applied to a specific setting, and therefore can not be imported as such. The discussion - also in the Committee- should drift from "which of the two is the most appropriate policy" to the question "what can we learn from this experience, and which elements of these policies can be of use in Greece". The description of the Greek setting, the stakeholder analysis and the SWOT analysis of the two systems provide the basis to draw the following guidelines:

A concrete legislative framework has to be established in order to ensure that changes take place across the board, to avoid favoring those who do not care (Free rider syndrome). Strict producer responsibility has to be introduced, thus leading to the internalization of external costs and fulfilment of the Polluter Pays Principle.

Prevention should be explicitly the first priority, specific targets have to be set for recycling, while incineration with energy recovery should not be excluded as a possible waste recovery method. The few remaining reuse systems should be enhanced and incentives should be provided for new companies to select reusable instead of one-way packaging.

The quantitative objectives concerning recovery and recycling have to be introduced by Law, following the German example. Intermediary recycling targets should be set for 2001, although Greece does not have such obligation. Nevertheless, these targets, established by the Committee in a consensus procedure, will promote recycling and facilitate both monitoring of the implementation of the policy and achievement of the 2005 EC objectives.

Concerning the return, collection and recovery system, the French solution can serve as a basis, since it is accepted by the majority of the key actors and it is compatible to the existing initiatives. Also the cost of the implementation of such a system is more reasonable while the Local Authorities maintain competence in packaging waste management. Nevertheless, the contribution fees should be calculated

in accordance to the targets set by the Law. There should be special provision for the SME's, both in terms of establishing reasonable fees and in terms of formulating a simplified contract system. On the other hand, the fees for massive production should not be too low, because this would not foster prevention adequately, a fact which has been detected in the French case.

Finally, the use of economic instruments is imperative, in order to create an integrated strategy for the sound management of packaging waste. The first useful instrument, used already in France, is the introduction of the landfill tax. This tax provides an incentive to the industry to reduce the volume and weight of the packaging, or to switch to the use of more recyclable materials. Additionally, a fund can be created to manage the revenues, which should be used further for the financing of packaging waste management schemes. Alternatively, the money from the tax could be allocated to a fund, having as an exclusive objective the development of a waste management plan for the islands. Aiming at the motivation of the industry to change their production process in order to reduce packaging, a series of measures can be implemented, including tax allowances or exemptions for the introduction of new technology or for switching to reusable packaging. Low interest loans can also be used towards this direction.

The last instrument that has to be used is the promotion of the Environmental Management Systems (EMS). The State should motivate industry to embrace these systems, by informing industry about them, by providing scientific and financial assistance, and by simplifying the accreditation procedures. This could prove exceptionally effective for the packaging issue, where possibilities for packaging reduction could be detected, and cost effective solutions implemented.

Concluding, the transposition and implementation of the 94/62 EC Directive in Greece require close cooperation and interaction of all actors and use of an instrument mix based on the Greek reality and on the experience gained in other Member States. The problems in Greece regarding the packaging issue actually reflect the reality that economic growth and environmental protection are still perceived as conflicting targets. Matching of these objectives is not only a requirement of the Directive, it is also the basis of sustainable development. Therefore, the transposition of the Directive should not constitute an effort towards compliance, but a first step in a process of change, a shift from the reactive response towards the EC environmental policy to a proactive approach.

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EFFECTIVENESS OF THE ENVIRONMENTAL POLICY IN THE FIELD OF HAZARDOUS WASTE

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ABSTRACT

The transportation and management of hazardous waste is a problem of growing concern during the last years. The implementation of the EU hazardous waste policy in Greece was investigated. The policy followed in Greece concerning this field is based on the implementation of strict and detailed regulation, requiring the involvement of a large number of state actors, thus leading to bureaucratic procedures and high administrative costs. This policy is effective only in terms of promoting compliance due to the lack of appropriate treatment and disposal facilities in the country and the absence of an integrated waste management and control system. Concluding a mix of instruments is required in order to deal with the individual interests of the actors involved in the Greek context.

ΑΠΟΤΕΛΕΣΜΑΤΙΚΟΤΗΤΑ ΤΗΣ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗΣ ΠΟΛΙΤΙΚΗ ΣΧΕΤΙΚΑ ΜΕ ΤΑ ΕΠΙΚΙΝΔΥΝΑ ΑΠΟΒΛΗΤΑ

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ΠΕΡΙΛΗΨΗ

Η διαχείριση και μεταφορά των επικίνδυνων αποβλήτων αποτελεί ένα σημαντικό πρόβλημα τα τελευταία χρόνια. Η εφαρμογή της Κοινοτικής πολιτικής σχετικά με το θέμα εξετάστηκε για τον Ελληνικό χώρο. Η πολιτική που ακολουθείται στην Ελλάδα βασίζεται στην εφαρμογή αυστηρής και λεπτομερής νομοθεσίας. Η πολιτική αυτή είναι αποτελεσματική όσον αφορά την εφαρμογή της Ευρωπαϊκής Νομοθεσίας, όμως δεν δίνει ουσιαστική λύση στο πρόβλημα λόγω της έλλειψης κατάλληλων μονάδων για την επεξεργασία και διάθεση των επικίνδυνων αποβλήτων και ενός ολοκληρωμένου συστήματος διαχείρισης και ελέγχου. Συνεπώς, απαιτείται η ανάπτυξη μιας πολιτικής που θα βασίζεται στην χρήση διαφόρων εργαλείων για την αποτελεσματική αντιμετώπιση του προβλήματος.

1. INTRODUCTION

The transportation of hazardous waste is a problem of growing concern during the last years in most industrialised countries [1]. The 259/93 EU Regulation as well as a number of Directives dealing with hazardous waste pose specific obligations to the Member States for the Transboundary Movement of Hazardous Waste and for the hazardous waste production and management. The implementation of the EU legislation varies between the Member States, depending on the national policy styles, the attitude of the stakeholders, the extend of the problem and the national capacities for hazardous waste management [2-3].

The problem of hazardous waste in Greece became significant after 1960 with the development of the industrial activity, which results in the production of hazardous waste. The main problems concerning hazardous waste were caused by the poor conditions of handling and storage and the improper disposal practices. This was due to the lack of an environmental control system and the absence of appropriate hazardous waste treatment and safety disposal facilities in Greece. Therefore, till recently the majority of waste were disposed off uncontrolled in landfills, private places or discharged untreated into the recipients. The national awareness concerning the problem of hazardous waste management arose during the last decade, due to the international concerns over the environmental impacts caused by the improper management of hazardous waste. Furthermore, Greece is trying to internalise the EU environmental policy concerning waste, which pays great attention to the principles of proximity and self-sufficiency as far as hazardous waste management is concerned, the development of control systems for the management of hazardous waste and the implementation of preventive strategies.

The implementation of the EU legislation in the Greek reality was investigated in the frame of a European project. The analysis of the policy adopted in Greece and the effectiveness of this policy are presented in this paper.

2. DIMENSION OF THE PROBLEM IN GREECE

The dimension of the problem of hazardous waste production in Greece is not as crucial as in other European countries, due to the fact that the quantities of hazardous waste annually produced are small in comparison to the produced quantities in the other countries while on the other hand there is a continuous reduction of these quantities during the last decade.

The reduction of hazardous waste production can be attributed mainly to the fact that the number of industries producing hazardous waste has been declined steadily during the last years. Several large size textile dying and finishing industries, metal products industries, tanneries and metal plating industries that were established in seventies and were producing large quantities of hazardous waste do not exist any more. Also, the number of newly established as well as the productivity level of a great number of existing industries has been declined. Furthermore, the reduction of hazardous waste production is a result of the fact that many of the existing industries have changed their production procedure due to the strict legislation concerning hazardous waste.

The quantity and quality of hazardous waste produced every year in Greece is not known with accuracy, since an integrated national inventory has not been performed yet, while on the other hand the determination of hazardous waste differs depending on the classification that is followed [4]. However, according to a report of the Ministry of Environment, Physical Planning and Public Works (Ministry of E.P.P.P.W) it is estimated that the hazardous waste production from the industrial

sector is approximately 350.000 tonnes/year. The number of large size industries generating hazardous waste do not exceed the number of 18, including industries which produce basic metals (steel, aluminium, copper), lead batteries, fertilizers, chemical and agrochemical products and paints. At this point it must be mentioned that there is a great number of small and medium size industries (tanneries, plating industries, textile-finishing industries) generating hazardous wastes in very small quantities compared to the production of the aforementioned enterprises [5,6].

There is also a significant amount of hazardous waste consisting of oil residues which are generated from refineries of crude oil, the units regenerating used lubricants, the units involved in distribution and commercialisation of liquid fuels, the shipyard units and the off-shore installations involved with the recovery of oil from ship waste. Also, the oil refineries are responsible for the production of other hazardous like sludge from the wastewater treatment plants and the shipyards for the generation of rust, paints and sandblasting material.

As far as PCBs are concerned, according to an inventory that has been performed by the Ministry of E.P.P.P.W. and the National Electricity Enterprise, the public electrical power stations have in their installations approximately 385 tonnes of PCBs, 306 tonnes of which exist in operational equipment (300 transformers and 14.000 condenser). It must be mentioned that there is also a small quantity of PCBs which belongs to various private enterprises.

3. COMPLIANCE : A MOTIVE AND A TARGET

During the last decade, a thorough attempt has been made by the Greek competent authorities to follow the European policy concerning hazardous waste production, management and transportation through the harmonization of the Greek legislation with the EU relative Regulations, Directives and Decisions. Nowadays, approximately all the EU directives and regulation have been incorporated into the Greek legislation as it is shown in Table 1, while all the European and international requirements concerning the transfrontier transportation of hazardous waste are followed.

A strict and detailed legislation framework has been formulated concerning the production, management and transportation of hazardous waste. This legislation except for the introduction of the European directives, regulations and decisions, determines in detail all the competent authorities, classifies the hazardous waste according to the relative EU decision, regulates the actions of all the actors involved in production, management and transportation of waste and contains specific provisions for the management and transportation.

The legislative framework concerning hazardous waste provides that anyone who manufactures, owns or manages these substances is obliged to keep records about their quality and quantity, their sources, the treatment methods and disposal practices. The Prefectures are the competent authorities for the collection of all these data which are given to the Ministry of E.P.P.P.W.. Also, the Prefectures have the duty to perform regular inspections to the generators of hazardous waste. Furthermore, the generators, owners or managers of hazardous waste are obliged to take a hazardous waste management Permit from the Prefectures according to which they are able to treat, transport or store hazardous waste. As far as storage is concerned, this Permit grants the permission to the generator to store temporarily his waste in private places, if it is assured that the prevention or recycling of the waste is not feasible. The necessary data for this permission are studies of the environmental impact assessment, preliminary approval of site allocation, risk assessment and disposal management. The responsible Prefectures have to carry out regular checks in order to ensure that the hazardous waste storage is taking place in an environmentally sound way.

TABLE 1. Compliance of the Greek Legislation to the European

EU Legislation	Compliance into the Greek Legislation
• Council Directive 78/319/EEC of 20/3/78 on toxic and dangerous waste	• JMD 72751/3054/85 «Toxic and hazardous waste and elimination of PCBs and PCTs» incorporates the directive 78/319 which has been replaced by the Directive 91/689/EEC
• Council Directive 91/689/EEC of 12/12/1991 on hazardous waste • Decision 94/904/EC of 22/12/1994 • Decision 96/350/EC of 24/5/1996	• JMD 19396/1546 of 18/7/1997, "Measures and terms for the management of hazardous waste" which includes the Catalogue of Hazardous Waste
• Directive 84/631/EEC of 6/12/84 on the supervision and control within the European Community of the transfrontier shipment of hazardous waste which has been replaced by the Regulation	• JMD 19744/454/88 which incorporates the directive 84/631/EEC
• Council Regulation (EEC) 259/93 of 1/2/1993 on the supervision and control of shipments of waste within, into and out of the European Community	• The Ministry of Environment is currently introducing and reconsidering some measures in the framework of the Regulation
• Basel Convention on the control of Transboundary Movements of Hazardous Waste and their disposal	• Law 2203/94 on the ratification of Basel Convention
• Council Directive 76/403 of 6/4/1976 on the disposal of PCBs and PCTs • Directive 76/769/EEC • Directive 85/467/EEC • Directive 87/101/EEC • Council Directive 96/59/EU of 16/9/1996 on the disposal of PCBs and PCTs	• JMD 72751/3054/85 «Toxic and hazardous waste and elimination of PCBs and PCTs» incorporates the EE Directives 76/403, 76/769, 85/467 and 87/101 • Decision of the General National Chemical Laboratory 1310/86
• Council Directive 75/439/EEC of 16/6/1975 on the disposal of waste oils • Council Directive 87/101/EEC amending Directive 75/439/EEC	• JMD 71560/3053/85 on the disposal of waste oils • JMD 98012/2001/96 Measures and terms concerning the management of waste oils
• Council Directive 91/157/EEC of 18/3/1991on batteries and accumulators that include dangerous substances	• JMD 73537/1438/95 of 28/8/95 that incorporates the directive 91/157 on batteries and accumulators that include dangerous substances

The legal framework concerning transfrontier transportation provides that anyone who wants to carry out a transportation should have the aforementioned hazardous waste management permit and should follow the International and European agreements and conventions which have been ratified by the Greek government (ADR International agreement, Basel Convention, IMDG code). This management permission is granted from the responsible Prefecture and it is different for each hazardous waste. The duration of that permission depends on the specific hazardous waste that will be transported. A similar permit, under the same conditions, is also issued for the movement of hazardous waste inside the country.

Every time a transportation of hazardous waste is to be accomplished, the transporter, in order to obtain the hazardous waste transfrontier shipment Permit, must supply a notification to the Ministry of E.P.P.P.W. and to nine other relative Ministries. This notification includes the Notification Form, the hazardous waste management permits, issued by the Prefectures which are involved in the waste movement under examination, the contract between the notifier and the consignee, the insurance policy contract, information on the hazards that the specific waste may cause and on measures to be taken in case of an accident, the relevant Material Safety Data Sheet, if there are any, and the driver's special training certificate which assures the driver's capability concerning hazardous

transportation. The hazardous waste transfrontier shipment Permit specifies certain provisions which make the whole procedure very complicated, including that the transportation vehicles must have a licence in order to transport dangerous substances and they must be escorted by the Traffic Police during the transportation and that there must exist a permission of the port competent authorities for temporary storage in a specific place of the port of departure, while for any intermediate storage of waste a Prefecture's relevant Permit must be issued.

4. NETWORK OF ACTORS INVOLVED IN HAZARDOUS WASTE MANAGEMENT AND TRANSFRONTIER TRANSPORTATION

The main actors involved in the hazardous waste management chain are the state actors, the industrial sector and the transporters/ handlers of hazardous waste.

The state actors includes all the authorities which are responsible for the formulation of the hazardous waste policy. The Ministry of E.P.P.P.W.. is the central actor which is responsible for the development and implementation of the hazardous waste policy in Greece. This Ministry is the competent authority for the formulation of the Greek legislation concerning hazardous waste in agreement with the Prefectures and other Ministries, which play significant role in the decision making procedures. Also, this Ministry has several responsibilities including the establishment of the framework for the environmental management plans at national level in collaboration with the Prefectures and the Local Authorities.

On the other hand the Prefectures are very important actors since they have several responsibilities including the granting of permissions to hazardous waste generators for safe disposal, the granting of permissions to transporters for transfrontier shipment and the collection of data concerning the hazardous waste production. It must be mentioned that the Municipalities and Prefectures play an important role in the decision making processes concerning the establishment of treatment plants and safe disposal sites, since they are usually opposed to the establishment of these facilities in their "neighbourhood" (NIMBY syndrome).

The industrial sector is mainly responsible for the production of hazardous waste in Greece and therefore it is responsible for the management, treatment, transportation and final disposal of the generated hazardous waste. The industrial sector is the actor mainly affected by the government's policy concerning hazardous waste on the one hand, while on the other it seeks for permanent solutions on the problem of hazardous waste, since it is trying to develop an environmental profile. Finally, the transporters constitute an intermediate actor, since they undertake the responsibility for the transfrontier shipment of hazardous waste in order to be treated or finally disposed off and therefore they are mainly involved in the complex procedure which is necessary for the transboundary transportation.

5. IMPLEMENTATION OF THE PUBLIC POLICY

The main instrument which is used for the implementation of the hazardous waste national policy is legislation, formulated in compliance with the EU requirements as they are expressed through the relative Directives, Decisions and Regulations and the international requirements concerning the transfrontier transportation of hazardous waste. The implementation of the legislative framework regarding transfrontier shipments is effective mainly due to the strict enforcement of the law and the numerous inspections that are performed by the authorities. Another very important reason which explains this effectiveness is the small quantities of waste that are transported every year, a fact that

facilitates the performance of inspections. More specifically the Prefectures carry out inspectorate controls very often while the containers are in the area of their jurisdiction. Also, all the responsible authorities are informed for the transportation and take appropriate actions which include escorting of the containers by the traffic police and inspections by the Port authorities, as provided for in the relevant legislation. The transporters keep records of the shipments which are submitted to the Prefectures every year.

However, there are certain difficulties concerning the implementation of the existing legislative framework concerning production and management of hazardous waste. This is due to the lack of appropriate treatment and disposal facilities in the country, the absence of an integrated waste management and control system and the high transportation cost of hazardous waste which derives mainly from the strict legislation, imposing a complex procedure and the involvement of a great number of actors for the transfrontier transport of hazardous waste.

The responsible authorities are trying to develop a national strategy in order to confront these problems. In this way, they are quite reluctant at the moment concerning the issuing of hazardous waste management permits as far as temporary storage is concerned, due to the absence of appropriate planned landfilling sites or thermal treatment facilities. Also, the Ministry of Environment, Physical Planning and Public Works has funded several studies during the last decade aiming at the data collection and assessment of hazardous waste, in order to develop an integrated national plan. Furthermore, the Ministry of Environment in collaboration with other Ministries and the Association of Local Authorities has scheduled the establishment of two hazardous waste management centers, one for the South part of Greece and one for the North. A programme aiming at the selection of the appropriate disposal site in Northern Greece is in progress since 1988 and came into conclusions concerning the specific site three years ago. However, there is great opposition from the public opinion and their representatives (Prefecture Committee), due to a very strong protest of people and their unwillingness to accept such a facility in their neighbourhood (NIMBY syndrome). This results in a constant postponement of the decision-making procedure. A similar programme has initiated in 1991 in Southern Greece and most of the environmental studies have been completed until today. However, it is anticipated that there will be serious oppositions concerning the selection of the disposal site.

A supplementary instrument used is the funding of programmes for the development of clean technologies in industries which are responsible for the generation of hazardous waste aiming at the promotion of preventive measures at the industry.

6. INDUSTRIAL SECTOR RESPONSE

The industrial sector as well as the transporters/managers of hazardous waste are aware of the fact that the management of hazardous waste is a subject with great interest, due to the great publicity that has been given in cases of illegal transportation or dumping. Also, the use of a demanding and complex legislation as the main instrument of the national policy force them to respond with great responsibility on the management of hazardous waste in order to comply with the legislation. However, the alternatives for the management of hazardous waste are very limited due to the lack of basic infrastructure in Greece. The possible solutions which are in compliance with the current legislation concerning the management of hazardous waste are either transportation to other EU countries in order to be treated or finally disposed off, or the appropriate treatment by the generators or by others or finally their safe storage in private places owned by the generators until the establishment of a thermal/chemical treatment plant and appropriate landfill site in the country.

Under the pressure of the legislation, a number of industries found alternatives ways for the management of hazardous waste. One popular solution is the transportation of hazardous waste in cement manufacturing plants. More specifically sludges containing lead from oil refineries are used as fuel supplement and particulates from steel industries are used as additives to the cement process. Another trend is the regeneration of used materials such as lubricants by specific industries. Also a significant number of industries has adopted preventive measures and clean technologies in their production procedures, in order to avoid the production of hazardous waste. However, most of the SMEs can not afford the cost of the introduction of such technologies.

Also, a number of industries including mainly the large industries and the units that produce specific hazardous waste such as PCBs or pesticides transport them to other EU countries for proper treatment. The main products that are transported are PCBs, cyanides, pesticides/herbicides, fly ash and phenols. The transportation of hazardous waste is performed by three companies. The small number of transporters is mainly due to the strict requirements in order to obtain a license from the public authorities for the transportation of hazardous waste. These companies transport the waste to a public thermal treatment facility in France, to Germany for thermal treatment and disposal in salt mines and to England for thermal treatment. The quantities of hazardous waste transported every year are relatively small (300 tonnes/year) and the main waste which are transported are PCBs (approximately 60 tonnes/year), due to the strict legislation that provides for their elimination in the following years. The transportation of small quantities is mainly due to the fact that the transportation cost is extremely high (approximately 2000 drachmas per kilo), since the great number of actors involved including the waste treatment company, the insurance company, the transportation companies and the state actors as well as the bureaucracy imposed by the legislation contribute significantly to the increase of transportation cost. Therefore, the solution of transportation is not economically feasible for most of the industrial units.

Due to the lack of substantial alternative solutions the majority of industries including refineries, fertilizers, tanneries, metal-plating industries, steel industries and petrochemical industries store their hazardous waste in private places, with the provision that they have obtained a hazardous waste management permit by the Municipalities, until a proper solution for their treatment will be found.

7. THE EFFECTIVENESS OF THE NATIONAL POLICY - CONCLUSIONS AND RECOMMENDATIONS

The main instruments used concerning hazardous waste management are first generation instruments. Strict and detailed legislation is in force, containing specific provisions for every stage of the transboundary transportation of hazardous waste, regulating the actions of all the actors involved. This strongly regulatory approach can be considered as the traditional policy tool used by the government in order to direct the private sector towards a prescribed behaviour. Also, the whole issue of transfrontier movement of hazardous waste is a subject in which legislation plays a key role, while other instruments (e.g. communicative) cannot contribute significantly in achieving the environmental policy goals.

However, the use of strict legislation creates problems in terms of high administrative costs, necessary for the implementation and enforcement of the legislative provisions. Also, the lack of appropriate treatment facilities in combination with the high transportation costs, does not leave much space for the industrial units to direct themselves towards alternative solutions. The policy followed through the use of first generation instruments almost exclusively, can be evaluated as effective in the short and medium term but it does not provide for sustainable solutions in the long

run. The temporary storage and the transportation to other countries are temporary solutions that are sufficient at the moment since the quantities of hazardous waste produced are small compared to other countries, however they can lead to the creation of great problems in the future, caused by the accumulation of hazardous waste.

A very interesting characteristic of the Greek reality is the co-existence of the IMBY with the NIMBY syndrome. On the one hand the legislation indirectly promotes the storage of the hazardous waste in the site (back yard) where it is generated. On the other hand, the Government is trying during the last 10 years to agree with the public and the local authorities on the allocation of the two major hazardous waste treatment plants. The attempts of the Government have not succeeded and have faced strong opposition on behalf of the local communities, the press and the NGO's. It is obvious that legislation by itself cannot solve the problem.

In order to deal with the problem of hazardous waste in an effective way, an integrated waste management and control system must be accomplished, which will be based in an instrument mix. First of all, an integrated approach towards hazardous waste treatment following the principle of proximity must be promoted with the development of hazardous waste treatment facilities in Greece. For the accomplishment of this goal, a mix of instruments is required in order to deal with the individual interests of the actors involved. The use of economic instruments both for the industry and for the local communities (e.g. by providing job opportunities for the inhabitants in the treatment plants or by funding local activities) is necessary in order to overcome the problem of the NIMBY syndrome. Furthermore, in this case the use of communicative instruments could also prove to be effective in terms of informing the public about the necessity of the plants and their real impacts. The dissemination of the appropriate information to the public through the mass media in general is a delicate issue which should be handled in the right way in order to avoid adverse effects from the use of this instrument. Also the needs of the industrial sector must be taken into consideration. This actually means that economic instruments such as incentives and funding for the introduction of clean technologies must be strengthened. Economic instruments in terms of funding programs and development of the necessary infrastructure for the creation of a market for hazardous waste is a necessary tool that will give solutions to the Greek reality. If such instruments were to be adopted, it would possibly lead to a positive response of the private sector, the administrative costs would be reduced and the results would be more promising.

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RISK ASSESSMENT OF CHEMICAL INSTALLATIONS AND LAND USE PLANNING AIMING AT PEOPLE WELFARE AND ENVIRONMENTAL PROTECTION

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ABSTRACT

A comparative assessment of three types of approaches in land use planning and in establishing protective actions in emergencies around chemical sites has been performed. Land use and emergency response plans, further to their self-standing value, help in the protection of public health, workers' health and the environment, main objectives of the so called "SEVESO" EU directive, already implemented in most of the European Member States. Three general approaches ranging from a purely "deterministic" approach to one exhibiting an, as complete as possible, quantification of the uncertainties have been examined. The validity of the general arguments is exemplified by applying these different zoning policies to a major hazard installation in Greece.

ΑΝΑΛΥΣΗ ΚΙΝΔΥΝΟΥ ΧΗΜΙΚΩΝ ΕΓΚΑΤΑΣΤΑΣΕΩΝ ΚΑΙ ΧΡΗΣΕΙΣ ΓΗΣ ΓΥΡΩ ΑΠΟ ΑΥΤΕΣ ΜΕ ΣΚΟΠΟ ΤΗΝ ΠΡΟΣΤΑΣΙΑ ΠΕΡΙΟΙΚΩΝ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΟΣ

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ΠΕΡΙΛΗΨΗ

Στην εργασία αυτή παρουσιάζονται τρεις προσεγγίσεις στην χωροθέτηση Χημικών Βιομηχανιών και στη λήψη προστατευτικών μέτρων γύρω από αυτές με σκοπό την προστασία των εργαζομένων, των περίοικων και του περιβάλλοντος, σύμφωνα με τις επιταγές της ονομαζόμενης "Οδηγίας SEVESO" των Ευρωπαϊκών Κοινοτήτων, η οποία εφαρμόζεται ήδη σε όλες σχεδόν τις χώρες μέλη. Εξετάστηκαν τρεις γενικές προσεγγίσεις, που κυμαίνονται από εντελώς "ντετερμινιστικές" ως τελείως πιθανολογικές με τη συνεκτίμηση των αβεβαιοτήτων που υπεισέρχονται στο πρόβλημα. Το παράδειγμα Εφαρμογής είναι μια μεγάλη Ελληνική Βιομηχανία.

1. INTRODUCTION

Risk analysis of chemical plants is a relatively new discipline in the engineering science which is gaining constantly pace over the "classical" approach of systems engineering and design, as the former constitutes another point of view for looking into the safety of a process plant and the possible unwanted consequences in the case of a major industrial accident to the people and the environment. The whole approach has been formulated through the EEC "SEVESO" Directive (concerning large industrial accidents) and its implementation in the greek legislation as well. This obliged a number of process industries (including Refineries, chemical production sites and LPG storage) to elaborate risk analysis studies for their sites in question.

Elaboration or reviewing of these studies may follow a well prescribed methodology, state-of-the-art for Probabilistic Safety Assessment (PSA) in Nuclear Power Plants and already tested for suitability and applicability to chemical installations comprising the following set of procedural steps [1]:

1. Hazard identification
2. Accident sequence modeling
3. Data acquisition and parameter estimation
4. Accident sequence quantification
5. Hazardous substance release category assessment
6. Consequence assessment
7. Integration of results.

The quantitative results produced in these studies can be also used in emergency and land use planning schemes. Actually, in this paper, a comparative assessment of three types of approaches in land use planning and in establishing protective actions in emergencies around chemical sites has been performed based on the results of quantitative risk assessments.
Implementation of the above mentioned Directive in Greece with respect to emergency schemes and land use planning around hazardous facilities has raised the issue of the appropriate philosophy to be applied.

Three general philosophies ranging from a purely "deterministic" approach to one exhibiting an, as complete as possible, quantification of the uncertainties have been examined. The validity of the general arguments is exemplified by applying three different zoning policies (as employed by three EU member countries) to a major hazard facility site in Greece.

2. LAND USE PLANNING (LUP) AROUND CHEMICAL SITES.

In the following three indicative philosophies of LUP are presented which correspond to the national policies of three E.U. countries, the major difference among them being the way that risk assessment is elaborated.

2.1 Design on the basis of the "Worst Possible Accident"

According to this approach all Land Uses around a dangerous chemical installation are determined on the basis of the consequences of a fully defined accident, which is thought to be the "worst possible" one. This is not always applicable as the worst possible accident can either not be defined or its consequences are considered extremely improbable, and thus is ignored. So the whole issue is

replaced by the definition of the "worst credible accident" which leads to the definition of a set of accidents which experts believe that are possible to happen.

A major representative of this philosophy is France where reference scenarios and the corresponding criteria are based on the analysis of past accidents as well as on possible events. There are six main scenarios referring to various types of facilities (see Ref.[2]). Each scenario is well-determined : the conditions under which the accident occurs (release characteristics, meteorological conditions, etc.) and criteria concerning the maximum acceptable effects (thermal radiation, overpressure or toxic dose) have been established.

Then, risk assessment procedure leads to the calculation of two distances (risk zones) :
- the distance at which the first death occurs (corresponding to probability of fatality 1%)
- the distance at which irreversible health effects occur.

The overall area of these risk zones can in most cases be converted into two areas with different development restrictions. The zones are called Z1 and Z2, Z1 being closest to the installation. Three types of development have been identified on the basis of their suitability in the different zones. These types of development are housing and public buildings, industrial installations and transport routes, which, in their turn, are also further subdivided. (see Ref.[2])

In zone Z1 only "housing and public building" developments not resulting in an increase in population density are allowed. In zone Z2 authorization is given for developments with limited density, that is all categories of "housing and public building" developments with the exception of high rise buildings and establishments receiving the public. Industrial installations can only be permitted in these zones if certain conditions are fulfilled :

- Limited number of staff in neighboring installations
- Compatibility with existing industrial activities
- Possible emergency training of staff in neighboring installations.

2.2 Design on the basis of Quantitative risk Assessment

A second basic philosophy which can be followed when designing Land Uses around chemical installations is the one based on Quantified Risk Assessment [3]. According to this approach LUP is not based on the consequences of the most possible or credible accident but on the consequences of all possible accidents weighted by their occurrence probability.

This philosophy allows both for the combination of different nature accidents (e.g. toxic releases, explosions, fires etc.) and for the accounting of mitigation measures taken on-site and affecting the occurrence probability of the accident. According to this philosophy, which is mainly followed in the Netherlands, the definition criteria of the various zones is not the intensity of natural phenomena following an accident (e.g. explosion, fire, toxic release) but rather the measures of quantified risk.

Two measures of risk are usually calculated : (i) the *individual risk,* defined as the probability of fatality due to an accident in the installation for an individual being at a specific point, and (ii) the *societal risk,* defined for different groups of people, which is the probability of occurrence of any accident resulting in fatalities greater than or equal to a specific figure. Individual risk is usually presented by the isorisk curves, while Frequency - Number of fatalities (F-N) curves provide a visualisation of the societal risk. The criteria used for the two measures of risk in the Netherlands are given in Table 1, in the following.

TABLE 1 : The Dutch risk acceptability criteria		
	Individual risk criteria	Societal risk criteria
Existing installations	10^{-5} per year	probability of N fatalities < $10^{-3}/N^2$
New installations	10^{-6} per year	probability of N fatalities < $10^{-3}/N^2$
Negligible risk	Always ALARA* applied	Always ALARA* Applied

* ALARA : As Low As Reasonably Possible, N : number of people exposed at risk.

Recently, the Dutch safety criteria were reviewed on the occasion of the safety report for the international airport of Amsterdam (Schiphol). The results of that review, from the land-use planning point of view, are summarised as follows :

1. Within the $5x10^{-5}$ per year risk zone : No new housing construction is permitted; existing houses are demolished.
2. Within the 10^{-5} risk zone per year: No new construction is permitted; existing houses can be replaced by new ones.
3. Within the 10^{-6} risk zone per year: An overall risk policy is adopted; restrictions on the construction of new houses are set; societal risk is taken into account.
4. In an even larger area the construction of new dwellings is restricted to some extent.

2.3 An intermediate approach

Several countries follow a policy which is based partly on both of the above mentioned approaches. In the UK. for example, the authorities started with the philosophy of the "worst accident" and now are shifting to Land Use policies that are more and more based on quantified risk assessment[4].

2.4 The proposed approach

Aiming at illustrating the above mentioned approaches of LUP and of the proposed methodology a Greek Chemical site has been selected for which a complete Risk Analysis according the SEVESO Directive requirements has been performed. The site is a Refinery containing both flammable (hydrocarbons) and toxic (Hydrogen Fluoride, HF) substances. For the French approach calculations have been done according to the prescriptions given in [2]. The quantitative risk assessment methodology used is the one adopted in the Reliability and Industrial Safety Laboratory (RISL) [1] and the computer code for the evaluation of consequences is called SOCRATES [5], also developed in RISL. The results of the study are presented in Table 2.

TABLE 2a : Zones identified in the French Approach by the reference scenarios and the corresponding criteria			
Accident Scenario	**Example of application**	**Distance corresponding to criteria for first death**	**Distance corresp. to criteria for first irreversible effects**
A : Boiling Liquid Evap. Vap. Explos.	Spherical gasholder of $3000m^3$ of butane	2100m (1% Fatalities)	2400 m (1% 2nd degree burns)
B : Unconfined Vapour Cloud Explosion	Break of a 800 mm pipeline from a propane vessel 3000kg/s outflow rate	780 m (140 mbar)	1725 m (50 mbar)
C : Total instantaneous loss of containment	Vessel containing 5 tons of HF	500 m (1200 kg in 60 sec) Stab:D, wind vel.: 3 m/s	1600(274 for 60 sec = $IDLH^2$x30min)

TABLE 2a *(Continued)*

Accident Scenario	Example of application	Distance corresponding to criteria for first death	Distance corresp. to criteria for first irreversible effects
D : Instantaneous breakage of the largest pipeline leading to the highest mass flow	Break of a 50 mm pipeline from a HF vessel	550 m (30 kg/s for 180 sec) Stab:D, wind vel.:3 m/s	1400m (180 ppm for 180 sec = $IDLH^2$x30min)
E: Fire in the largest tank	Fire in a reservoir of 120000 m^2 containing fuel oil	175m (5 kW/m^2)	215 m (3 kW/m^2)

TABLE 2b : Zones identified in the Dutch Approach

Zone	Average Radius
10^{-5} /yr. Individual Risk	750 m
10^{-6} /yr. individual Risk	1500 m

3. THE MULTICRITERIA ANALYSIS METHODOLOGY.

Three major steps can be distinguished:

1. Generation of alternatives. The area around the refinery is subdivided into 2500 cells of 100mx100m each. For each cell a number of Land Development Types (LDT) has been defined, following relevant analyses (see Table 2). Each LDT, when applied to a cell, implies the population distribution and economic benefit given in Table 3. In order to achieve homogeneity cells characterized by the same risk level are grouped into zones and in each zone the same LDT is applied. A Land Development Pattern (LDP) is defined when for each and every zone of the area an LDT is determined.

2. Calculation of Consequences. The consequences of each LDP are measured in two dimensions i.e. Potential Loss of Life (PLL) and Economic Benefit. The former is calculated on the basis of the risk profile implied by the hazardous facility (refinery) and the population distribution implied by the LDP. Economic benefit is calculated as the sum of the economic benefits implied by the LDT of each zone in the area.

3. Generation of Efficient Frontier. From the definition of an LDP in step 1 above it follows that a great number of LDPs is possible. Of interest is the set of efficient or non-dominated LDPs that is, those solutions for which there is no other solution that is better in all criteria (here, Economic Benefit and Potential Loss of life). An algorithm that generates the efficient set without necessitating generation of all possible alternatives has been imbedded in a computerized decision support system. This system develops the set of efficient solutions in the consequence space along with the corresponding LDPs [6,7,8].

Table 3 : Land Development Types-associated Parameters

Land Development Type	Population Density	Economic Benefit
LDT1 No further Development	0 (existing)	0
LDT2 Recreation	10 people/cell	0.2 monetary units
LDT3 Residential	100 people/cell	1 monetary unit
LDT4 Blocked	-	-

4. RESULTS AND CONCLUSIONS

In Figure 1, the overall risk profile of the installation is presented, namely isorisk curves 10^{-5}, 10^{-6} and 10^{-7} per year, while in Figure 2 the two zones Z1 and Z2 of the French LUP are drawn which correspond to a conditional individual risk of 10^{-2} and 10^{-3} , conditional on the fact that the worst BLEVE accident has occurred in the installation.

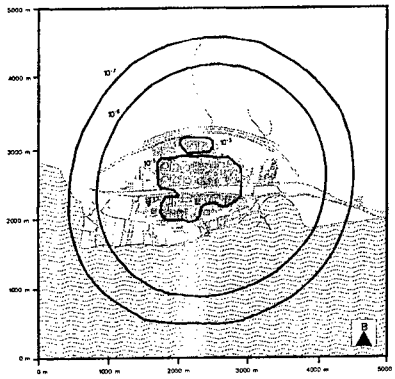


Figure 1. Installation with isorisk curves

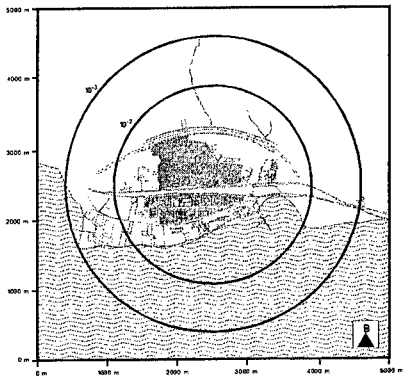


Figure 2. Installation with conditional isorisk curves (BLEVE), French approach

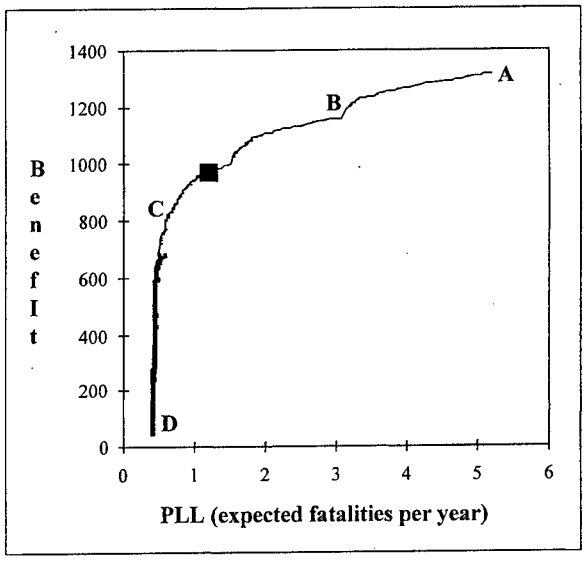


Figure 3. Efficient Frontier of solutions

Figure 3 presents the efficient frontier of solutions for the two measured consequences of our study: Economic Benefit vs. Potential Loss of life. The fine continuous line depicts the "no limit" policy on LUP, while the bolder line expresses the French approach which is slightly suboptimal (includes "dominated" LDPs) to the efficient frontier of solutions. The square on the frontier corresponds to the upper limit for LDPs according to the development constraints imposed by both the Dutch and English approach (without taking, though, the societal risk into consideration). Each point of the efficient frontier depicts a thoroughly defined LDP in the study area as it can be seen in Figure 4 where three points of the frontier are chosen and the relevant LDPs are also presented (each Land Use Policy is depicted with a different gray tonality and corresponds to different population density and benefit).

The efficient frontier can form the basis for a discussion on the available alternatives without formally establishing value tradeoffs. For example, it can be argued and easily accepted by the various stakeholders that solution (B) (see Fig. 3) would be more preferable than solution (A) since it implies a substantial decrease in PLL while the corresponding decrease in benefit might be judged as not equally significant. Furthermore, it could be argued that C is more preferred to D since the latter solution implies a large decrease in benefit with marginal decrease in PLL. The whole discussion can concentrate on whether the gains in PLL from the level implied by point A to the level implied by point B justifies the corresponding reduction of benefits. If the answer is affirmative and if, furthermore, further gain in PLL from C to D is judged marginal, then any solution in the area BC might represent an acceptable solution.

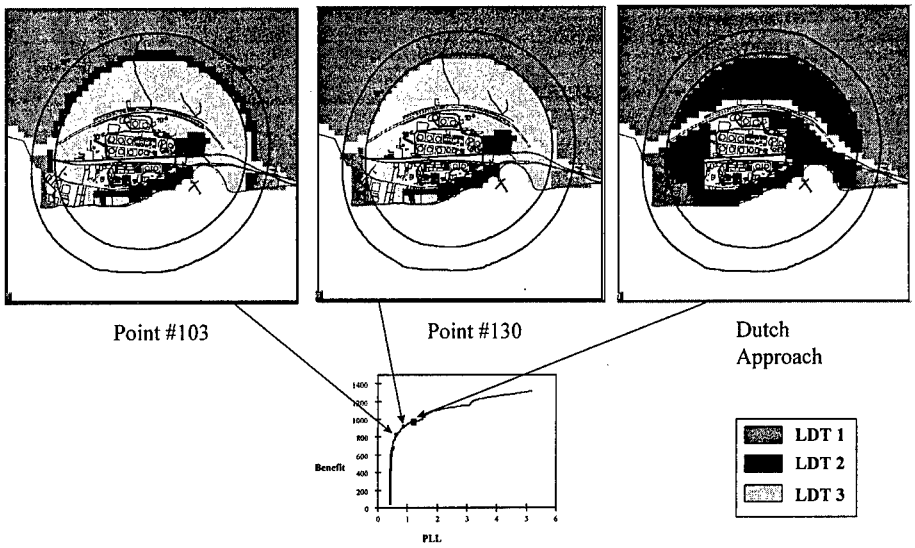


Figure 4. Three LDPs and their mapping on the Efficient Frontier

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OPTIMAL USE OF MULTIPLE STATISTICAL CRITERIA IN BAYESIAN DECISION-MAKING

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ABSTRACT

The maximum expected utility has been traditionally used as the sole criterion for selection of the optimum action in Bayesian decision-making. We demonstrate, through the study of an environmental project, that the use solely of this criterion can lead to erroneous decisions in the presence of uncertainty and we discuss the application of additional statistical measures to illuminate the consequences of alternate actions. We conclude by providing a procedure for cases where the uncertainty in parameters is not described by statistically sharp probability values but rather by a range of values.

ΒΕΛΤΙΣΤΗ ΧΡΗΣΗ ΠΟΛΛΑΠΛΩΝ ΣΤΑΤΙΣΤΙΚΩΝ ΚΡΙΤΗΡΙΩΝ ΣΤΗ ΘΕΩΡΙΑ ΛΗΨΗΣ ΑΠΟΦΑΣΕΩΝ

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ΠΕΡΙΛΗΨΗ

Παραδοσιακά, ως μοναδικό κριτήριο επιλογής της βέλτιστης ενέργειας, στη θεωρία λήψης αποφάσεων (Bayesian) χρησιμοποιείται η μέγιστη αναμενόμενη τιμή της ωφελιμότητας (utility). Μέσω της μελέτης ενός περιβαλλοντολογικού έργου, αποδεικνύουμε πως παρουσία στατιστικής αβεβαιότητας, η χρήση αποκλειστικά του ανωτέρου κριτηρίου, οδηγεί στη λήψη της μη-βέλτιστης απόφασης. Προτείνουμε την εφαρμογή επιπρόσθετων στατιστικών χαρακτηριστικών για να διασαφηνίσουμε τις συνέπειες εναλλακτικών ενεργειών. Ολοκληρώνουμε παρέχοντας μία διαδικασία για περιπτώσεις όπου η αβεβαιότητα στις παραμέτρους περιγράφεται από εύρος τιμών.

1. INTRODUCTION

In most practical applications a scientist or engineer is required to decide among different actions when unknown or unpredictable elements are involved in the analysis of the situation at hand. Such examples include: construction of a dam when the magnitudes of future flood events are uncertain; choice between alternate foundation designs for a bridge when the supporting capacity of the soil is not completely determined; selection of the location and construction materials of a landfill when the hydrologic conditions are subject to uncertainty.

Traditionally these kinds of problems are treated in the context of the Bayesian statistical decision theory. A basic element of the structure of such a problem includes a set of alternate actions among which the selection is made. The choice of a particular action over another depends on "the state of nature" such as the magnitude of the maximum flood, the supporting capacity of the soil, or the hydrologic conditions. The various states of nature are subject to uncertainty and probability values are assigned to them. The choice of each action leads to a different numerical measure or utility (say dollars) for the action-state pair.

It has been suggested in the literature [1, 2, 3] that the criterion of choice among alternate actions is that of the maximum expected utility (Bayes Risk Principle). Hence, it has been customarily recommended that the analysis of a decision-making situation be reduced to the calculation of expected utilities and the selection of the action that returns the largest expected value.

In this paper we will demonstrate that the sole use of this criterion may lead to a poor selection of the optimum action. We will provide a numerical illustration of this point and show that the utilization of additional statistical measures provides insight, eventually leading to a different selection than that suggested by the largest expected value criterion. Finally, we conclude by providing a theoretical procedure for the analysis of cases where the states of nature are not assigned statistically sharp probability values but rather a range of values.

2. PROBLEM DEFINITION

We consider the situation where the appropriate level for a contract bid toward an environmental project (such as a landfill of domestic, industrial or hazardous wastes) has to be selected by a company. There are three main components considered in this analysis: (i) the transportation of the wastes from the location of origin to the proposed operating facility, (ii) the construction of the facility and burial of the transported material and (iii) the operation of the facility and monitoring of the wastes for a fixed period of time. The action space A contains action α_1, which involves putting forward a bid for the construction, transportation and burial of the wastes, and action α_2, that additionally includes the operation of the facility and monitoring for t-years. By actions here, we mean the different distinct strategies a company may select in bidding on a project. In this study we are interested in contrasting the profitability and return on capital invested of a strategy that considers bidding on part of a project (α_1) with a strategy that bids on the totality of the same project (α_2). Practically, action α_1 leads to a consortium of companies with a primary contractor investing only on part of a project and subcontracting the remaining part whereas in α_2 a single contracting company is involved.

Of concern in the transport of wastes are two factors: whether one can (or does) transport the waste to the facility from the originating site without a spill at some cost C_1 and if there is a spill during transport then not only must the original material be re-collected and transported but, so must any

other contaminated material, at a higher cost C_1'. Designate the probabilities of transport without and with spill by p_s and $p_f = 1 - p_s$, respectively.

Once the waste material reaches the facility there is a direct cost C_3 for burial (C_3 also incorporating all costs for construction of the landfill itself). In the case where a leak occurred during transport this cost would be higher at C_3' because material contaminated at the spill site must also be emplaced at the facility with requirements for additional space, etc.

In the case where the facility is operated and the buried material is being monitored for leakage (because of defective lining, corrosion of containers etc.) over a period of t-years, there is a cost M per year in the case of only the initially transported material, and a higher cost M' for the case of spill during transportation because more material has to be monitored over the years. These various probability branches and associated costs are depicted in Figure 1 together with the contract bid B offered by a company. All cost values are considered in fixed year dollars.

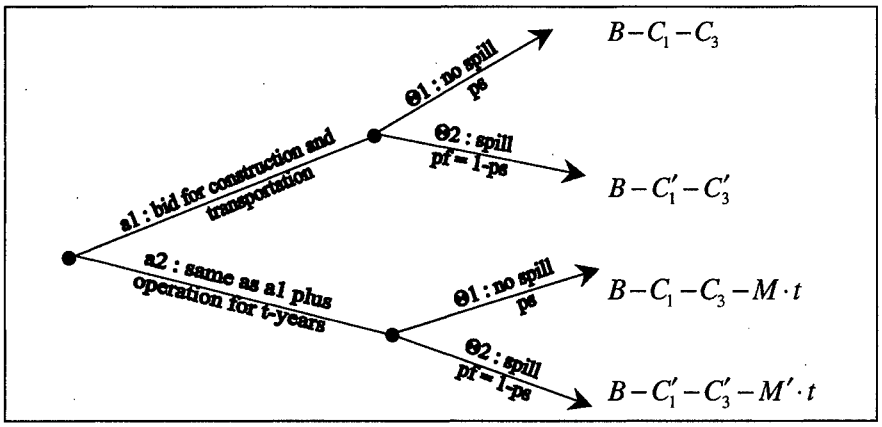


Figure 1. Decision tree: Contract choice for engineering project.

The analysis proceeds by evaluating, initially, each action independently, and eventually comparing their outcomes in terms of the optimum selection. We utilize four statistical measures in our study: the expected value, the variance, the volatility and the probability of making a profit. We conclude our paper by providing a theoretical framework for the analysis of cases where the probabilities of success, p_s and failure, p_f, are not single values, but rather are given as estimated ranges of values.

2.1 Statistical measures

We are considering four statistical measures for the analysis of the optimum action. The expected value, E, of each branch that corresponds to an action, the variance, σ^2, as a measure of the accuracy of the expected value, and the volatility, ν, defined by

$$\nu = \sigma / |E|, \tag{1}$$

a measure of the worth of the expected value. A low value of ν ($\nu << 1$) implies but little uncertainty on E, whereas $\nu >> 1$ implies a large uncertainty.

Finally, based on both the expected value, E, and the variance, σ^2, one can write an equivalent Gaussian probability value, P(V), of obtaining a value greater than or equal to V as

$$P(X \geq V) = 1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{a} \exp\left[-u^2/2\right] du \tag{2}$$

where the standardized variable U = (X - E) / σ (mean 0 and standard deviation 1) and a = (V-E) / σ were utilized. Note that if one wants a value V greater than or equal to the mean, E, (i.e., V = E) then equation (2) returns P(E) = 1 / 2, as it should. Conventionally, one often considers the minimal situation of a value greater than zero (V = 0) as relevant, in which case

$$P(0) = \frac{1}{2} - \frac{1}{\sqrt{2\pi}} \int_{0}^{b} \exp\left[-\frac{1}{2}u^2\right] du \tag{3}$$

where b = -E / σ = -(ν)$^{-1}$. Thus a high volatility (ν >>1) makes $|b| << 1$ and then, through Taylor series expansion of the integrand, one obtains the following approximation to (3)

$$P(0) \approx \frac{1}{2} - \frac{1}{\sqrt{2\pi}} b. \tag{4}$$

A low volatility (ν <<1) makes $|b| >> 1$ and then through asymptotic expansion of the integral [4] a good approximation is

$$P(0) \approx \frac{1}{2}\left(1 + \mathrm{sgn}(E)\right) + \frac{b}{\sqrt{2\pi}} \exp\left[-\frac{b^2}{2}\right]. \tag{5}$$

The above cumulative probability expressions can be used in two ways: for a given set of parameters for the decision tree diagram of Figure 1, one can evaluate E and σ, and so b, and then calculate the corresponding probability P(0) that the contract bid B will exceed or at least cover all possible costs; or one can require a given probability P(0) be enforced, and then determine the b-value needed, and so determine parameters in the decision-tree diagram in order that on has, say, a 90% chance (P(0)=0.9) of the contract bid covering all costs.

2.2 Analysis of alternate actions

We consider first the case where a bid is offered for the transportation and burial of wastes only. The expected value is then given by

$$E_{t=0} = B - C_1' - C_3' + p_s(C_1' - C_1) + p_s(C_3' - C_3). \tag{6}$$

The minimum bid that can be offered is B = C_1+C_3 corresponding to a no-profit situation under the optimum conditions. The minimum optimum bid is B = C_1'+C_3' corresponding to a break-even situation under the worst anticipated conditions, whereas the contract under which, on the average, one can expect a no-loss situation is $B = C_1' + C_3' - p_s(C_1' - C_1) - p_s(C_3' - C_3)$. If we were to assume C_1 = 0.2B, C_3 = 0.5 B (cost of transportation and burial correspond to 20% and 50% of the contract, respectively) and C_1' = 2C_1 and C_3'= 2C_3 (cost of transportation in the event of spill increases by a factor of 2, followed by a similar raise in the burial component), the expected value for B_{min} = 0.7 (minimum costs) is $E_{t=0}^{min}$ = –0.07, σ_{min}= 0.21, ν = 3 and P(0) = 37%. The expected value and standard deviation for bids that are multiples of B_{min}, B'= a·B_{min}, a ≥ 1, are given by: $E_{t=0}' = E_{t=0}^{min} + (a-1)B_{min}$ and $\sigma' = \sigma_{min}$. Thus, increase of the contract bid improves the expected return but the uncertainty on the outcome remains the same. Depicted in columns 1, 2, 5, and 6 of Table 1 are the effects of different levels of bids B' normalized by the minimum bid B_{min}= 0.7 on the expected value $E_{t=0}$, ν, and P(0).

Correspondingly, one can evaluate the effect of operating the facility and monitoring the wastes for periods of t = 5, 10 and 20 years. The expected value for action a_2 is given by:

$$E_t = B - C_1' - C_3' - M' \cdot t + p_s(C_1' - C_1) + p_s(C_3' - C_3) + p_s \cdot t(M' - M). \tag{7}$$

In addition to the values of the previous parameters C_1, C_3, C_1' and C_3' one considers that the costs of operation and monitoring per year, M and M' are 1% and 2% of the contract B, respectively. The

minimum possible bid is then given by 0.7+0.01·t, the minimum contract under the worst conditions is 1.4+0.02·t and the bid under which there exists at least 50% chance of profit is 0.77+0.011·t.

$B_{t=0}$ / Bmin	$E_{t=0}$	$B_{t=20}$ / Bmin	$E_{t=20}$	ν	P(0)
1.00	-0.070	1.29	-0.087	3.00	37 %
1.02	-0.056	1.32	-0.066	3.70	39 %
1.04	-0.042	1.34	-0.052	5.00	42 %
1.06	-0.028	1.37	-0.031	7.70	45 %
1.08	-0.014	1.39	-0.017	15.0	47 %
1.10	0.000	1.42	0.000	∞	50 %
1.15	0.035	1.48	0.045	5.90	57 %
1.20	0.070	1.55	0.095	3.00	63 %
1.25	0.105	1.61	0.137	2.00	69 %
1.30	0.140	1.68	0.186	1.50	75 %
1.35	0.175	1.74	0.228	1.20	79 %
1.40	0.210	1.81	0.277	1.00	84 %
1.45	0.245	1.87	0.319	0.85	88 %
1.50	0.280	1.94	0.368	0.75	91 %
1.60	0.350	2.06	0.452	0.60	95 %
1.70	0.420	2.19	0.543	0.50	98 %
1.80	0.490	2.32	0.634	0.43	98.9 %
1.90	0.560	2.45	0.725	0.37	99.6 %
2.00	0.630	2.58	0.816	0.33	99.9 %

TABLE 1. Statistical measures for actions a_1 and a_2 (t = 20 yrs).

If one considers the minimum bid of 0.7+0.01·t then the expected return would be E_t= -0.07-0.001·t and the standard error would be σ_t = 0.21+0.003·t. Hence, both the expected return and its uncertainty vary linearly with the time horizon of the project. The various statistical measures for a time period of 20 years are shown in columns 3, 4, 5 and 6 of Table 1. Figure 2 plots the probabilities P(0) for actions a_1 and a_2 for various time horizons as a function of the contract bid normalized by B_{min}=0.7 of action a_1.

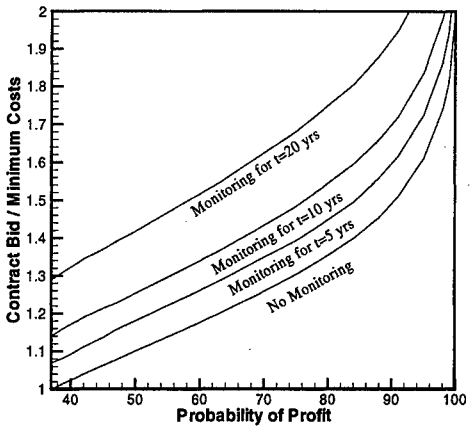


Figure 2. Probabilities of profits for different actions and contract bids.

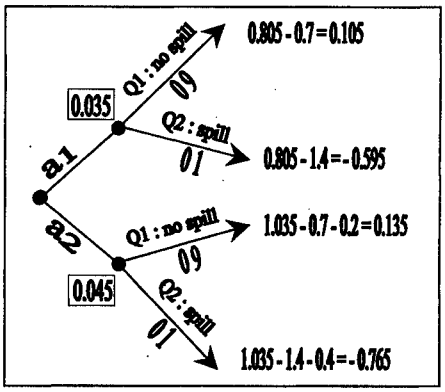


Figure 3. Comparison between a_1 and a_2 (t = 20 yrs).

Compare now actions a_1 and a_2 with offering bids of 0.805 and 1.035, respectively (row 7 of Table 1). The various probability branches and associated costs are depicted in Figure 3. The expected value of each action is indicated within a box at the right-hand end of the action branch.

Figure 3 indicates that according to the Bayes Risk Principle action a_2 is the preferred action because the largest expected value is returned. Detailed evaluation reveals that the difference between E_{a1} and E_{a2} (in millions of dollars) is \$10,000. This profit is realized by expending an extra capital of \$230,000 with the same high volatility of v=5.9 and P(0)= 57% as for action a_1 (but with a higher standard error of 0.27 instead of 0.21). It is important to realize here that the value that will be received if a_2 is preferred will not be $\$0.045*10^6$ but rather either a gain of $\$0.135*10^6$ or a loss of $\$0.765*10^6$. The potential gain of action a_2 over a_1 is \$30,000 and the loss is \$170,000. Thus, if the action recommended by the maximum utility criterion is favored, an extra capital of \$230,000 must be expended to realize, at best, a gain of \$30,000 over a_1. Such a decision requires a willingness to accept a loss of an extra \$170,000 over a_1. In other words in order to expect 13% return on the additional investment one needs to be willing to risk losing 74% of the extra capital required for action a_2. It is clear from the above analysis that the exclusive use of the Bayes Risk Principle leads to selection of a high risk action; the use of additional statistical measures provides a cautionary sign (high volatility and increase of standard error) for a more detailed evaluation that points to the correct strategy α_1.

3. PARAMETER UNCERTAINTY EFFECTS

The evaluation of expected value, E, variance, σ^2, and cumulative probability, P(V), have so far been predicated on statistically sharp values for the parameters in the decision tree of Figure 1, with the uncertainty arising from the probabilities along the different possible paths. But there is a second form of uncertainty that arises due to the fact that one does not have statistical sharpness on each and every parameter but rather an estimated range of values within which a parameter can lie.

For instance one might calculate a success probability, p_s, of transporting wastes without leakage at, say, $p_s = 0.9$, but different methods of estimation and different underlying assumptions can produce a range of estimates of p_s, say $0.8 \leq p_s \leq 0.99$.

Two factors are apparent: (i) there is no particularly valid, objective justification for preferring any one value of p_s out of its range over any other value; (ii) one needs to evaluate which ranges of which particular parameters are causing the largest uncertainty in estimates of the expected value E, its variance σ^2, and the cumulative probability P(V). Then one has available the relative importance of each parameter in contributing to system uncertainty and so one can then determine where to place effort to narrow the ranges of uncertainty of the most important parameters - and with a clear determination of the definition of importance as it relates to the specific system of study.

3.1 Means and Variances

Let us assume that one selects at random from the range of each variable parameter. Then, for each choice -i- of such a set of parameter values one can calculate an expected value E_i, and a variance σ_i^2, together with a cumulative probability $P_i(V)$. Clearly, by performing a series of Monte Carlo computations with N total selections, one produces both a mean expected value

$$< E > = N^{-1} \sum_{i=1}^{N} E_i \tag{8}$$

and a direct uncertainty $< \rho^2 >$ in $< E >$ due solely to the statistical variations in each parameter given by

$$< \rho^2 > = N^{-1} \sum_{i=1}^{N} (E_i - < E >)^2 . \tag{9}$$

In addition, one also has a mean value for the variance, $< \sigma^2 >$, from

$$< \sigma^2 > = N^{-1} \sum_{i=1}^{N} \sigma_i^2 \tag{10}$$

and an uncertainty, $< \delta^2 >$, in the mean variance calculated from

$$< \delta^2 > = N^{-1} \sum_{i=1}^{N} (\sigma_i^2 - < \sigma^2 >)^2 . \tag{11}$$

Because the direct uncertainty, $< \rho^2 >$, in $< E >$ is due to fluctuations in parameter values, while the variance $< \sigma^2 >$ is due to the different probabilistic paths, the total uncertainty on $< E >$ is then measured by the variance σ_E^2 where

$$\sigma_E^2 = < \rho^2 > + < \sigma^2 > . \tag{12}$$

Equally, for the cumulative probability P(V) there are several measures of worth. Thus, one can compute a mean cumulative probability, <P(V)>, from

$$< P(V) > = N^{-1} \sum_{i=1}^{N} P_i(V) \tag{13}$$

and an associated uncertainty, $< \delta P(V)^2 >$ from

$$< \delta P(V)^2 > = N^{-1} \sum_{i=1}^{N} (P_i(V) - < P(V) >)^2 . \tag{14}$$

One can also compute an approximate mean value, $\overline{P}$, using $< E >$ and σ_E in equation (2). If the difference

$$\left| < P(V) > - \overline{P}(V) \right| \leq < \delta P(V)^2 >^{1/2} \tag{15}$$

then it is an accurate enough approximation to use $\overline{P}(V)$, otherwise one must use the ensemble value <P(V)>.

3.2 Relative Importance

In addition to having the ability to compute ensemble averages and their fluctuations, one also requires knowledge of which uncertainty ranges of which parameters are contributing the most to the total system uncertainty.

This relative importance problem can be addressed simply as follows. Each parameter in the decision tree diagram of Figure 1 has a mean value within its range of variation. Let a vector **q** denote all of the component parameters, with the j-th component, q_j, having a mean value $< q_j >$ when $q_{j\min} \leq q_j \leq q_{j\max}$ where $q_{j\min}$ and $q_{j\max}$ are respectively, the minimum and maximum values of q_j.

Suppose one were to use only the vector of mean values, **<q>**, to calculate the quantities in the previous subsection. Then this is precisely the same as choosing specific values of the parameters. In which case $< \rho^2 > = 0$ and $< \sigma^2 >$ is the same as σ^2(**<q>**). Now consider the influence of uncertainty in each variable in contributing to variations in σ_E^2, because there is an intrinsic value for σ_E^2 even when the parameters are statistically sharp. The changes in σ_E^2, relative to the value σ^2(**<q>**), due to variations in each parameter around its mean value, are then determined as follows.

Let all except one, say the j-th, of the components of the parameter vector **q** be held at their mean values. This j-th component of **q** is then varied, randomly, around its mean value. The result is obviously a value for $< \rho^2 >$ and σ_E^2 which is dependent on $< q_j >$ and on $q_{j\min}$ and $q_{j\max}$. Denote these values as $< \rho(j)^2 >$ and $\sigma_E(j)^2$. Repeating the process for all components of **q** one can then calculate the relative fractional uncertainty contribution (RC_j) to $< \rho^2 >$ from each q_j as

$$(RC_j) = < \rho(j)^2 > / \sum_{k=1}^{N} < \rho(k)^2 . \tag{16}$$

Equally, one can compute the relative importance, RI_j, to σ_E^2 from

$$RI_j = \sigma_E(j)^2 / \sum_{k=1}^{N} \sigma_E(k)^2 . \tag{17}$$

Similarly, for the ensemble mean value, < E > and the cumulative probability, P(V), one can compute relative importance values from, respectively,

$$RI_j(E) = < E(j) > / \sum_{k=1}^{N} < E(k) > \tag{18}$$

and

$$RI_j(P) = P_j(V) / \sum_{k=1}^{N} P_k(V) \tag{19}$$

which provide measures of the contributions.

4. CONCLUSIONS

The following conclusions can be drawn from this paper.

1. The Bayes Risk Principle recommends a preferred action returning the maximum expected value; but this action may lead to erroneous decisions. The use of additional statistical measures, such as standard error, volatility and cumulative probability, provides insight to the selection process leading to a more appropriate decision.
2. When parameters of a decision tree take on values lying within estimated ranges, a series of Monte Carlo simulations provides the framework for relevant decision-making.
3. The use of the relative uncertainty can guide one towards selection of those parameters that dominantly influence the total system uncertainty, thus allowing one to concentrate resources on efforts to minimize the range in such dominant parameters.

ACKNOWLEDGMENTS

The work reported here has been partially supported by Grant DE-FGO2-97EWO9999 to the first author from the U.S. Department of Energy, Office of Environmental Management, and the Center for Water Research at the University of South Carolina.

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DECISION ANALYSIS ON INDUSTRIAL DESIGN FOR ENVIRONMENT

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ABSTRACT

The industrial design for environment methodology consists a comprehensive framework for industrial innovation respecting sustainability criteria. Four conceptual blocks are identified, spanning the whole spectrum of industrial development, from natural resource exploitation to waste management practices, and integration of market signals and regulatory requirements to the design process. The practical implementation of these concepts requires support from an appropriate decision making process which can ensure the identification of the different attributes of industrial systems, the enumeration of the relevant stakeholders, the respective relative preferences of the latter with regard to particular technological options and the provision of the necessary information for transparent negotiation. An appropriate decision support system is outlined.

ΑΝΑΛΥΣΗ ΑΠΟΦΑΣΕΩΝ ΓΙΑ ΒΙΟΜΗΧΑΝΙΚΟ ΣΧΕΔΙΑΣΜΟ ΓΙΑ ΤΟ ΠΕΡΙΒΑΛΛΟΝ

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ΠΕΡΙΛΗΨΗ

Η μεθοδολογία βιομηχανικού σχεδιασμού για το περιβάλλον αποτελεί ένα ολοκληρωμένο πλαίσιο για βιομηχανικό νεωτερισμό που σέβεται κριτήρια βιωσιμότητας. Αναγνωρίζονται τέσσερα θεωρητικά τμήματα, που καλύπτουν όλο το φάσμα της βιομηχανικής ανάπτυξης, από την αξιοποίηση των φυσικών πόρων μέχρι τις πρακτικές διαχείρισης αποβλήτων, και την ενσωμάτωση σημάτων της αγοράς και νομικών απαιτήσεων στην διαδικασία σχεδιασμού. Η πρακτική εφαρμογή αυτών των εννοιών απαιτεί υποστήριξη από την κατάλληλη διαδικασία λήψης αποφάσεων η οποία πρέπει να μπορεί να βεβαιώσει την αναγνώριση των ποικίλων χαρακτηριστικών των βιομηχανικών συστημάτων, των σχετικών μετόχων και των προτιμήσεών τους ως αναφορά τις τεχνολογικές επιλογές, και τις απαραίτητες πληροφορίες για διαφανείς διαπραγματεύσεις. Στην παρούσα εργασία σκιαγραφείται ένα κατάλληλο σύστημα υποστήριξης στη λήψη αποφάσεων.

1. INTRODUCTION

The current state of technological development represents a clear transition in the way we understand how technology interacts with the natural and human environment. The concept of man as a custodian of the environment has been receiving increased appreciation, in the form of global concerns over deforestation, global warming, the destruction of the ozone layer, acid rain, problems associated with toxic waste disposal and elimination, etc. 'Sustainability' has been accepted and adopted internationally as a framework for guiding future development within which economic, social, and environmental goals must be adopted which are consistent with each other and mutually attainable [1]. Appropriate legislative tools have been developed over the last five years. Among the most advanced legislative texts is the European Council Directive on Integrated Pollution Prevention and Control (IPPC) adopted in 1996 [2]. Its purpose is to achieve integrated prevention and control of pollution arising from a large array of industrial activities that fully cover process industries. It lays down measures designed to prevent or, where non-practicable, to reduce emissions in the air, water and soil, including measures concerning waste, in order to achieve a high level of protection of the environment taken as a whole. According to the IPPC legislation the acceptability of a process depends upon a balance between the relative harm of releases in different media and economic cost. There is, therefore, little basis for an objective comparison between economic and environmental costs. Consequently decisions need to be made using techniques such as ranking (hazard prioritisation) or multi-attribute analysis. An increasing number of recommendations and decisions of legislative bodies both in the European Union and the United States take the view that such analyses will have to be introduced in the process planning at the earliest possible stage. Indeed, leaving pollution control considerations until a later stage in the process design and development process will almost certainly result in the use of end-of-pipe technology.

Integrated environmental assessment of industrial processes includes resource consumption in terms of raw materials and energy requirements), quantification of emissions and discharges (in the form of gaseous, airborne, liquid, dissolved, or solid waste), and assessment of the impacts on human and animal welfare. Development of appropriate environmental impact indicators allows the coupling of plant and process parameters with their impact on the natural and human environment. Integration of the indicators within the process optimisation functions currently used in chemical plant synthesis can provide an effective tool for the internalisation of external costs of industrial production. This is the Design for Environment methodology outlined in this work.

2. THE DESIGN FOR ENVIRONMENT METHODOLOGY

The industrial design for environment methodology described herein can be broken down in three phases, i.e. optimal selection of materials, process plant synthesis and optimisation, and industry-wide synthesis [3]. Materials selection is based on life-cycle analysis of products and materials. Plant synthesis and optimisation is based on methodologies combining economic and energy optimisation of processes with minimisation of impacts on the environment and public safety. Industry-wide synthesis relies upon multi-criteria decision making that allows industrial actors to make choices taking into account all relevant criteria, and public authorities to develop policies acceptable at an industry-wide scale to promote best available industrial techniques. Each of the above phases is indispensable for complete process design for environment, yet it is characterised by complementary yet diverse objectives. Moreover the industrial and laboratory practices that provide the required experiential information differ largely. Hence the need for an integrating information processing and decision-making support tool.

2.1. Materials Selection

The materials selected for the development of a given product or service in the frame of the Design for Environment methodology need to pose minimal hazards to man and the natural environment. The minimal materials hazard requirement can be met by selection of appropriate materials, minimisation of hazardous inventories in the plant, recycling of process waste streams as part of the feedstreams in other parts of the same or other plants and/or industrial sectors. Determination of the best available materials for a given industrial process begins with the life cycle analysis (LCA) of the materials considered. Life-cycle analysis as defined by the Society for Toxicology and Chemistry [4] includes 3 stages: (a) life cycle inventory (LCI), (ii) technological impact analysis, and (iii) improvement analysis. Following the Hannsen and Asbjørnsen [5] model to describe LCA mathematically, the material and energy flows to produce the amount of product is given by vector **M**. Let the mass of product needed to fulfil the functional unit be M_p. Material and energy flows are

$$M = f(M_p) \qquad (1)$$

Each of the vector components is associated with emissions to air and water, as well as the generation of solid and also hazardous waste. The emissions will be proportional to the flows, if the efficiency of the production processes are considered constant. Emission factors are grouped into matrix **N**. The total effluents vector is,

$$E = NM \qquad (2)$$

Each effluent contributes to the environmental impact by an impacts matrix **C**. **C** can be computed following the impacts pathways analysis method avoiding however to convert all impacts to common units. The matrix elements c_{ij} represent the contribution to environmental impact i per unit of effluent j. The total environmental impact vector **I** is then,

$$I = CE = CNM = CNf(M_p) \qquad (3)$$

Hannsen and Asbjørnsen aggregate the impacts to construct an environmental performance indicator (EPI); this is a scalar quantity where the total effect of environmental impacts is calculated from a weighted average of the impacts.

$$EPI = w^T I = w^T CNf(M_p) \qquad (4)$$

The practical application of the EPI model requires availability of w^T. EPI is thus a weighted index based on 13 impact categories from the three groups: (i) resource depletion and efficiency, (ii) health impact, and (iii) ecological parameters. This last phase of the analysis is not suggested by the author; instead, a multi-criteria based decision support technique is offered as a solution that respects the relative importance of different incommensurate criteria to different stakeholders.

2.2 Process plant synthesis and optimisation

This methodology suggests the introduction of safety and environmental considerations in the synthesis and optimisation stage accounting for the integrated impact on environmental media (land-water-air) and man. With regard to safety assessment and optimisation of a process plant, a scheme coupling mechanistic models and probabilistic information in order to minimise the inherent uncertainty of the analysis at the design stage is suggested. The analysis follows a coupled top-down / bottom-up process which ensures that novel emergent technologies abide by national

and international regulations regarding public and operational safety and environmental impacts. According to this bi-directional approach, starting from the premises of existing national and international regulations, general safety and environmental design criteria independent of the particular design selections can be derived. Applying these general criteria at the specific plant and function level, the accident basis for safety design of the particular plant and the corresponding safety strategy (including normal and off-normal safety procedures) can be put forth. Depending on the uncertainty of the available operational performance data the specific multiple lines of defence can be determined and safety functions needed after the occurrence of some accident initiating event can be allocated to particular systems. In this context, passive means to ensure safety functions should be given preference. This method provides a first qualitative evaluation in the risk domain (consequence x frequency) and helps set requirements early in the design phase. The specific system requirements and implementation of the pre-defined safety functions can be integrated into the plant design through the implementation of functional and safety design and optimisation tools [6].

From the point of view of overall risk minimisation, the defence-in-depth and lines-of-defence concepts and the passive safety means contribute to the reduction of the likelihood that accidental situations will occur---passive safety mechanisms in this context are very important because they are the ones less exposed to human error. Minimisation of hazardous inventories and control of energy sources in the plant reduce the possible consequences. The bottom-up implementation of this methodology can be coupled with a rigorous probabilistic risk assessment (PRA) procedure at the plant level as the knowledge of the operational characteristics of the technologies in question advances. Hence, more precise evaluations of the final risk to operators and the public can be done, converging to a final stage of overall risk acceptance by plant operators and regulatory authorities.

2.3. Industry-wide synthesis

The incorporation of environmental and safety concerns in the design of one process plant and the subsequent optimisation reduces the related impact but it may very well fail to minimise it. For instance, the possibility of using the waste streams of one plant as part of the feed of another would tremendously help towards the integrated minimisation of waste disposal requirements in an industrial system. Given the large number of possibilities of interaction between different actors in such a system and their different points of view respectively, multi-attribute analysis is necessary in order to analyse the possible options and optimise the system response comprehensively.

The proposed methodology allows industrial actors to make choices taking into account all possible criteria, and public authorities to develop policies acceptable at an industry-wide scale in order to promote the introduction of best available technologies in industrial production. It consists of the definition by decision makers of the possible actions, aggregation into groups as a function of their nature and assignment of appropriate weights depending upon their preferences. Inevitably analysis and decision support has to deal with approximate information; fuzzy set theory can be used to describe the problem; let a fuzzy goal represented by the membership function $m_G(a)$ and a fuzzy constraint represented by the $m_C(a)$. A fuzzy optimal decision is given by the membership function

$$\max_a m_D(a) = \max_a \min\{m_G(a), m_C(a)\} \qquad (5)$$

The two-dimensional model of Bellman and Zadeh [7] described above can be easily extended to cover n goals and m constraints as it is generally required when dealing with environment and technology management systems. In general, a multi-criteria evaluation methodology that provides input to the fuzzy optimisation problem can be delineated as follows:

- Assembly of all envisageable actions including technological and financial parameters

- Description of list of problem and actions dimensions through consultation with the principal actors
- Disaggregation of the above dimensions to criteria and evaluation of each envisageable action
- Construction of a judgement matrix (including decision thresholds, actors preferences, vetoes, and agreement in specific actions)
- Definition of strategy nucleus by using superposition graphs to prioritise actions taking into account the relevant values of the judgement matrix; a sensitivity analysis may provide input on the robustness of the chosen strategy
- Elaboration of decision-support analysis; integrated system simulation to provide estimates of impacts

A list of criteria of relevance to industrial management systems include:
(a) the investment and annual operational cost;
(b) expected results of the technical interventions envisaged;
(c) industrial hazard intensity;
(d) pressure on various environmental media;
(e) interactions among different media and among different pollutants;
(f) technological impact on working conditions and availability;
(g) relations among stakeholders.

3. INFORMATION FLOW REQUIREMENTS

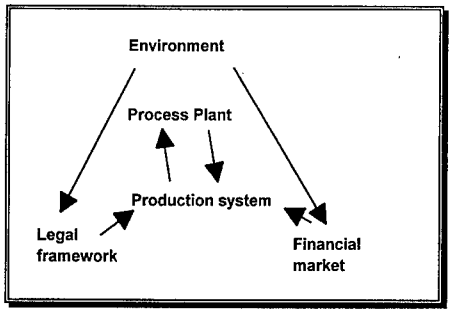


Figure 1 Information flow among concerned stakeholders for industrial design for environment

The information flow between the two aggregation levels of industrial systems described above is inherently recursive as in figure 1. The respective decision processes are analogously characterised by qualitatively different sets of criteria:

- design for environment at the plant level incurs the use of a limited number of criteria principally related to the technical characteristics of the materials used and generated (primary, secondary, and by-products) and the performance, efficiency and reliability of the processes involved. The information requirements needed to assess the technologies according to these criteria include:
  - energy intensity of production processes and technologies
  - materials flow intensity of the technologies implemented in the installation
  - use of non-production materials and natural resources depletion related to the production process (e.g. use of clean fresh water resources, environmental pressure on water reservoirs, land availability, clean air)
  - risk to human life posed by the technologies used in the installation
  - risk to animal life and pressure on bio-diversity in the ecosystem around the installation

- design for environment for industrial systems requires the assimilation of information for the evaluation of a much larger set of criteria going beyond the technical and environmental performance of technology (e.g. financial markets related to industrial investments, market penetration potential of finished products and unusable by-products, social effects of the industrial system in particular as it relates to macro-societal compatibility as described by Sarigiannis and Volta [8], jobs creation, etc.). The information requirements include:
  - economic performance of the particular plant in relation to associated examples of relevant industrial sectors
  - "green" accounting of technologies used
  - legal and institutional framework within which the technological system is developed
  - social effects including job creation and compatibility with social culture and function

The description of the information required for an integrated assessment of technology makes evident the need for multi-attribute analysis; it is impossible to integrate this large a variety and number of qualitatively different indicators in a single multi-attribute utility function without falling into the trap of allowing one dimension of the interactions between technology, society and the natural environment to compensate for another. Multi-criteria based analysis is therefore needed. This includes identification of stakeholders, elicitation of their preferences with regard to the various technological and management possibilities for the creation of an integrated industrial system following the design for environment criteria.

4. SUPPORT TO DECISION-MAKING

One of the main obstacles to the effective implementation of the design for environment methodology described above in actual and novel industrial systems is the requirement for integrated management of a large variety of objectives, including economic, environmental, safety, and social considerations. A decision hierarchy can be identified:

a. meeting safety and regulatory requirements are a must. Safety of consumers, plant operators, and the surrounding ecosystem is ensured by the use of risk assessment methods;
b. once compliance with safety and regulatory requirements has been assessed and ensured, improvements in resource use and management of waste will follow in a stepwise and continuous manner. Every decision made needs to assess the information produced by the different tools used, taking into account the existing decision hierarchies.
c. Final decisions will be an amalgam of environmental and economic considerations, since an environmentally improved product or process will only deliver the benefit if it substitutes in the marketplace a less environmentally desirable option.

From a decision analysis point of view the problem of integrated industrial design and development can be affronted as a γ-type problem following the categorisation by Roy [9]. Namely, it consists of posing the problem in terms of ordering all or part of the possible alternatives **A** (decision options) based on a given set of preferences. Thus, the "sufficiently satisfactory" options are identified as part of a sub-class of **A**, $\mathbf{A}' \subset \mathbf{A}$. Two actions are put in the same class when the data available do not allow us to distinguish between them according to the stakeholders' preferences (see figure 2).

The outranking synthesis approach consists in comparing pairs of alternatives in order to examine whether one alternative technique outranks the other, i.e. whether it is "at least as good" as the other. This approach generally deals with relational preference systems which include preference, indifference and incomparability, or outranking and incomparability. Moreover this approach does not impose transitivity to these binary relations and to the supporting preferences. An analysis synthesising the outranking graph, made up of the alternatives linked together by their outranking

relations, provides a prescription including the possibility of incomparability.

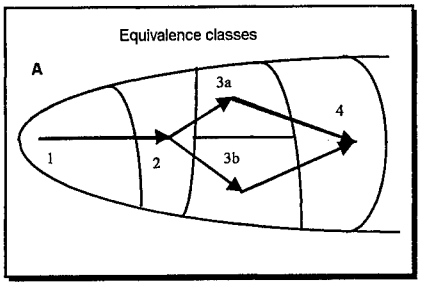


Figure 2 Results of ordering alternatives in equivalence classes

In this field there is much ordinal, fuzzy and even contradictory information leading very often the decision-maker to a situation of incomparability, i.e. the information available does not allow a decisive choice between two alternatives. It is of fundamental importance for strategic technology decision and policy-making to recognise this condition and try to add valuable information instead of attempting to make a decision at all costs with the information available. This translates in industrial decision-making the "precautionary principle", a regulatory concept which finds extensive use in international environmental legislation during this decade. Another critical reserve to so-called mono-criterion approaches is the compensatory logic that lies behind them. In order to aggregate local utilities, replacement rates between the various attributes have to be established. There are, however, circumstances in environmental impact assessment where the decrease on one criterion is unacceptable beyond a certain level, and cannot be compensated for by the cumulative increase on the other criteria. A method envisioned in this work is a discrete multi-criteria method described by Paruccini *et al* [10], that does not use the classic criteria weighting techniques and allows the use of all relevant information available even if the latter is of varying uncertainty. The impact matrix (criteria/alternative techniques) can be completed by inserting fuzzy, stochastic, qualitative and crisp information. Preferences on the criteria and the required minimum acceptance levels are specified. Through pairwise comparison of alternatives and criteria aggregation techniques a merit ordering of the alternatives can be generated.

The investigation of the decision alternatives and of their impacts can also be done using the complex systems dynamics based decision support approach as follows:

1. "Acceptance limits" for important decision quantities are defined. Such decision "criteria" include economic, social, and physical measures for evaluating the performance of the industrial system with regard to sustainability targets.
2. By randomly varying key model parameters and running the model for a sufficiently large number of times it is possible to estimate the probability that the decision quantities will fall between the acceptance limits. The uncertainty that is inherent to the technical and non-technical information supporting the decision-making procedure can be evaluated and reduced through:
   - evaluation of the model's sensitivity (key quantities) with respect to critical parameters;
   - derivation of distributions for the key quantities;
   - evaluation of the sensitivity of the derived distribution's key parameters with respect to the critical parameters and suggestions in order to minimise the negative or non-positive effects.
3. This information can be used to support the dynamic analysis of alternative scenarios developed in the decision-making procedure and to foster the dialogue among concerned stakeholders. At this point, a comparative assessment of the alternative management scenarios can be done.

Both seasonal and annual scenarios can be processed in order to obtain the spatio-temporal evolution of the key parameters. Such an approach handles in an efficient way the problems derived from seasonal variations in the use of natural resources and industrial products.

5. CONCLUSIONS

The industrial design for environment methodology outlined in this work comprises a framework for industrial innovation respecting sustainability criteria. Four methodological blocks include:

- materials selection;
- process plant synthesis/optimisation including cost, safety and environmental impact concerns;
- industry-wide synthesis providing the premises for the integration of novel clean technologies in order to further reduce the generation of waste and adverse impacts of the industrial system to the environment and society;
- identification of the information flow requirements and increase in transparency in the debate among industrial stakeholders and decision makers.

The practical implementation of the design for environment concepts requires support from a structured decision making process. Such a decision support system can be based on multi-criteria decision analysis (MCDA) and two possible methods are given here. This methodology has so far been applied in an integrated framework for advanced energy systems including renewable energy technologies [11] and thermonuclear fusion [12].

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SUSTAINABLE DEVELOPMENT AS A STRATEGY TO PROTECT THE ENVIRONMENT: THE CASE OF THE CITY-STATE OF SINGAPORE

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ABSTRACT

Just as Athens under the leadership of Pericles (495-429 B.C.), is commonly referred to as the Golden Age of Athens, the city-state of Singapore aspires to be a world-class global city which transcends the particularities of place to become the Golden Age of Singapore in the 21st century. To complement the urban planning strategy of using IT at the macro level, an intense multiple-use development of smart buildings as the urban design strategy at the micro level is used. This two-pronged synergistic approach is decidedly central to Singapore's sustainable development strategy in the IT age to conserve space and protect the environment at the same time.

Η ΒΙΩΣΙΜΗ ΑΝΑΠΤΥΞΗ ΩΣ ΣΤΡΑΤΗΓΙΚΗ ΠΡΟΣΤΑΣΙΑΣ ΤΟΥ ΠΕΡΙΒΑΛΛΟΝΤΟΣ: Η ΠΕΡΙΠΤΩΣΗ ΤΗΣ ΠΟΛΗΣ-ΚΡΑΤΟΥΣ ΤΗΣ ΣΙΓΚΑΠΟΥΡΗΣ

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ΠΕΡΙΛΗΨΗ

Όπως η Αθήνα υπό την ηγεσία του Περικλή (495-429 π.Χ.) δημιούργησε τον «Χρυσούν Αιώνα των Αθηνών», έτσι και η πόλη-κράτος της Σιγκαπούρης φιλοδοξεί να δημιουργήσει τον 21ο αιώνα την δική της χρυσή περίοδο σε παγκόσμιο επίπεδο, ξεπερνώντας τις τοπικές δυσκολίες. Η χρήση της τεχνολογίας της πληροφορίας είναι η στρατηγική πολεοδομικού σχεδιασμού σε μακροκλίμακα, η οποία συμπληρώνεται με την εντατική ανάπτυξη έξυπνων κτηρίων, ως στρατηγική πολεοδομικού σχεδιασμού σε μικροκλίμακα. Αυτή η διττή προσέγγιση, παίζει αποφασιστικότατο ρόλο στον σχεδιασμό της βιώσιμης ανάπτυξης της Σιγκαπούρης, που αποσκοπεί στην εξοικονόμηση χώρου και στην προστασία του περιβάλλοντος.

1. INTRODUCTION

Sustainable development in Singapore can be discussed at two levels:

(i) Using IT as the urban planning strategy at the macro level, and
(ii) Using multi-use development as the urban design strategy at the micro level.

Just as Athens under the leadership of Pericles (495-429 B.C.) pursued an open policy of strategic trade alliances, Singapore, long known for its international outlook, is particularly receptive to the question of globalisation. First founded as an entrepot, Singapore from the beginning has been plugged into the trading and business networks of Southeast Asia and the world. Despite the many changes in Singapore's economic environment, it has always prospered from being international.

2. SUSTAINABLE URBAN DEVELOPMENT STRATEGY IN 21ST CENTURY SINGAPORE

Two instruments are central to sustainable development in Singapore. They are: IT2000 masterplan and Revised Concept Plan.

2.1 IT2000 and Revised Concept Plan

2.1.1 IT2000

In anticipation of the strategic role IT will play in the next lap of Singapore's development, the government initiated the IT2000 Report - a national IT masterplan to transform Singapore into an Intelligent Island - in tandem with the 1991 Revised Concept Plan. In endorsing the IT2000 Report, Prime Minister Goh Chok Tong noted that Singapore was forced [1]:

"To run on the fast track of economic development ... or face being left behind ... It is our lot in life that we continue running in the fast lane to keep up with changes in the new world economy ... The (IT2000) plan reaffirmed the strategic role IT will play in the next lap of Singapore's development, and showed that because the country dared to dream it will become a reality."

The vision of the Intelligent Island is based on the far-reaching use of IT. It sees Singaporeans tapping into a vast web of electronically-stored information and services which they can use to their best advantage - to improve their business, to make their work easier and to enhance their personal and social lives. The essence of IT2000 to transform Singapore into an Intelligent Island is therefore, the synergistic development of a well-integrated and extensive national information infrastructure. Louis Beckerling investigates [2]:

"There is no end to the metaphors nor visionary language being used to describe the single biggest policy initiative currently underway in Singapore. The Intelligent or Smart Island ... the Next Lap ... IT2000 ... What does it mean? The vision which all of these expressions seek to describe is of an island where Information Technology (IT), has been harnessed in an island-wide programme without parallel anywhere in the world, to make Singaporeans smarter, more efficient, and thus more productive."

2.1.2 Revised Concept Plan

Acting in concert, the Revised Concept Plan is to plan for the long-term physical development of Singapore into a Tropical City of Excellence and an international investment hub for a population of 4 million by the first quarter of the 21st century. For this to happen, the long-range landuse plan is [3]:

(i) To plan for growth and wealth.
(ii) To plan for a better quality of life.
(iii) To plan for a good infrastructure.

It is significant to note that the decentralisation strategy of the Concept Plan through regional centres to accommodate information and knowledge-based industries complements the national information infrastructure (NII) of IT2000. Information is fast becoming a crucial factor of production in many industries and is transforming every sector of the economy. Its innovative exploitation holds the key to Singapore's success in the international marketplace. The potential benefits of the NII to the economy are immense. Together both IT2000 masterplan and the Revised Concept Plan are to help Singapore develop its external wing of economy to realise the above three objectives by way of sustainable urban development through IT.

The research paper postulates that the unprecedented opportunities offered by IT allow Singapore to cap its domestic population at 4 million people as planned, while promoting the synergy of strategic trade alliances worldwide to create offshore space to become sustainable Singapore Unlimited [4]. The island-wide fibre optic network plugged into the global information superhighway already circling the earth facilitates the virtually limitless growth of sustainable Singapore Unlimited in an intense and livable environment. As envisioned by the Economic Development Board [5]:

"Singapore Unlimited is rooted in a vision of a better Singapore. This vision is of an economically vibrant Singapore that has a developed country standard of living, a high quality of life, a strong national identity and the attributes of a global city. It is a quantum leap from our current level of development. It represents a whole new world of possibilities ... that exist beyond the realm of the ordinary."

2.2 The Network Paradigm of Synergy

To realise the effects of IT2000 and the Revised Concept Plan, a network paradigm of synergy at the national level cannot be overemphasised.

2.2.1 National Information Infrastructure

In the global economic network of the 21st century IT will drive change just as manufacturing has been the driving force in the industrial era. To equip the city-state for the IT age, Singapore is building a National Information Infrastructure which will enable the national information, communication, and transaction system to work. Since Singapore is already a hub for businesses, financial services and transportation, the application of IT has obvious relevance. By the turn of the century, it is envisioned that Singapore will interconnect computers in virtually every home, office, school and factory [6]. Singapore Telecom, already one of the most modern and sophisticated telephone networks in the world, was privatised by the government for the express purpose of bringing in private sectors to assist with its transition from a state utility to a dynamic multinational competing for business in both its own and overseas market.

With the inauguration of the world's longest optical fibre submarine cable system in October 1994 costing over S$1 billion, Singapore has emerged as a major telecommunications hub of the world. Known as SEA-ME-WE2 (Southeast Asia-Middle East-Western Europe2) the system spans some 18,000 kilometres from Singapore across the Indian Ocean to Marseilles in France, connecting some 2 billion people or about a third of the world's population. In the process, SEA-ME-WE2 links eleven other countries in three continents: Indonesia, Sri Lanka, India, Djibouti, Saudi Arabia, Turkey, Cyprus, Egypt, Tunisia, Algeria and Italy [7]. At the same time, a new *bridge* is formed to connect existing optical submarine cable systems in the Pacific and Atlantic Ocean. Thus there is

now a global information superhighway literally circling the earth. With the cable in place, Singapore Telecom Chairman Koh Boon Hwee noted [8]:

"The key to Singapore international competitiveness lies in having superior communications and information networks and that we can deliver timely and reliable services. Such networks and services support Singapore as an international business financial and high-tech manufacturing centre ... video-conferencing will soon become a common form of meetings."

2.2.2 Globalisation

The trend of IT is highly globalised, with multinational corporations competing and spawning alliances around the globe. As the world economy is increasingly more dependent on telecommunications, Singapore is poised to exploit the many unprecedented opportunities offered by IT to enhance economic competitiveness and cooperation in the global marketplace. Competition and cooperation have become the Yin and Yang of the global marketplace of sustainable development. Like Yin and Yang they are always seeking balance and always changing. One thrust of the new cooperation in setting up the new strategic alliances, is to carve out a piece of the world market in which you agree to cooperate with your strongest competitor who very much remains your competitor [9]. The growing success of the Growth Triangle formed by Singapore, Malaysia and Indonesia substantiates this observation. The three have created a win-win situation and complement one another. Singapore has the technology, the telecommunications, and the transportation infrastructure, while Malaysia and Indonesia offer much-needed land, low-cost labour, water and electricity. Examples of leading international and Singapore companies operating in the Growth Triangle include AT&T, Sumitomo, Matsushita, Philips, Thomas, Smith Corona and UIC Electronics. The economic viability of the Growth Triangle validates Singapore's guiding philosophy that a wise nation will make sure its survival and well-being are in the interests of others. Reaffirming Singapore's philosophy, Professor Michael Leifer, an Asia expert at the London School of Economics and Political Science summarises it well [10]:

"If you can lock regional neighbours in the wider Asia-Pacific into a constructive network of cooperative relationships, then the nexus of economic advantage will hopefully have the effect of making countries good regional citizens and unlikely to engage in adventurist policies."

The wonders of networking are not new. Some 2,500 years ago, Sun Tzu, the greatest Chinese military strategist had already made this call in his book, the *Art of War* [11]:

"Form alliances with neighbouring States on intersecting ground ... The ground that is enclosed by three States and whoever is first in occupying it will gain the support of All-Under-Heaven is intersecting ground."

This is what has come to be called networking which is the act of setting up cooperative relationships. Instead of only three parties contending for an advantage, more could actually be involved in today's strategic alliances to promote sustainable development.

Through webs of strategic alliances, it is now possible for companies utilizing IT to produce a product anywhere, using resources from anywhere, to be sold anywhere. Mazda, for example, produced a sports car designed in California, financed in Tokyo, and assembled in Michigan and Mexico. Some of its advanced electronic components were invented in a laboratory in New Jersey but manufactured in Japan [12]. Thus in the IT scenario, a car or a computer can be built in four countries and assembled in a fifth. Markets, too, expand beyond national boundaries. This is synergy, borrowing external resources to complement one's own. For this to happen, companies must be equipped for electronic interaction known as the electronic data interchange (EDI)

networks. The EDI networks simply permit the electronic exchange of documents between companies - invoices, specifications, inventory data, and the like. By wedding one another's data bases and electronic systems, companies are able to form highly intimate partnerships. The benefits of EDI are not only a reduction in paperwork and inventory, but quicker, more flexible response to customer needs. Together these can amount to massive savings. The rapid adoption of TradeNet by the international trading community has spurred the development of MediNet, LawNet and other sectoral networks. Singapore is among the top few countries to have effectively exploited the EDI technology.

As an emerging global city, Singapore is keenly aware that the global economy is not a zero-sum game, but an ever-expanding universe. With IT increasingly at its disposal, Singapore is able to conserve and expand space by creating space outside the country. GE's Transportation Systems division builds locomotives. When it began using advanced information - processing and communications to link up with its suppliers, it was able to turn over its inventory twelve times faster than before and to save a full acre of warehouse space [13]. More importantly, the new telecommunications capacity makes it possible to disperse production out of the high-cost urban centres, and to reduce energy and transport costs even further. This is consistent with the strategy of Singapore Concept Plan to tie in with the Growth Triangle concept to conserve and expand space by creating space outside the city-state to sustain development in an intense urban environment at home.

This is decidedly central to Singapore's sustainable development strategy in the IT age. More and more therefore, new industries in which telecommunications needs with the world at large are vital, are expected to emerge from the IT urban scene which begins to indicate the diminishing centredness of the city as decentralisation increases. The 1991 Revised Concept Plan decentralising Singapore into five regional centres in tandem with the IT2000 masterplan sets the stage on which the strategic role IT will play in the next lap of Singapore's development to become sustainable Singapore Unlimited.

2.2.3 The Chinese Diaspora

To reinforce the concept of sustainable Singapore Unlimited, it is significant to note that Singapore played host to the First Overseas Chinese Entrepreneurs Convention in 1991. The convention discussed the changing economic trends in the new global order, and the role of Chinese enterprises and entrepreneurs in contributing to the new world order. The convention also strengthened economic and cultural exchange and cooperation among them. It is estimated that there are more than 50 million overseas Chinese around the globe. Many have long entrepreneurial experience. Describing the enterprise and industry of the overseas Chinese as long ago as 1900 Rudyard Kipling wrote [14]:

"If we had control over as many Chinese as we have natives of India, and had given them one tithe of the cosseting, the painful pushing forward, and studious, even nervous regard of their interests and aspirations that we have given India, we should long ago have been expelled from, or have reaped the reward of, the richest land on the face of the earth."

But perhaps it was the lack of cosseting that spurred them. Among the overseas Chinese themselves, a very complimentary self-image is upheld [15]:

"... they see themselves as nothing less than the very embodiment of Diligence and Thrift, and the claim that these are Chinese qualities. Their confidence in the superiority of their own culture reinforced at every turn by the visible evidence of their wealth, they have no doubt at all that it is

hereditary flair that does it. To their way of thinking, to be Chinese is to be business-minded, and it is a combination of genetics and upbringing that makes them the dedicated entrepreneurs they are."

The passion for business, to be sure, is by no means a general Chinese trait, and in China itself, the merchant has been disparaged as the lowest of people. In a society ordered by Confucian values, the ability to profit from trading was never admired, and this put rather a damper on a universal flowering of Chinese entrepreneurship. The majority of the Chinese believed that entering the civil service was the surest way of getting on in the world. For every Chinese who prospered from trading there were hundreds who held themselves aloof from commerce. If there is such a thing as a tradition of enterprise among the Chinese, it is to be found mainly among the Chinese Diaspora [16], of which Singapore is part of the phenomenon. The overseas Chinese entrepreneurs have demonstrated a talent for forming partnerships and joint ventures with expatriates and citizens alike based on economic self-interest. Plugged into this global network of the Chinese Diaspora referred to by Harvard Professor John Kao as the "Chinese Commonwealth", the growth and expansion of Singapore Unlimited in its regionalisation and globalisation drive is exponential. Indeed, the Singapore Chinese Chamber of Commerce & Industry (SCCCI) in 1995 launched the World Chinese Business Network (WCBN) system to deliver on-line information via the Internet. The WCBN, the first on-line Chinese business directory system in the world, gathers information on global Chinese business organisations. The network provides corporate data like company name, contact number and address, year of establishment, line of products and services, key personnel and other operational characteristics. As a result of the innovative use of IT, an opportunity is created for the world of Chinese-speaking business to communicate and conduct business on-line.

3. MULTIPLE-USE DEVELOPMENT CONCEPT AS AN URBAN DESIGN STRATEGY

Singapore's present population of 3 million people within a land area of less than 700 square kilometres is expected to stabilise at 4 million by the first quarter of the 21st century as conceived in the 1991 Revised Concept Plan. By then the population density would have reached 6,000 people per sq km as compared to the current population density of over 4,000 people per sq km (which is already 20 times more congested than the most congested country in Europe - Holland). Capitalising on such an intense urban environment, it is conceivable that a highly charged multiple-use development strategy at the urban design level where a multiplicity of programmes that exploits density and complexity in an unusually compressed space becomes a positive phenomenon of 21st century Singapore.

The strategy is to set up a dialogue between constituent elements of the complex which generates its own urban effects [17]. From a distance it is perceived as a single mass. Upon coming closer, the division into separate volumes becomes apparent, opening up the complex. To lend support to such an urban multiple-use development, it is inevitable that a broad spectrum of events with successive and simultaneous peaks is created to fill a 24-hour activity cycle to maximise the location and its existing infrastructure. In such a 24-hour activity cycle, light plays an important role to intensify the multiple-use development.

The task therefore, is to coordinate and constitute a sustainable unified development with seemingly contradictory realities. For example, the revenue-producing uses are positioned in relationship to uses that do not produce revenue so as to give each its appropriate emphasis and image. Such a multiple-use development demands that the different facilities be segregated with different centres of control, having the ability to operate independently but at the same time to combine the different functions together such that it works as a single complex to ensure a market synergy.

4. CONCLUSION

To conclude, the present city-state of Singapore of 3 million people seems to be shaping up exactly as Le Corbusier would have wanted for his visionary city of 3 million inhabitants when he said in 1922: "A city built for speed is built for success" [18]. Anticipating the strategic role IT will play in the next lap of Singapore's development, the government has already put a state-of-the-art telecommunications infrastructure in place. Singapore is poised to become the first fully networked society - one in which all homes, schools, businesses, and offices will be interconnected in an electronic grid. Well tapped into the global information superhighway through webs of strategic economic alliances, the growth of Singapore Unlimited is virtually limitless. Over time, it is envisaged that the locals and expatriates working with overseas Singaporeans will acquire citizenship rights through marriage and trade alliances thereby extending Singapore Unlimited not unlike the unprecedented growth and prosperity of Athens under the leadership of Pericles in the 5th century B.C. In the dispersal of overseas Singaporeans around the globe, the Singapore International Net serves as a vehicle to bring Singaporeans overseas closer. This can be an extension of the community telecomputing network to Singaporeans overseas, strengthening emotional attachments and national consciousness [19]. In the IT scenario emerging, the network paradigm of synergy at the macro urban planning level translating into an intense multiple-use development of smart buildings at the micro urban design level will propel the city-state to become the Golden Age of Singapore in the 21st century.

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THE INTENSITY OF TOURISM ALONG THE HELLENIC COASTAL AREAS

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ABSTRACT

The concern for the coastal areas has increasingly risen, especially after the involvement of the sustainable development principle in the environmental policy. Simultaneously, along the long Hellenic coastline many activities without regulation are taking place. Hence, the problems of conflicts over land use should be answered as soon as possible, since the former efforts in the field of spatial policy have no visible results.
This paper will focus on the spatial expansion of tourism development, aiming at the assessment of the potential harmful impacts on the coastal environment. In the above context, it proposes the formulation of new indexes, pointing at the tourism intensity.

Η ΕΝΤΑΣΗ ΤΟΥ ΤΟΥΡΙΣΜΟΥ ΣΤΙΣ ΕΛΛΗΝΙΚΕΣ ΠΑΡΑΚΤΙΕΣ ΠΕΡΙΟΧΕΣ

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ΠΕΡΙΛΗΨΗ

Το ενδιαφέρον για τις παράκτιες περιοχές διευρύνεται συνεχώς, παράλληλα με τη σταδιακή εμπέδωση της αρχής της βιώσιμης ανάπτυξης στη συνείδηση των αποφασιζόντων, των μελετητών και του κοινού. Ταυτόχρονα είναι ευρέως αποδεκτό ότι οι ελληνικές ακτές χρήζουν άμεσων ενεργειών έλλογης διαχείρισης των εκεί συγκρουόμενων χρήσεων γης.
Σκοπός της παρούσας εισήγησης είναι να συζητήσει τρόπους πληρέστερης μέτρησης των χωρικών παραμέτρων του τουρισμού, προκειμένου να καθίστανται πιο εμφανείς οι ενδεχόμενες αρνητικές επιπτώσεις στο περιβάλλον των ελληνικών ακτών. Για το σκοπό αυτό προτείνει δείκτες τουριστικής έντασης, για τη συμπλήρωση της ήδη υπάρχουσας δέσμης πρωτογενών στατιστικών σειρών.

1. INTRODUCTION

During the recent decades, the broadened scarcity of many resources and a related series of severe energy crises have forced to the establishment of the sustainable development principle. This (not new) notion includes actions to ensure that the needs of the today generation do not compromise the ability of future generations to meet their own needs. [1] The implementation of such a conceptual framework in everyday governmental practice claims appropriate tools and the collaboration of many scientific fields. Therefore, the related technical issues (e.g. criteria for the assessment of environmental impacts) are very important and require accurate description. [2]

At the same time, there is no unique and widely accepted definition for the coastal areas, in spite of the noteworthy economic and environmental significance of them. [1, 3, 4] In general, a coastal area is: "the part of the land affected by its proximity to the sea, and the part of the sea affected by its proximity to the land, as the extent to which man's land-based activities have a measurable influence on water chemistry and marine ecology". [5, 6] To surpass the dilemma of the coastal area optimum width, the specialists propose more than one level of approaching. [6, 7]

Whatever width has been adopted, the coasts are recognised as geographic, economic, cultural and administrative space. This paper will examine coasts only from the physical planning point of view, by evaluating **impacts on coastal environment generated by tourism as a land use**.

2. THE USES OF THE LAND

2.1 Resources exploitation and the meaning of intensity

Opposite to land cover (which denotes the physical state of the land, the way that it appears) the meaning of land use is firmly connected to the manner the human being takes advantages from a piece of earth's surface. In all cases, the employment of the land has a financial character that's why economists, investors and planners are some of those who are strongly interested in land uses. Simultaneously, each region offers a variety of resources and every land use is strictly connected to the exploitation of the existent resources, which can have multiple use. Many of the possible uses are complementary, whereas other lead to conflicts among them, while the overuse threats the resources sustainable future.

On the other hand, an intense usage of a region means that the adjacent regions are at a different level of profit for each combination of region and land use, at every time. Generally, high intensity is the result of human needs' expansion; needs of the indigenous population or of foreigners. The usually following phenomena are the augmentation of traffic, the rise of plants and animals harvesting, the modification of earth's surface, the change of drainage systems etc. In parallel, **it occurs a transposition of the frontier between man-made and natural environment**. [space aspect]. [8] In the previous context, the intensification of a land use is a kind of land use change and it indicates a situation different from an earlier one. Thus, intensity has duration and it is rather a dynamic than a static situation, which shows the potential of each land use. [temporal aspect].

A common way to evaluate the intensity of land uses seems to be the measurement of the occupied area. Some more penetrating parameters measuring the intensity's scale could be: the volume of production, the features (number, origin, social class etc.) of benefit people, the features (size, nationality etc.) of involved enterprises, the evolution of land prices, the consumed recourses etc. [9] On the other hand, duration and frequency are the principal features to be indexed for the temporal aspect of land uses intensity.

2.2 Coastal land uses

It is generally agreed that along the coastline assembles a large amount of human activities. In fact, the uniqueness of the coastal environment offers economic opportunities to agriculture, fisheries and aquaculture, industry and energy production, transportation and the complex: tourism - recreation - civilisation. As a result of the previous activities, the expansion of urban settlements on the littoral is

an international ongoing fact. Besides, near the sea there are some of the more sensitive ecosystems (natural environment) and many monuments as well as modern infrastructure (man-made environment). [10, 11]

The final outcome of that multisectoral attractiveness is the continual transformation of the coastal environment. The overexploitation leads to marine, freshwater and air pollution; losses of marine, land and cultural resources; soil degradation; loss of public access to the sea and noise and congestion. [12] To mitigate the previous consequences, the world-wide interest is driven to the concept of the integrated management of coastal activities. **The control of land uses intensity** seems to be a key target, in an effort not to exceed the carrying capacity limits of coastal areas.

2.3 Tourism and coastal environment

As societies become more affluent and mobile, tourism is recognised of even more important economic, social, cultural and environmental significance. It includes the providing of pleasure to somebody, in a region different from his habitual residence. Therefore, it comprises the visit of an area, which initially is planned to cover only the needs of its permanent residents. Hence, tourism is a priori linked with space "consumption" and almost all its kinds need facilities extended to large and -quite often- to enormous areas.

The history of international tourism indicates preference to coastal areas, particularly in the case of mass tourism that is the predominant model of tourism development in Mediterranean states like Hellas. [3, 13, 14] The natural and man-made coastal resources are the fundamental ingredients of the tourist product (destination) and simultaneously they suffer from the tourism development. It is remarkable that as the life cycle of every tourist destination is in progress, the participation of the natural environment is diminishing, while that of the man-made is increasing. [15] Apart from the foregoing long-term basis, time is a significant factor in monthly basis. In fact, the statistics show a peak of tourist demand for coastal destinations during the summer months.

3. THE HELLENIC COASTAL AREAS

3.1 General description

More than two thirds of the total Hellenic territory (130.000 sq. km.) are mountainous. On the other hand, the geographic distribution of the population shows that the majority (69%) of the 10 million inhabitants lives in plains. The population living in a distance less than 2 km from the sea represents the 33% of the total, while in a coastal zone of 50 km lives the 85% of Hellenes. As coasts attract the bulk of the population, the coastal density is bigger than this of the whole country. [16, 17]

The 15.000 Km. of Hellenic coastline are regarded as national wealth since the existence of plentiful natural (fauna, flora, coastal landscape, sunny weather, clean waters etc.) and man-made resources (ancient monuments, attractive build environment, tourism infrastructure etc). According to the criterion of dominant land cover, the main types of coasts are i) beaches and sand dunes (about 1.000 Km, where are located the main part of human activities), ii) rocks (almost 75% of the total length) and iii) a big variety of wetlands (e.g. deltas, lagoons, estuaries). On the other hand, the dominant categories of coastal economic activities are built up areas with or without the presence of second sector, tourist areas and agricultural or natural areas. [18]

3.2 Physical planning

Regardless of the long coastline and the maritime character of their inhabitants, there is no specific spatial legislation or integrated policy for the Hellenic coasts. [19, 18] Remarkable related efforts are i) a national program for coastal management (early '80); ii) two series of special spatial studies during the last decade and iii) an ongoing endeavour (of the Ministry of Environment, Physical Planning and Public Works in collaboration with the University of Aegean) to prepare a guideline for the Hellenic coasts. On the other hand, under the existent law the applicable tools for the Hellenic coasts

are the administrative enlargement of the coast, the prohibition of fences near the coast and the establishment of a zone of controlled urban development. In parallel, the following facts are considered as essential constraints in the direction of an effective policy implementation:

- Absence of a national cadastral information system.
- Absence of a national plan of the allowed land uses.
- The spread expectation to build everywhere in case somebody owns a big enough property. [19]
- The involvement of numerous ministries in the coastal issues. [21]

Besides the previous controlling factors, the big projects and especially the transportation networks - which are currently under construction- will change the spatial image of the Hellenic territory. [22] This fact creates new development potential and as a result: **the coastal areas is strongly possible to become even more stressed.**

3.3 Tourism development

After 1960, many laws and financial incentives have favoured the tourist investments and in our days Hellas attracts the 3% of tourist arrivals in Europe and the 5% of those in Mediterranean countries. Most of the about 10 million (yearly) visitors originate in Europe. More than the four-fifth arrives by air and the 60% of the total by charter flights. The great majority of (35-40 million) nights spent by foreigners is recorded in coastal area; one-third in Dodekanissos and Kyklades, 25% in Kriti, 10% in Ionian Islands etc. The spatial distribution of hotel units shows the same preference to coasts. [14, 23]

In our days, the Hellenic coasts sustain from uncontrolled (and illegal) building, waste disposal etc. Simultaneously, they are considered to be of high economic importance, mainly in the smaller islands, where the development depends excessively upon tourism. In parallel to the (international) tourism, the desire of Hellenes to own a second home near the sea has the same result: **graduate urbanisation of the Hellenic coasts**. This double inclination produces an intense transformation process, according to which forests and agricultural land near the coastal urban centres are replaced by tourist infrastructure and facilities or become resort areas (second home villages).

4. MEASURING THE TOURISM PHENOMENON

4.1 Existing statistical series

The yearly-published statistics on Hellenic tourism are traditionally divided into four items: i) tourist movements, ii) hotels units, iii) exchange and iv) spas. [23] In a second level, they are classify as:

I. Arrivals of tourists. [By citizenship, means of transport, place of entrance and month].
II. Arrivals of tourists by charters. [Numbers of related flights, passengers by country of aircraft's departure and the monthly frequency of arrivals by airport].
III. Movement of yachts. [Flag and port of origin, first Hellene port etc.].
IV. Hotel capacity. [Hotels by type and class, by administrative region ("peripheria") and department ("nomos", prefecture). Campings and rented rooms are examined in a similar way].
V. Movement of hotel units. [Arrivals and nights spent by Greeks and foreigners in hotel units by administrative region, department, type and category of unit. Also, nights spent by tourists' nationality in almost 30 Hellenic tourist destinations, usually smaller than a prefecture].
VI. Foreign travel. [Balance of invisible transactions and the foreign travel receipts by month].
VII. Movement of principal spas. [Users and treatments in the spas of tourist or local importance].

It is obvious that all the previous primary data (as the equivalent of OECD, WTO etc.) follow the traditional division of tourism in demand and supply and they focus chiefly on its financial significance. Even in this framework, they concern mainly with the demand, as the participation of tourism supply is limited in accommodation units. Moreover, there are not handled all kind of tourism, except yachting and spas.

In general, the short-term temporal aspect of tourism intensity is quite good showed, as the smaller

inspected time unit is usually the month. On the other hand, the long-term temporal aspect is scanty, as the stage of life cycle for each tourism destination is not at all apparent. Simultaneously, the registration of the interaction among tourists, environment and local population is not obvious. The cartographic display is totally absent and the spatial distribution of the tourism activities is not familiar with an area scale smaller than a prefecture. Consequently, **the spatial dimension of the tourism intensity is poorly examined** by the already maintained statistical series. [14]

4.2 New approach

In the light of the foregoing noted lacks, the main scarcity to be satisfied is the combined study of the already gathered data (of tourist supply and tourist demand) with a **smaller area unit** than the prefecture and with the **size of the host population**. By this binary approach, a more reliable representation concerning the spatial distribution of the tourism intensity is strongly expected.

According to the author's opinion the territory of the administrative boundaries of Hellenic municipalities or communities (either the old or the new ones, law 2539/1997) is an appropriate choice as smallest area unit. In spite its disadvantages (e.g. unequal shape and area), it offers the prospect to investigate different level of coastal areas width, according to a proposed variable, the **proximity** or vicinity. [24] On the other hand, the use of islands as area unit could be a reliable alternative option, especially in the case of the smaller ones.

In the context of a more elaborate approach of the tourism intensity the previous parameters are not enough. More acute indicators are needed to measure:

- The generated earth's reshapes by the used infrastructure.
- The result (waste) on the "consumed" area and the loss of the utilised natural resources.
- The provoked (permanent and seasonal) host population movements.
- The tourists mobility in the vicinity of the main destination.
- The price and the rate of change of land values, etc.

The list of variables can be exhaustive, but it is common sense to reduce its number by customising it to each coastal area. As the interest of this paper is the physical planning vision, the above roughly exposed spatial integrated approach of the tourist phenomenon is concentrated rather in tourist supply than in tourist demand. Moreover, many of the proposed indexes are non-quantitative or not easy-quantitative, as the quantitative indexes are favourable mainly for homogenous regions [25] and not to express the fluctuation of tourism intensity. On the other hand, **if the homogeneity is ensured (with the use of smaller area unit) quantitative indexes will be acceptable**.

5. CASE STUDY

5.1 Methodology

As tourist data are not available for the Hellenic (coastal) municipality or community, a group of islands is chosen to inspect the usefulness of the proposed new approach. The selection of the 14 foremost islands of the Dodekanissos complex (for which are available full data) seems to be suitable, as it offers a variety of small territories (so the entire island is considered as coastal area) and population. Moreover, Hellas and Dodekanissos are examined as a whole, during the same period of time (1994, the last year with full data), to furnish the prospect of comparative study.

Because of the data lack, the methodology is confined to the first level of the proposed new approach. Thus, the examined primary, quantitative statistical data for each island are: area, population (after a conversion from the 1991 census [16]), length of coastline, beds and nights spent in hotel units. The two latter variables are the average of three years (1993, 1994 and 1995, [23]) in a way to minimise the potential influence of an extreme value. On the other hand, apart from the population density, the examined composite indexes/ratio are [Table 1] :

i. Beds / Area. It shows the maximum awaited impact on the coastal area in a day.

TABLE 1
MEASURING THE TOURISM INTENSITY IN DODEKANISSOS

REGION	AREA	POPULATION	COASTLINE	HOTEL UNITS	TOURISM DEMANT	POPULATION DENSITY	BEDS / AREA	BEDS / POPULATION	NIHTS / AREA	NIGHTS / POPULATION	NIGHTS / COASTLINE
	sq. km	1994	km	beds	nights						
	[1]	[2]	[3]	[4]	[5]	[1] : [2]	[4] : [1]	[4] : [2]	[5] : [1]	[5] : [2]	[5] : [3]
1. RHODES	1.401	99.889	253	57.633	9.106.363	71	41	0,58	6.500	91	35.994
2. KOS	288	26.823	121	25.970	3.767.729	93	90	0,97	13.082	140	31.138
3. KARPATHOS	300	5.416	180	2.775	149.714	18	9	0,51	499	28	832
4. KALYMNOS	111	15.980	105	1.760	94.777	144	16	0,11	855	6	903
5. PATMOS	34	2.710	72	1.699	54.717	80	50	0,63	1.607	20	760
6. SYMI	58	2.373	88	392	21.387	41	7	0,17	368	9	243
7. LEROS	54	8.200	82	965	18.193	152	18	0,12	337	2	222
8. NISSYROS	41	945	30	182	8.303	23	4	0,19	201	9	277
9. TILOS	61	284	75	71	5.405	5	1	0,25	89	19	72
10. ASTYPALEA	96	1.092	128	110	3.576	11	1	0,10	37	3	28
11. MEGISTI	9	280	20	32	2.816	31	4	0,11	308	10	141
12. LIPSI	16	617	39	28	977	39	2	0,05	61	2	25
13. KASSOS	66	1.107	59	32	802	17	0	0,03	12	1	14
14. CHALKI	27	286	40	41	-	11	2	0,14	-	-	-
DODEKANISSOS	2.714	166.331	1.500	91.691	13.234.759	61	34	0,55	4.876	80	8.823
HELLAS	131.957	10.426.289	15.000	521.734	50.803.080	79	4	0,05	385	5	3.387
							SUPPLY RATIOS		DEMAND RATIOS		

ii. Beds / Population. It is already well-known and widely used as index of tourist supply. [15]
iii. Nights / Area. It shows the impact of the finally carried out tourist demand.
iv. Nights / Population. It outlines the tourists-inhabitants interaction.
v. Nights / Coastline. It refers strongly to carrying capacity of coastal areas.

Some very important remarks, related to the above ratios, are:

- The three latter ratios (those with "nights") can be divided by the number of the tourist season days (max. 365 days) to provide the tourism intensity in daily basis. Moreover, instead of the total number of spent nights, those that refer to a special group (e.g. the foreigners) can be used.
- The number of beds can be smaller (e.g. by not considering all types/classes of the hotel units) or bigger (if the complementary accommodation units are included).
- Instead of the coastline of the whole island (in general: of the whole coastal area), the length of the easily accessible coasts or other choice (e.g. sandy coasts) can be used.

5.2 Indicative results

The more impressive outcome of the proposed approach is that not Rhodes but Kos is the Dodekanissean island with the higher tourist intensity. Indeed, apart from the nights/coastline ratio the values that refer to Kos are bigger than those of Rhodes. Moreover, the tourism intensity (according to the supply ratios) in the island of Patmos is unexpected higher than that in Rhodes. Simultaneously, the tourism intensity in Karpathos is lower than that supposed from the usually used (and officially adopted as representative) indexes of tourist supply and demand [columns 4 & 5 of Table 1]. Similar are the comments for the islet of Megisti.

All the previous results seems to be acceptable as they are in accordance with the already known vulnerability of small coastal areas / coastal ecosystems. On the other hand, the Dodekanissos-Hellas comparison certifies the vigorous tourism development of the studied islands, whereas the comparison between the entire complex and each island proves the need for more analytical regional studies and statistical series, as homogeneity in (tourism) development is an illusion. In general, the comparative study and the use of relative indexes increase the provided information and lead to more reasonable classifications.

6. CONCLUSION

First of all, the adoption of islands as area unit offers a quite apt and practical possibility to detect the tourism intensity along the Hellenic coastal areas. In addition, the adoption of an even smaller area unit (like municipalities) is an option that could offer more credible results for the environmental impacts of tourism (e.g. in the case of the big enough island of Rhodes). Finally, the used indexes seem to be adequate for a preliminary study of the tourism development along the Hellenic coastal areas.

It is obvious that further research should be undertaken to inspect the features of the tourism-space relationship and to assess the impacts on the coastal environment. A special concern should be directed towards the **transportation networks**, considering that a new "road" (routes, highways, ports, airports, parking facilities etc.) is the predominant motive factor that presses the Hellenic coast by favouring the tourists' movements. Furthermore, the study of an **accessibility aspect** of tourism intensity in a coastal area could be very useful. Moreover, the reckoning of the **volume** (over the natural earth surface) of the supplier infrastructure could be a very representative index of tourism intensity, especially if it could be calculated with the single property as area unit.

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ECONOMIC AND ENVIRONMENTAL IMPACT OF MARINE TRANSPORTATION OF HAZARDOUS MATERIALS

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ABSTRACT

A high level strategic problem faced by various regulatory agencies and commercial shippers is that of the evaluation of the merit of various alternative policies for transportation of oil. We model the problem as a network flow model with multiple objectives (transportation and risk cost minimization), multiple commodities, multiple modalities and multiple origin-destination pairs. The model will also facilitate the identification of "weak" (high-risk) routes in the system and could further be used for alternative shipping policies ("what-if" type of analysis).

ΟΙΚΟΝΟΜΙΚΕΣ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΙΚΕΣ ΕΠΙΠΤΩΣΕΙΣ ΘΑΛΑΣΣΙΩΝ ΜΕΤΑΦΟΡΩΝ ΕΠΙΚΙΝΔΥΝΩΝ ΥΛΙΚΩΝ

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ΠΕΡΙΛΗΨΗ

Η αξιολόγηση διαφόρων πολιτικών μεταφοράς πετρελαιοειδών (έχοντας σαν αντικειμενική συνάρτηση την ελαχιστοποίηση κόστους μεταφοράς και ρίσκου) είναι ένα στρατηγικό πρόβλημα υψηλού επιπέδου που αντιμετωπίζουν διάφορες δημόσιες υπηρεσίες και ναυτιλιακές εταιρείες. Στην εργασία αυτή μοντελοποιούμε το πρόβλημα σαν ένα πρόβλημα ροής δικτύου με πολλαπλά κριτήρια, πολλαπλά προϊόντα, πολλαπλά μεταφορικά μέσα και πολλαπλά ζεύγη αφετηρίας- άφιξης. Το μοντέλο διευκολύνει επίσης την αναγνώριση διαδρομών υψηλού ρίσκου του συστήματος και μπορεί να χρησιμοποιηθεί για την αξιολόγηση εναλλακτικών πολιτικών μεταφοράς.

1. INTRODUCTION

The designer of a hazmat logistics system has to determine an optimal assignment of different products on different modalities, in shipping the products between different cities, warehouses etc. The means of transportation may differ in their capacities to hold different products, their speeds, and their costs (leading to economies of scale). Routing analyses with two or more criteria, or their weighted sums, have been performed by many researchers (Saccomanno and Chan [14], Zografos and Davis [16], List and Mirchandani [12], Wijeratne et al. [15], Iakovou et al. [7]). Batta and Chiu [11], Patel and Horowitz [13] among others, on the other hand have emphasized single objective models.

Reviews by Erkut and Verter [5] and List et al. [8] provide some of the more comprehensive reviews into the problem of hazardous materials transportation. Clearly, in the hazmats transportation literature, there has been more of an emphasis on road and rail transportation. Marine transportation and risk analysis models are few in numbers, or are mostly qualitative [1]. However, recent quantitative work by Li et al. [6] and Iakovou et al. [7] has tackled the marine transportation of hazmats, and specifically oil products. NMOTSM [2] allows for the quantification and modeling of oil transported within the geographic boundaries of the United States, for the analysis of risks and effects of oil spills and the identification of appropriate technologies to support intervention and mitigation to reduce damages from spills in high-risk areas. A serious gap in the literature concerning a very important input for such marine oil transportation models is the estimation and assignment of risk costs on the links of the network. Recently Douligeris et al. [4] and Yudhbir [18] have tackled the issue of first quantifying risk associated with marine transportation of oil products and secondly, allocating and assigning the risk cost estimates to the routes employed by different transportation modalities.

In this paper, we address the crude oil tanker routing problem that is faced by commercial shippers controlling a fleet of a fixed number of crude oil tankers. The four types of most commonly used tankers, namely, Afromax, Suezmax, VLCC (Very Large Crude Carriers) and ULCC (Ultra Large Crude Carriers) differ from each other through their capacities, their travel times and the costs of transportation. The crude oil routing problem is a medium-range strategic problem with a quarterly, semiannual or annual planning horizon. The choice of three months is predicated on the voyage legs of tankers between any two ports, lasting anywhere from two days to two months. The major concern of a fleet operator (or a regulatory agency), given an assignment of different tanker types on routes, is to determine how to ship crude oil not only at a minimal transportation (voyage) cost, but also at a minimal expected risk cost (due to oil spills).

We present a multiobjective, multicommodity, multiple source-destination, multimodal formulation that captures the various objectives that a fleet operator (or a network regulator) faces while in the context described above. After the introduction of the U.S. Pollution Act of 1990 (OPA 1990), risk costs have become extremely important, as captured in the motto of U.S. oil shipping companies - "not even a drop of oil spilled". We present an interactive algorithm (**Interact**) that captures the multiobjective nature of this problem. This algorithm will allow the user to investigate various decisions based on different weights of the transportation vs. risk costs and conduct various "what-if" analyses. Due to ever growing governmental regulations stemming from an increased public awareness about the environmental impact of oil spills, the fleet operators need to have tools that can assist in the identification of "high risk" routes, and for obtaining "optimal" routing policies. The "what-if" analysis can be further extended to validate the current tanker assignments (the types of

tankers and the number of tankers on the different routes) by comparing the different scenarios run on **Interact**. The algorithm further assists the fleet operator for contingency planning: to mitigate against different types of disaster that can affect a maritime route such as a hurricane. The analysis can further aid in planning when fewer tankers are available (due to breakdowns and repairs). Such information is quite valuable to a fleet scheduler.

The rest of the paper is organized as follows. The problem formulation along with its related nomenclature is presented in the next section. Section 3 presents the development of the solution methodology. An example problem is presented in section 4, along with a brief description of **Interact**. Finally, conclusions are presented in section 5.

2. OIL TRANSPORTATION PROBLEM

According to most of the research in the logistics of hazmats literature, the carriers of hazmats need to solve the problem of selecting route(s) between an origin-destination pair for a given hazmat, transportation mode and vehicle type (the single commodity, single origin-destination, route planning problem is known in the literature as a local route planning problem [5]). This is however, not the problem that fleet operators (or governmental agencies) face, since all the hazmats that need to be transported, have to be taken into account in order to determine the "high risk" paths in a region. This is an instance of a multiobjective, multicommodity, multiple O-D, mutimodal problem, known in the literature as the global routing problem [5]. The hazardous materials routing problem in the United States is "many to many" with several destinations for each origin [3].

Most of the prior work in the area of hazardous materials routing has focused on the selection of routes between a given origin-destination (O-D) pair for a specific hazmat. However, a comprehensive model should allow for different types of hazardous materials that are to be transported over a transportation network with multiple O-D pairs.

2.1 Problem Formulation

We consider a directed transportation network G = (N, E), where N is the set of nodes that includes origins, destinations and junctions (ports/port groups, import/export points), and E is the edge set including the modalities that make up the transportation infrastructure. The arcs correspond to tanker routes, waterways and other coastal navigational channels. Any arc is characterized by its length, transport rate per ton-mile, risk cost, capacity etc. We concentrate on the four types of tankers, most commonly used for the transportation of crude oil and petroleum products. Each route is assigned a risk cost, based on spills that can be determined by the methodology provided by Douligeris et al. [4]. The following nomenclature is used:

$M_1 = \{1,...,m_1\}$: set of sources (producers) (i), $M_2 = \{1,...,m_2\}$: set of destinations (customers) (j), $M_3 = \{1,...,m_3\}$: types of products (p), $M_4 = \{1,...,m_4\}$: tankers of different types (tankers) (k)

X_{ij}^{pk}: Amount of product p which will be transported from source i to destination j via transport mode k.

C_{ij}^{pk}: Transportation costs to transport p from source i to destination j via transport mode k.

R_{ij}^{pk}: Risk costs (due to spills) in transporting p from source i to destination j via transport mode k.

S_{ip}: Amount of product p shipped (produced) from source i.

R_{jp}: Amount of product p received (demanded) at destination j.

U_{ij}^{k}: Available capacity of transport mode k which will be transported from source i to destination j (capacity refers to the total capacity of tankers assigned to the route between node i and node j).

The objective function of the formulation consists of a multiobjective function:

- The first criterion deals with the minimization of transportation or voyage costs.
- The second objective deals with the minimization of risk costs due to oil spills.

$$\text{(P)}\ \min \sum_{i=1}^{m_1}\sum_{j=1}^{m_2}\sum_{p=1}^{m_3}\sum_{k=1}^{m_4} C_{ij}^{pk} X_{ij}^{pk} \qquad (1)$$

$$\min \sum_{i=1}^{m_1}\sum_{j=1}^{m_2}\sum_{p=1}^{m_3}\sum_{k=1}^{m_4} R_{ij}^{pk} X_{ij}^{pk} \qquad (2)$$

subject to

$$\sum_{j=1}^{m_2}\sum_{k=1}^{m_4} X_{ij}^{pk} = S_{ip}, \qquad i \in M_1, p \in M_3 \qquad (3)$$

$$\sum_{i=1}^{m_1}\sum_{k=1}^{m_4} X_{ij}^{pk} = R_{jp}, \qquad j \in M_2, p \in M_3 \qquad (4)$$

$$\sum_{p=1}^{m_3} X_{ij}^{pk} \le U_{ij}^{k}, \qquad i \in M_1, j \in M_2, k \in M_4 \qquad (5)$$

$$X_{ij}^{pk} \ge 0, \qquad i \in M_1, j \in M_2, p \in M_3, k \in M_4 \qquad (6)$$

The constraints of the formulation assure that oil flows are realistic given the structure of the transportation network. More specifically:
(i). The inbound traffic by product for each port must equal the total traffic from all other ports, for all products and tankers (3).
(ii). The outbound traffic by product for each port must equal the total traffic to all other ports, for all products and tankers (4) and
(iii). Capacity constraints - The total amount of product p flowing between ports i and j, for all i and j, and being transported via tankers of type k, can at most be equal to the capacity for this type of tanker assigned on the route from i to j (5).

3. SOLUTION METHODOLOGY

Often, it is impractical for a decision-maker to combine the different criteria into a single utility function. Simultaneous minimization of different objectives will lead to a point, where a further reduction of the value of one criterion is likely to be obtained only at the expense of the other criterion. A whole class of algorithms, known as interactive algorithms, or methods of progressive articulation of preferences has been developed [17]. Interactive algorithms are all based on the following approach. The algorithm starts with the generation of one or more nondominated solutions. A solution is nondominated if and only if no other solution leads to any further minimization of the different criteria. The decision-maker is then asked to identify the most preferred nondominated solution. Based on his/her answers, the problem is then modified, and the algorithm is then repeated iteratively, until the decision-maker is satisfied with a solution. Of course, a satisfactory solution is something that the user gets to decide on, but a solution must exist. Two such algorithms are provided by Ringuest and Rinks [10].

Instead of obtaining the weights by solving a set of homogeneous system of linear equations, we let the decision-maker determine the appropriate weights ([18]). The decision-maker is then responsible for the preference information that goes into deciding these weights. The solution methodology proceeds in the following manner:

1. First solve the two single objective subproblems, i.e. minimize (1) and (2) subject to (3),(4),(5), and (6) and compute the the two nondominated solutions of the form
$$Z_k = \left[Z_1(X_{k\cdot}), Z_2(X_{k\cdot})\right]$$
where $X_{k\cdot}$ is the optimal extreme point for the k th subproblem.
2. At this stage the decision-maker decides if any of the solution is the most preferred nondominated solution.
3. The decision-maker needs to decide if the solution obtained in the previous step is satisfactory.
   3.1 If it is satisfactory, **STOP**.
   3.2 Else, proceed to the next step.
4. Construct a function that passes through the two current nondominated solution vectors, Z_k. The function is of the following form:
$$Z_t(X) = \sum_{k=1}^{2} W_k Z_k(X) \qquad (7)$$
with $W_1 + W_2 = 1$, where W_1, W_2 are the weights that are applied correspondingly to the transportation cost matrix and the risk cost matrix. The weights signify the emphasis that the user may want to place on each of the criterion for a route in the network.
5. Optimize (7) subject to the same constraints (1) and (2) are subject to.
6. Identify the least preferred solution between $Z_t(X)$ and Z_k and delete it from the set of the current nondominated solutions. Then return to Step 4.
7. User decides upon the most preferred solution from the set of nondominated solutions, **STOP**.

The first step in the solution methodology determines an initial set of the nondominated solutions. The solutions determined in step 1 are included so that the algorithm starts in step 2 with a set of solutions that span the solution space. The user then identifies a linear combination of the two objectives in steps 4 and 5. Steps 4-7 are iteratively repeated until the most preferred solution is

identified. The methodology is capable of backtracking, since it can retrieve the solutions that may have been removed in previous steps.

4. Application of *Interact* on an Example Problem

An interactive problem software package, **Interact** was developed. The software package was written in C and was implemented on a Sun Sparc II workstation running on SunOS 4.1.3.
Interact implements the methodology presented in the previous section. The user is an inherent participant in the process leading to a solution for the problem mentioned above. At each step, the package solves a problem with the help of CPLEX (a commercially available LP solver). The user then either accepts the current set of solution or replaces the previous worst solution with the new solution, if the current solution is new and better than the previous ones. The program is run iteratively, until a desired solution is achieved.

To exhibit the performance of the algorithm a hypothetical problem with 3 sources and 4 destinations is generated (Figure 1). The amount of product, crude oil shipped out and received by the sources and the destinations respectively are shown on the graph, adjacent to each node. The numbers on each arc represent the availability of the different types of transport (tankers) on that arc, e.g. 3,4 for the 3-4 O-D pair implies that one tanker of type 3 and one of type 4 is available on that arc. We assume that there is only one product being shipped , crude-oil, and the tankers transporting the crude are all of equal capacity and they differ only in their transport costs. The transportation and risk costs for every source-destination-transportation type are shown in Table 1.

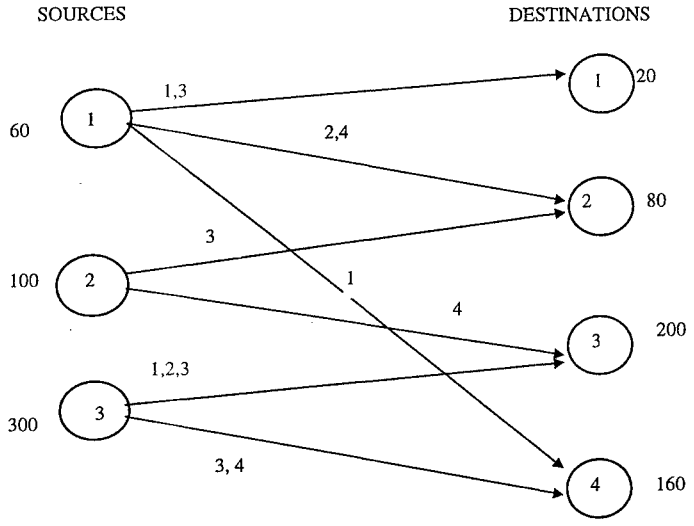


Figure 1. Network of Three Supply Ports and Four Demand Ports

Interact first solves (1) subject to all the constraints, (3)-(6) and then (2) subject to the same constraints. The optimal solution for (1) and (2) achieved costs of $23,200 and $22,900 respectively. If the user is not satisfied with this solution, a new problem is generated. As an example, one was generated with a cost matrix where the transportation costs weighed more than the corresponding risk

costs for each route. We chose to weigh transportation costs vs. risk costs using a 0.8:0.2 ratio. After the weights have been chosen, the optimal cost of $13,148 was achieved. Since the current solution is better than the first solution in the pair (namely, the new optimal value pair consists of $13,148 and $22,900. At this stage, the user may want to solve the same problem, but with more emphasis on risk costs than on transportation costs.

Source	Destination	Tanker Type	Trans. Cost ($/unit weight)	Risk Cost ($/unit weight)
1	1	1	10	75
1	1	3	30	40
1	2	2	20	36
1	2	4	40	60
1	4	1	10	15
2	2	3	30	40
2	3	4	40	60
3	3	1	10	15
3	3	2	20	36
3	3	3	30	40
3	4	3	30	40
3	4	4	40	60

TABLE 1. Transportation and Risk Costs for every Source-Destination-Transport Type

As an example, a 0.20:0.80 split was chosen. A new cost matrix is then generated, and is subsequently solved for, while being subjected to the same constraints as before. A new solution of $6,544 is achieved. After replacing the current undesired solution ($22,900) with the new solution of $6544, the user is prompted to decide if the new solution is satisfactory. The decision-maker may decide that this optimal solution is indeed what was desired, and answers 'yes' to the question. **Interact** then acknowledges the response and *stops*. The optimal solution finally achieved is: $X_{11}^3 = 20$ (the amount of crude oil to be transported by a tanker of type 3 from the source node 1 to destination node 1 is 20 units), $X_{14}^1 = 40$, $X_{22}^3 = 80$, $X_{23}^4 = 20$, $X_{33}^1 = 180$, and $X_{34}^3 = 120$. Notice that all the supply and demand is satisfied by such an assignment of crude oil to the different tanker types.

5. CONCLUSIONS

We have addressed a medium-range strategic problem often encountered by commercial shippers of crude oil and oil products (and by governmental regulatory agencies). We captured the multiobjective nature of the problem and modeled it as a multiobjective, multicommodity, multiple source-destination and multimodal problem for crude oil transportation. We also developed an interactive algorithm to solve the above problem. This solution methodology is such that the decision-maker's role is an "active one" , i.e., the decision-maker is involved in the process of determining a desired solution. A software package, **Interact,**, was developed to implement the above mentioned algorithm. To exhibit the solution methodology, an example problem was presented and solved.

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ECONOMIC ASPECTS OF WATER SUPPLY POLICY IN GREEK CITIES

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ABSTRACT

This paper examines the existing situation -in the section of municipal water- in the cities all over Greece where Water Authorities (DEYA) exist. Water price policy, quality and quantity problems, funding of water planning projects and alternative resources are among the most important issues analysed. Useful remarks and suggestions for the improvement of the current situation, concerning the economic aspects of the water supply policy are finally derived and presented.

ΟΙΚΟΝΟΜΙΚΗ ΠΟΛΙΤΙΚΗ ΣΤΟΝ ΤΟΜΕΑ ΤΗΣ ΥΔΡΕΥΣΗΣ ΣΤΙΣ ΕΛΛΗΝΙΚΕΣ ΠΟΛΕΙΣ

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ΠΕΡΙΛΗΨΗ

Η παρούσα εργασία έχει σκοπό να καταγράψει τα πιο σημαντικά προβλήματα που παρουσιάζονται στον τομέα της ύδρευσης,στις διάφορες πόλεις της Ελλάδας που έχουν αρμόδιες υπηρεσίες νερού (ΔΕΥΑ). Παράμετροι όπως το κόστος του νερού, η ειδική κατανάλωση, η πιθανή αύξηση της τιμής του νερού, η επάρκεια και η ποιότητα νερού, η εξεύρεση νέων πηγών και η κατασκευή νέων έργων είναι τα πιο σημαντικά θέματα που αναλύει η εργασία. Παρουσιάζονται προτάσεις για την βελτίωση της υφιστάμενης κατάστασης στις πόλεις καθώς προκύπτουν χρήσιμα συμπεράσματα από την έρευνα που διενεργήθηκε στον Τομέα Υδραυλικής και Τεχνικής Περιβάλλοντος του Α.Π.Θ.

1. INTRODUCTION

Because of the political, environmental and economic changes that are happening throughout the world, towards the implementation of the main principles of sustainable water management, there is an intensive need to consider demand management to meet future needs.
The challenge today is to integrate demand management into long range water supply planning in order to achieve an appropriate balance between capacity expansion and water conservation [2]. The concept of considering water as an economic resource, which means recognition of its full price, and use of economic instruments as well, is among the main advantages of a sustainable water supply policy. It is evident that the traditional emphasis on water supply management has led into depletion of freshwater, to overexploitation and underestimation of water itself. Therefore, we need to develop new alternative sustainable schemes with the goal of balancing the appropriate conservation and demand management policies with any needed development of new supplies [1]. In order to do this, Water Supply Authorities need to integrate all economic, environmental, social and political aspects of water and give special consideration on both, rational design and environmental impacts of water supply projects[4]. This paper describes and evaluates the economic aspects of the municipal water supply policy in Greek cities. The results of the survey that was conducted in order to gather data from the different Water Authorities are analyzed and useful remarks and recommendations are derived and presented.

2. DISCRIPTION OF THE SURVEY

2.1 Sample: 49 cities were examined. The total number of cities having Water Supply Authorities all over Greece are 79. (Athens and Thessaloniki are not included). Among them, 27 belong to islands, and were examined separetely, [9], and the rest 3 didn't respond to our survey.

2.2 Distribution of the sample: All cities were classified according to the geographic districts they belong:

- Eperos (Arta, Preveza, Ioannena, Igoumenitsa)
- Thessalia (Trikala, Larisa, Volos, Karditsa, Tyrnavos, Almyros Volou)
- Peloponessus (Nafplio, Tripoli, Patra, Pyrgos, Amaliada, Korinthos, Xylokastro, Sparti, Gythio, Kalamata, Argos, Zaharo)
- Thrace (Alexandroupoli, Orestiada, Xanthi, Komotini)
- East Macedonia (Drama, Kavala, Seres)
- West Macedonia (Kastoria, Kozani, Florina, Ptolemaida)
- Central Macedonia (Veria, Kilkis, Gianitsa, Katerini, Halkidiki, Alexandria, Paralia Katerinis, Eginio)
- Sterea Hellas (Mesologi, Agrinio, Livadia, Theva, Karpenisi, Lamia, Megara, Halkida)

2.3 Methodology: Personal interview from the directors of the Water Authorities of every city through a questionnaire was conducted. Whenever there was no director of a certain Water Authority, information was given from persons responsible for water supply issues.

2.4 Data analysis: Data analysis was made with the method of "construction of double entrance matrices of absolute and relative frequencies". The double entrance matrices were used to derive the qualitative relationships among all the variables under examination.

2.5 Volume Charge for the Consumption of Reference: In order to overcome the differences in time periods and in scales of the tiered rate structure among the various cities, it was nessesary to

assume a uniform basis for the water rates. The water rate parameter that was introduced therefore, was the Volume Charge for the Consumption of Reference, (VCCR), which equals to the weighted mean volume charge for the first 60 m3 of water consumption. The corresponding uniform time scale was assumed to be three months. To calculate the volume charge for these first 60 m3 per 3 months consumption, the following equation was used:

$$VCCR = 3\ [(a.b) + (c.d) + \ldots\ ] / 60n$$

where a,c is the scale of the tier structure rate for the b and d m3 till the first 60m3 of consumption.
n corresponds to the different time scales of the tiered rate structure in the various cities.
3 stands for the time period of the three months.

2.6 Questionnaire: The questionnaire covers questions that concern the current water needs, the water supply and water pricing policies, the funding of water projects and other related financial issues, the existence of water quality and quantity problems, and the perspectives of the economic aspects of the water supply policy in the cities under examination.

3. RESULTS

3.1 Water rate structure

Districts	Max VCCR (drs./ m3)	Min VCCR (drs./ m3)	Average VCCR (drs./ m3)	St. Dev.
Ipiros	168 (Praveza)	47 (Igoumenitsa)	91	40
Thessalia	145 (Larisa)	105 (Tyrnavos)	129	16
Peloponessos	135 (Argos)	34 (Gythio)	89	31
Thrace	220 (Komotini)	60 (Xanthi)	112	73
Cen. Macedonia	240 (Alexandria)	25 (Halkidiki)	114	59
West Macedonia	150 (Kozani)	95 (Ptolemaida)	115	21
East Macedonia	228 (Seres)	193 (Drama)	177	77
Sterea Hellas	357 (Megara)	67 (Mesologi)	139	96

TABLE 1: Statstical analysis of the current water rates in Greek Districts

All the above water rates shown in Table 1, concern the volume charge for the first 60 m3 of water consumption, corresponding to a time period of 3 months (Volume Charge for the Consumption of Reference).
After careful examination it was found that there is a big range of variety in water rates throughout the cities as a result of a non existence of a certain economic policy.
The average VCCR in the Greek cities in total is 118 drs/m3, with a standard deviation equal to 67.
The distribution (Relative Frequency and Cumulative Frequency) of the above water rates, is shown in figure 1.
More than 40% of the total volume charges are below 100 drs/m3, while more than 80% are below 150 drs/m3, as shown in figure 1.

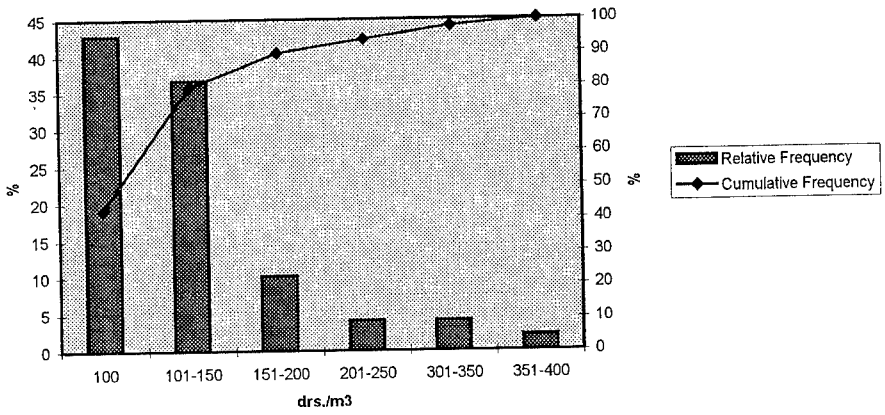


Figure 1: Volume charge distribution

3.2 Specific consumption

The distribution of the specific consumption (Relative Frequency and Cumulative Frequency), is shown in figure 2.

As it is shown in this figure, approximately the 40% of the Greek cities have a specific consumption higher than the normal rate of 250 lt/cap/day. This remark, in relation to the fact that the relevant volume charges are rather low, (more than 90% of the cities have a water rate lower than 250 drs. / m3), indicates the need for a more sustainable demand management policy.

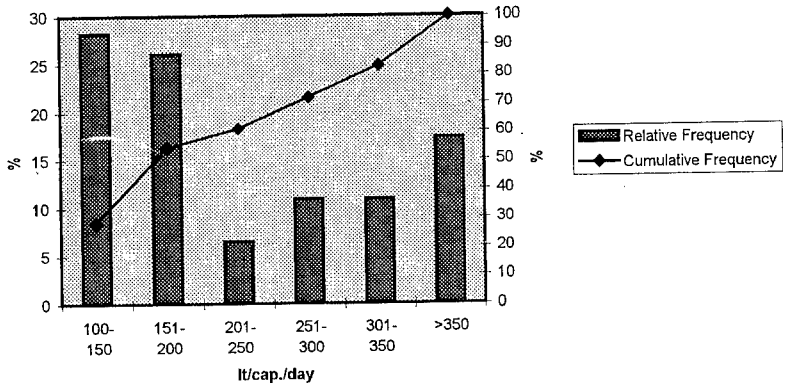


Figure 2 : Distribution of the specific consumption

3.3 Correlation between water rates and specific consumption

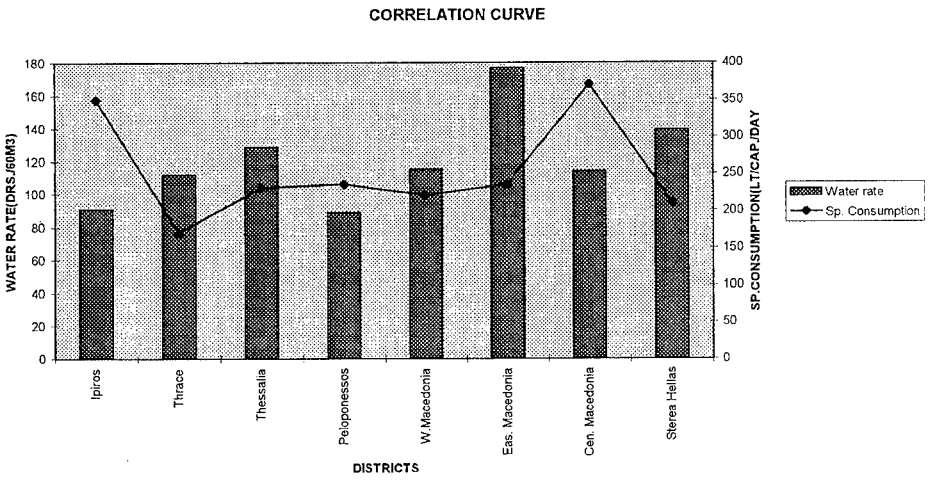


Figure 3 : Correlation between water rates and specific consumption

The correlation between water rates and the specific consumption is shown in figure 3. As shown, there are certain cases with normal correlation, like in Eperos and Central Macedonia, where the high rates of the specific consumption are followed by rather low volume charges. This indicates that in these cases there is ground for a water demand policy, in the form of reducing consumption rates by increasing the volume charges.
In other cases, (East Macedonia), the high volume charge is not followed by a reduced consumption rate, which means that the economic policy applied was not effective.
Finally in Peloponesus, where the lowest volume charge appears, the specific consumption is not very high as expected, but around the average.

3.4 Water related problems

In figure 4 the distribution of the water related problems in the examined Greek cities is shown.
Apart from water quantity problems claimed by the Water Authorities of the examined cities that reach a 40.8% as it is shown in figure 4, generally there were not referred major water related problems in Greek cities. More specifically, Central Macedonia seems to face the most severe water quantity, water resources availability and water engineering problems. In the contrary, in East Macedonia, there are no other water related problems than engineering and financial ones. In Sterea Hellas were found the most severe water quantity problems, while in Eperos, they mostly have water quality and engineering problems.
In West Macedonia they mostly have new resources availability problems.

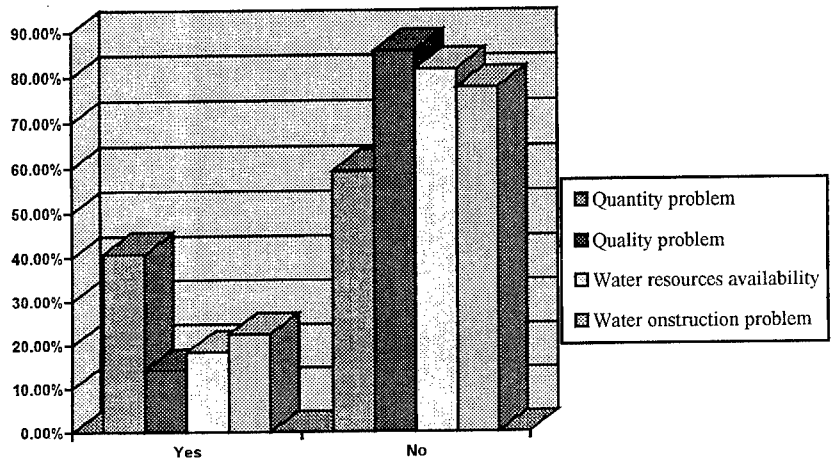


Figure 4: Water related problems

4. CONCLUSIONS

- The correlation between volume charges and specific consumption does not follow the expected curve between price and demand. As the price goes up the consumption should fall. This is not happening in our case.
- The volume charges in the Greek cities can be considered rather low with an average of 118 drs/m3, and a standard deviation of 67 (for the Volume Charge of the Consumption of Reference).
- In many cities exist different tiered - rate structure bills seperated into categories, (higher for professional use, lower for multifamilies).
- The only demand management practice applied in water supply policy in Greek cities is the tiered - rate structure.
- Some cities however have no tiered - rate structure (Ptolemaida, Kavala, Orestiada, Paralia Katerinis), while Naousa has no mesuring at all.
- It doesn't exist any uniform water supply policy throughout Greece. Instead, every city applies its own water policy under special circumstances defined by the administrative council of every Water Authority.
- Water seems to be only a social commodity without recognizing its full price.
- The Water Supply Authorities claimed they don't face severe water related problems at the moment.
- The specific consumption is high especially in cities where the volume charge is very low (Paralia Katerinis).

5. SUGGESTIONS

Emphasis should be given in demand management through the increase in water rates accompanied also by other economic instruments. There is a great fluctuation and variety in water rates as a result of an absence of an economic water supply policy.

The correlation between volume charges and specific consumption shows that there must occur a reorientation of the economic policy in water supply towards the reduction of the increased rates of the specific consumption.

The only demand management practice applied in Greek water supply policy is the tier-rate structure as we mentioned above. This measure should be expanded in all cities and also become more effective in cities were it is applied. This could happen by :

1. Mesuring the social factor (willingness to pay, comsumer satisfaction).
2. Appling economic analysis before defining the water rate (compare costs, cost-benefit analysis)
3. Estimating future demands in water
4. Separating values from every customer billing class (residential , industrial , etc.)

Today water is considered to be only a social commodity. But what should happen is that the full price of water should be recognized. This means that it should be taken into consideration not only the costs and the expences of the Water Authority but also the following:

- environmental cost
- opportunity cost (value of water for alternative uses)
- cost of water provision

People should be informed and they need to participate in all stages of the implementation of a sustainable water policy. The Water Supply Authority should establish a strong and carefully crafted public involvement and education effort concurrently with the development of a conservation-oriented rate structure.

Success depends on political sensitivity, administration reform, citizens participation and good information. Environmental concerns can be integrated into the development policy.

At last, what is important, and should be realized by everybody, is that the aim is not to gather more money by the Water Authority but to maintain the sustainability of water resources and give the opportunity to future generations to respectively meet also their water needs.

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THESSALONIKI WATER AUTHORITY: HISTORY AND ENVIRONMENTAL POLICY THROUGH WATER MANAGEMENT

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ABSTRACT

In this paper the 2000 years of water history of Thessaloniki are presented, under the title PAST. The evolution and change of some critical data concerning water production and consumption are comprised in the chapter PRESENT. From the point of view of water demand, our predictable FUTURE up to the year 2020 is presented. In this chapter we ooutline the progress of works from river Aliakmon, which comprise the treatment plant and the transportation ring network, from treatment plant to the city of Thessaloniki.

ΟΡΓΑΝΙΣΜΟΣ ΥΔΡΕΥΣΕΩΣ ΘΕΣΣΑΛΟΝΙΚΗΣ: ΙΣΤΟΡΙΑ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗ ΠΟΛΙΤΙΚΗ ΜΕΣΩ ΤΗΣ ΔΙΑΧΕΙΡΙΣΗΣ ΤΟ Υ ΠΟΣΙΜΟΥ ΝΕΡΟΥ

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ΠΕΡΙΛΗΨΗ

Στην εισήγηση γίνεται μια σύντομη ιστορική αναδρομή των 2000 χρόνων της υδατικής ιστορίας της πόλης της Θεσσαλονίκης, κάτω από τον τίτλο ΠΑΡΕΛΘΟΝ. Η εξέλιξη και μεταβολή ορισμένων σημαντικών μεγεθών παραγωγής και κατανάλωσης πόσιμου νερού τα τελευταία 40 χρόνια, καθώς και η μεταβολή του αριθμού των καταναλωτών του Ο.Υ.Θ. για την περίοδο 1956-1995 συνιστούν την χρονική περίοδο του κεφαλαίου ΠΑΡΟΝ. Το προβλεπτό μας μέλλον από άποψη ζήτησης πόσιμου νερού για την πόλη εκτείνεται ως το 2020, και κατ' ουσίαν παρουσιάζονται τα υπό εξέλιξη έργα μεταφοράς και διώλισης νερού από τον ποταμό Αλιάκμονα καθώς και της περιμετρικής μεταφοράς και διανομής τους από το Διυλιστήριο προς την πόλη τηες Θεσσαλονίκης.

1. INTRODUCTION

Water Authority of Thessaloniki (W.A.T.) is an Organisation of the Public Sector, whose purpose is to cover the drinking water needs of the city of Thessaloniki. One million people and the Industrial area, are among the customers of our Company.

In this paper we are going to present briefly the 2000 years history of Thessaloniki Water Company (PAST), the evolution of some critical data for the last 40 years (1956-1996) (PRESENT) and our future plans until the year 2020 (FUTURE).

The main idea which goes through all this paper is that the ECOHYDROLOGY of an area is strongly connected with the changes of people, during the time, that live in this area.

2. PAST

You can trace the History of Thessaloniki, through the water technology which was used from the inhabitants of this area during the last 2000 years. The mountain Hortiatis, which covers the east side of the city, was all this time one of the main water sources for the people of the area. Galerios, the Roman Governor of Thessaloniki at the begining of 4th century AD, constructs wells, mains and waterbridges in order to transfer the water from the mountain to the city. Some of these waterworks were in use until today and constitute part of Galerios heritage in this city.

The Water-Bridge of Hortiatis connects the 4 centuries of Roman conquest, the 10 centuries of Byzantium and the 5 of Othoman Empire. All these establishments watered the inhabitants of Thessaloniki by using the same mountain resources and the same network. Christian churches were the water distribution points during Byzantium period and Turkish minarets during the Ottoman period.

The changes of population of Thessaloniki all these 19 centuries were not so important. The water sources of Hortiatis and Retziki and the Roman network were sufficient to satisfy this water demand. Some important changes happened in this situation only after the year 1890, when the increase of population in the area obliged the Turkish Governor to entrust the watering of the city in a Belgian Water Company. A number of wells, some Pump Stations, two Tanks and the demanded transfer and distribution Networks, are among the waterworks that the Belgian Company constructed during the 50 years of its life. Most of them are in use until today.

In 1939 Water Authority of Thessaloniki became a Greek Company and since then the responsibility of this importand social demand burdens Greek authorities.

3. PRESENT

Under the title PRESENT we cover 40 years of 1956-1995 period, for which we have available data. During this period the consumers' number became 16 times larger and the billing water quantity, increased 14 times.

Thessaloniki became a megalopolis of 1.000.000 inhabitants and this growth has its consequenses in contamination of its harbour. On the other hand the water demand of the city is covered by pumping water from long distances (Aravissos and Aliakmon river).

In Fig. 1 we can see the increase of WAT customers during the last 40 years (1956÷1995) and in Fig. 2 the billing water quantity at the same period. Table A gives us the same data for every year.

Fig. 3 shows the flunctuation of the water production per year for the period 1981÷1995, while Fig. 4 gives us the flunctuation of daily average consuption per month, for four years (1981, 1986, 1991, 1995). Every year, the peak of consumption occurs the months June and September.

In order to cover this demand WAT has 450 employees, 80 wells, 23 pumping stations and 22 tanks: These waterworks pump 250.000 m^3 water per day (average) which is transported through a network of 1.200 Km.

4. FUTURE

Water from Aliakmon River, a Treatment Plant of a Total Capacity 600.000 m^3/d, and a Transportation Network of Pipes, Pump Stations and Reservoirs, which will surround the city, constitute the Future Plans for covering the Water Demands of broaden area of Thessaloniki. Part of this Aliakmon Project has already been completed and a quantity of 150.000 m^3/day, are expected to be added in our Network until the year 2000. In addition to these 150.000 m^3/day more will be added untill the year 2007.

In the meantime the Ring Network will be constructed and will be connected with our Distribution Network which services the present consumption. New customers, which are neighbored communities, will be connected in the Ring Network. The rest 300.000 m^3/day are expected to satisfy the water needs of the broader area up to the year 2020.

In conclusion, we can say that Water Authority of Thessaloniki inherrited a long PAST, controls efficiently the PRESENT and aims at an optimistic FUTURE.

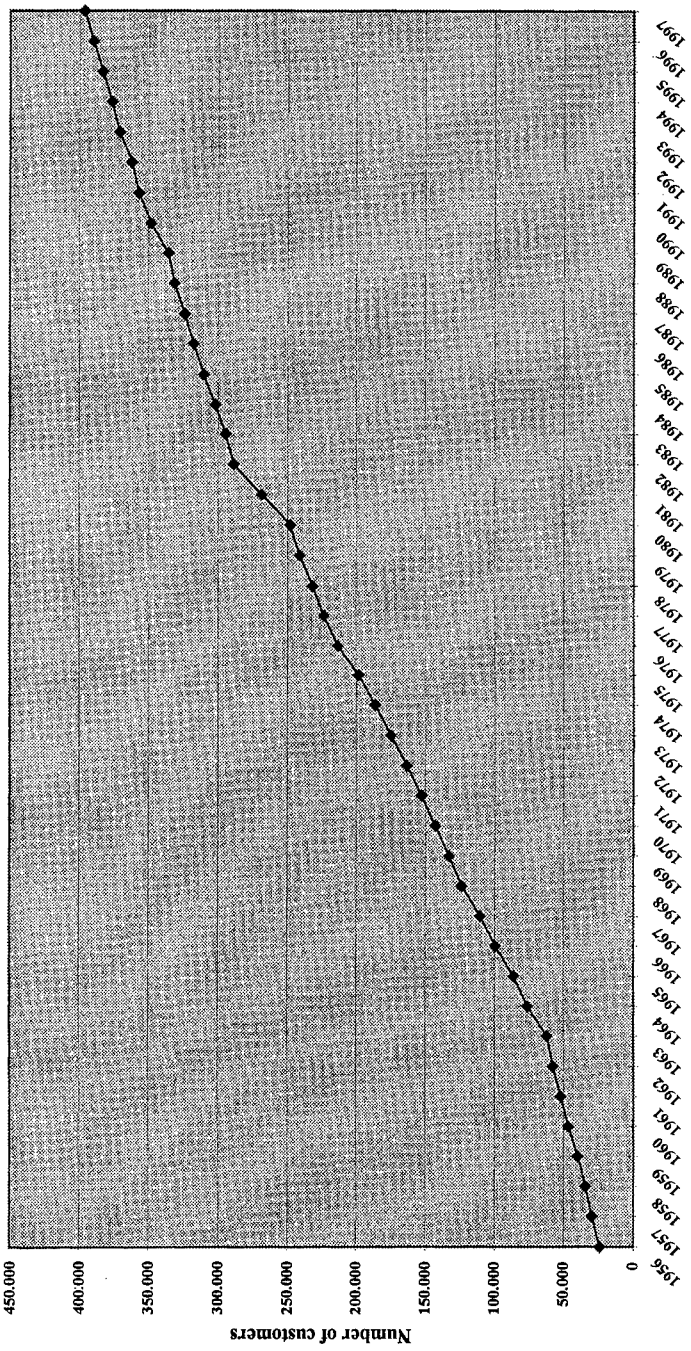


Figure 1: Increase of WAT customers

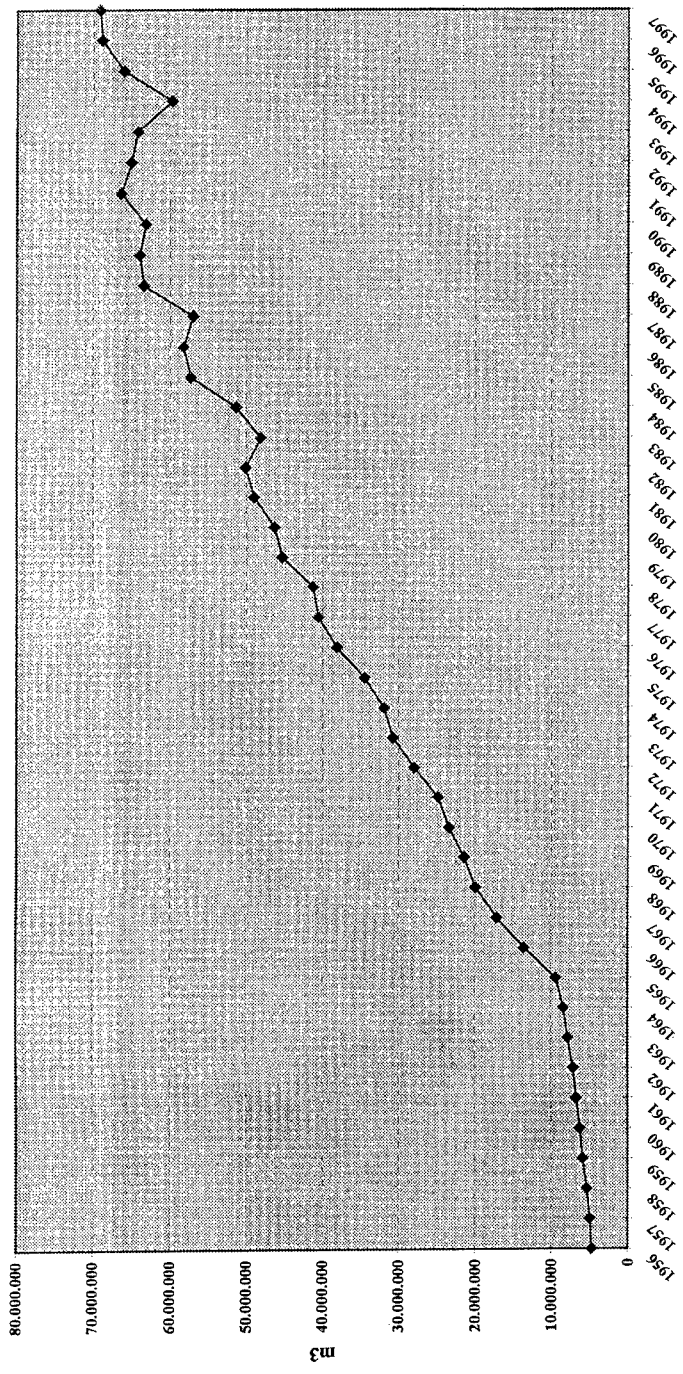


Figure 2: Billing Quantity (m3/year)

WATER AUTHORITY
OF THESSALONIKI
(W.A.T)

Year	Number of Consumers	Billing Quantity (m3)
1956	23.859	4.707.000
1957	29.706	4.940.000
1958	34.184	5.274.000
1959	39.860	5.852.000
1960	46.675	6.229.000
1961	52.153	6.698.000
1962	57.740	7.113.000
1963	62.254	7.788.000
1964	76.068	8.360.000
1965	86.001	9.375.000
1966	99.054	13.518.000
1967	110.027	17.097.000
1968	123.449	19.925.000
1969	132.711	21.409.000
1970	142.858	23.374.000
1971	152.879	24.840.000
1972	163.309	27.935.000
1973	175.048	30.740.000
1974	186.345	31.933.000
1975	198.511	34.485.000
1976	213.443	38.114.000
1977	223.657	40.550.000
1978	231.540	41.278.000
1979	241.090	45.276.000
1980	248.219	46.305.000
1981	268.338	49.005.000
1982	288.819	50.085.000
1983	294.457	48.117.000
1984	301.904	51.374.000
1985	310.378	57.208.000
1986	317.476	58.211.000
1987	324.135	56.954.000
1988	331.087	63.371.000
1989	336.154	63.918.000
1990	348.174	63.143.000
1991	357.134	66.303.000
1992	362.274	65.000.000
1993	371.021	64.200.000
1994	376.600	59.715.000
1995	382.899	65.977.000
1996	389.804	68.838.000
1997	396.057	69.083.000

Table A: Consumers Number and Billing Quantity of Water
for the period 1956 - 1997

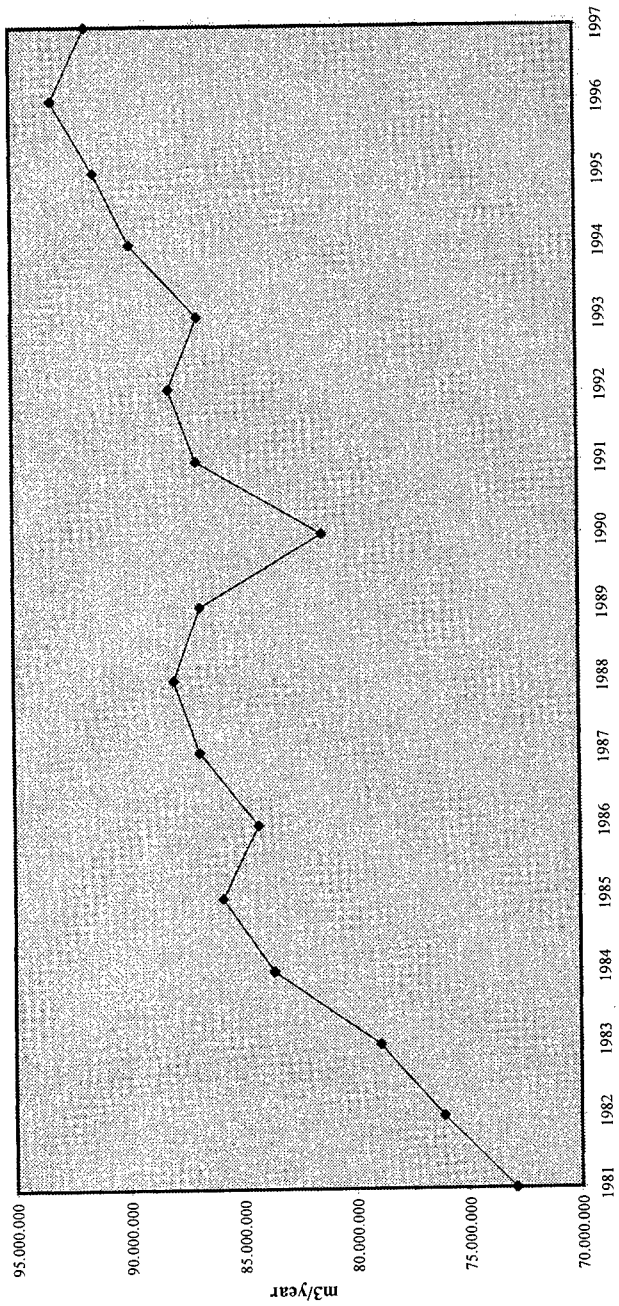


Figure 3: Water production per year

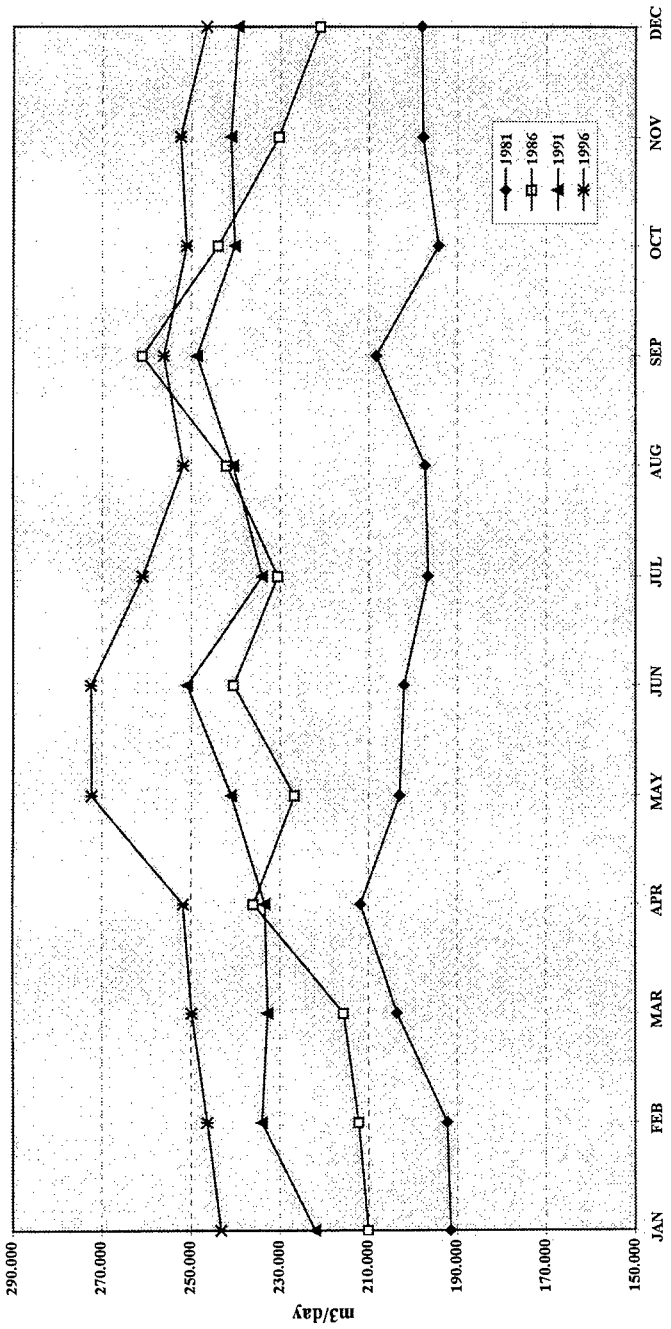
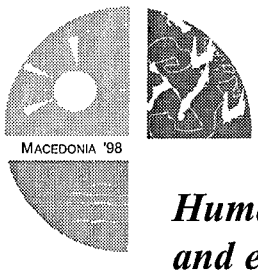


Figure 4: Water production (m3/day) for the years 1981, 1986, 1991 & 1996



Human health, social and educational issues

A COMPARATIVE STUDY OF ENVIRONMENTAL ENGINEERING CURRICULA

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ABSTRACT

A search has been conducted in the curricula, both at the undergraduate and graduate levels, of Environmental Engineering, Civil Engineering, Chemical Engineering, and other related departments in universities the USA, Europe, Greece, and selected countries of the world, using recently published documents, course catalogs, other informative material and the Internet. The information on coursework was put into a database. Based on the search, the comprehensive 5-year undergraduate curriculum of the Department of Environmental Engineering at Democritus University of Thrace is presented.

ΣΥΓΚΡΙΤΙΚΗ ΜΕΛΕΤΗ ΠΡΟΓΡΑΜΜΑΤΩΝ ΣΠΟΥΔΩΝ ΜΗΧΑΝΙΚΩΝ ΠΕΡΙΒΑΛΛΟΝΤΟΣ

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ΠΕΡΙΛΗΨΗ

Προγράμματα σπουδών τμημάτων Μηχανικού Περιβάλλοντος, Πολιτικού Μηχανικού, Χημικού Μηχανικού και άλλα συναφή από Πανεπιστήμια των ΗΠΑ, χωρών της Ευρώπης, της Ελλάδας και άλλων κρατών αναζητήθηκαν από υπάρχουσα βιβλιογραφία, καταλόγους σπουδών, διαφημιστικό υλικό και το Internet και καταχωρήθηκαν σε βάση δεδομένων. Από την αναζήτηση προέκυψε και παρουσιάζεται το πρόγραμμα σπουδών στο Τμήμα Μηχανικών Περιβάλλοντος του Δημοκριτείου Πανεπιστημίου Θράκης.

1. INTRODUCTION

According to the Association of Environmental Engineering Professors (AEEP) [1], "Environmental Engineers are the technical professionals who identify and design solutions for environmental problems. They provide safe drinking water, treat and properly dispose of wastes, maintain air quality, control water pollution, and remediate sites contaminated due to spills or improper disposal of hazardous substances. They monitor the quality of the air, water and land. And they develop new and improved means of protecting the environment. In addition to being a field for doing, the environmental engineering (EE) field and EE education are multi-disciplinary. They involve traditional engineering components such as mathematics, physics, chemistry, and engineering design. But EE education and practice also includes a range of other disciplines, such as biology, microbiology, ecology, public health, geology, meteorology, economics, political science, and computer science. To address the spectrum of issues facing the environment, environmental engineers are broadly educated, as well as technically trained." Environmental Engineers also gain knowledge and skills in the fields of chemical technology, water and atmospheric chemistry, toxicology, hydrology, soil science, and environmental law. According again to AEEP [1], Environmental Engineers work in: (1) engineering consulting firms that design and construct air and water pollution-control systems; (2) industries that need to treat their wastewater discharges; (3) private and municipal agencies that supply drinking water; (4) companies that treat and dispose of hazardous chemicals; (5) companies that operate treatment facilities for municipalities or industries; (6) government agencies that monitor and regulate waste discharges; (7) private and government laboratories that develop the new generation of pollution-control systems; (8) international agencies that transfer knowledge to the developing world; (9) and public interest groups that advocate environmental protection.

Based on the above one can conclude that the work assignments or occupation of an environmental engineer may involve, among others: (1) engineering computations and design; (2) communication with various disciplines and people (in addition to other environmental engineers), such as other engineers (e.g., civil, mechanical, electrical, naval, computer engineers, etc.), scientists (e.g., biologists, ecologists, geologists, chemists, meteorologists, toxicologists, hydrologists, soil scientists, epidimiologists and public health specialists, lawers, and economists to mention a few), politicians (that take decisions on protection areas and restoration areas, introduce environmental laws, decide on environmental policies and actions, decide on major construction activities, etc.), diplomats from foreign countries (that are involved in environmental treaties and international water right assessments), labor workers (in the construction sites, the treatment plants, etc.), and simple people (who worry about the protection of the environment, their health and the wellfare of their children). Therefore, two main things are important in any EE curriculum: (1) a strong engineering analysis and design component: environmental engineers are expected to produce buildable designs; (2) a multi-disciplinary course work in general engineering, sciences and humanities: although the EE component should be the strongest, environmental engineers should also gain knowledge in general engineering, the sciences and the humanities, to be able to communicate with the afore-mentioned diverse groups. A third thing is also important. In some countries, professional rights, i.e., which engineer is doing what kind of a project or what kind of a project an engineer of a certain discipline can do, have been set by law years ago. New disciplines, like EE, have to fight to get a place in the work market. Their only weapon is the coursework in the undergraduate curriculum.

This paper summarizes existing EE programs and curricula in the USA, Canada, Europe, New Zealand, and Greece, and presents a list of suggested courses that need to exist in an EE program or curriculum in order to meet the afore-mentioned definition and expected work assignments of an environmental engineer.

2. MATERIAL

2.1 Previous studies

The above listed thoughts lead to the conclusion that designing a proper EE program or curriculum is very difficult and one should be very careful. Several professors, educators, and engineers have dealt in the past with EE curricula and programs. For example, Chang and Pytel [2] conducted a survey between academicians, practitioners, and between the various undergraduate curricula in the USA, in their effort to properly design the undergraduate EE curriculum at the University of Riverside, California. Based on review of existing programs, they concluded that: (1) the USA EE curricula consist of courses in humanities and social sciences, basic sciences and mathematics, engineering sciences, civil engineering, other engineering design electives and EE. On the average, the respective distribution of these general categories of courses in the curricula is approximately: 18, 30, 20, 4, 10, 18 percent. (2) The faculty of the EE programs in the USA has the following training on the average: 40% EE, 26% civil engineering, 13% chemical engineering, 3% other engineering and 18% non-engineering. This variety, and particularly the 18% non-engineering training, indicates the multi-disciplinarity of this profession. Based on a survey in a workshop, they designed a 180-quarter unit curriculum which consisted of 36 units (20%) of humanities and social sciences, 67 units (37.2%) of basic science and mathematics (e.g., chemistry, physics, biology, geology and calculus), 41 units (22.8%) of engineering sciences (e.g., statics, dynamics, mechanics of materials, fluid mechanics, hydrology, transport phenomena, process analysis, statistics, probabilities, risk analysis, computer programming,, computer graphics), 24 units (13.3%) of core EE specialty (e.g., principles of EE, air quality, water quality, solid wastes, EE laboratory), 6 units (3.3%) of water quality electives (groundwater hydrology and pollution control, public health engineering, aquatic chemistry, environmental microbiology, hazardous wastes, industrial wastes, ecological engineering) and 6 units (3.3%) of air quality electives (e.g., air quality system design, combustion engineering and incineration, air quality modeling).

A draft of EE program criteria for accreditation by the Accreditation Board of Engineering and Technology (ABET) in the USA was presented at a common conference organized by the American Academy of Environmental Engineers (AAEE) and the AEEP [3]. Major points regarding an EE curriculum are that it should include the following : (1) appropriate elements of design integrated throughout to lead to a comprehensive design experience; (2) appropriate concepts of waste minimization, pollution prevention and resource management; (3) quantitative and experimental laboratory training and experience; (4) training in modern computing information technology and modeling of processes in environmental systems; (5) courses in mathematics and basic sciences (mathematics through differential equations, probability and statistics, calculus based physics, general chemistry, water or organic chemistry, an earth science course and a biological science course); (6) engineering courses in the following focus areas: fluid mechanics, hydrology, groundwater hydraulics and hydrology, hydrogeology, water and water resources, environmental systems modeling, environmental chemistry, wastewater, solid wastes, hazardous wastes, atmospheric systems, air pollution control, and environmental and occupational health.

2.2 Programs in the USA and Canada

Based on the American Society for Engineering Education (ASEE) [4], there are 27 EE undergraduate programs in the USA. There are also 9 more undergraduate programs in 13 universities that are closely related to EE (i.e., environmental and resource engineering, environmental engineering science, environmental health engineering, environmental quality engineering, environmental quality science, environmental science, environmental science and engineering, environmental studies and environmental health, and environmental systems engineering). Finally, there are 24 Civil & Environmental Engineering, 183 civil engineering, and 144 chemical engineering undergraduate programs. Among these

391 programs and universities, the AEEP [5] list about 96 programs as "undergraduate environmental engineering and related degree" programs. These programs may belong to 4 categories of departments (i.e., civil engineering, civil and environmental engineering, chemical engineering and environmental engineering or related) and may generally offer 6 types of undergraduate degrees, i.e., (1) BS in civil engineering with EE option or emphasis or specialty (77 cases, 66.4%); (2) BS in chemical engineering with EE option or emphasis or specialty (5 cases, 4.3%); (3) BS in EE from a civil or a civil and environmental engineering department (12 cases, 10.3%); (4) BS in EE from a chemical engineering (1 case, 0.9%); (5) BSEE from an EE department (7 cases, 6.0%); and (6) a non-degree, interdepartmental, interdisciplinary program in EE or a minor in EE through a single department (14 cases, 12.1%).

The type 1 programs generally offer required typical EE courses, such as fluid mechanics, hydraulics, hydrology, groundwater hydrology, introduction to EE, water supply and wastewater treatment. They may also offer electives, such as thermodynamics, chemistry for environmental engineers, ecology, biology, geology, solid waste, hazardous waste and air pollution management, water quality modeling, and others. Type 2 programs are similar. The courses in hydraulics, hydrology, and groundwater hydrology are generally missing and their place is taken mostly by type 1 electives and in addition transport phenomena, unit operations, recycling, radiation protection, nuclear waste management, and others. Type 3 and 4 programs, in most schools, offer courses similar to those in type 1 and 2, respectively. The difference is generally in the number of core courses (comparatively higher) versus electives (lower). However, some universities have a larger number of additional courses in the sciences (chemistry, biology, microbiology, biochemistry, geology, limnology, soil science), and courses such as ecosystem modeling, public health, aquaculture engineering, remediation, dynamics of environmental systems, environmental policy, wetlands management, noise control, geophysics, global climate change, environmental impact assessment, and others. Finally, type 5 programs offer a great variety of courses specific to EE. A representative example of such a program is the one at the University of Florida, Gainesville, Department of Environmental Engineering Sciences. Courses of this program are summarized in Table 1. Of course, although mostly specialization courses in EE were described in all the these programs (types 1 to 5), they also contain a strong component in humanities and social sciences, basic sciences and engineering sciences. Finally, type 6 programs, are non-degree programs and are not considered here. They generally offer a specialization with additional coursework in EE (something between BS and MS). Universities in Canada [6] follow the typical types 1 and 2 universities in the USA. Type 3, 4 and 5 EE programs are not known to the authors.

2.3 Programs in New Zealand

From New Zealand, the experience of the University of Canterbury [7] was available. This university offers a BE degree within a civil, or chemical or environmental engineering department (similar to types 3 and 4). Core science courses are common to the three departments and include chemistry, physics, mathematics and engineering mechanics. Electives are also common and include geology, geography, biology and another chemistry. After completing these courses, students can select the department to take the EE degree from, and study for three more years. The first year they take core courses of the discipline they selected and the following two years they take core courses of the discipline and some EE electives. Core courses are similar to the ones described in the USA universities. EE electives include: environmental analysis, Geographic Information Systems, geological hazard mitigation, physical geography, plant ecology, aquatic ecology, microbiology, environment and society, public health, geophysics, limnology, marine biology, and aquaculture, among others.

2.4 Programs in Asia

Information on programs in Asia were obtained from a position paper [8] regarding studies at the Asian Institute of Technology in Bangkok, Thailand. Although this was referring to graduate level studies,

conclusions can be made on courses of importance. For example, agricultural management, energy planning and policy, remote sensing and GIS, regional and rural development, resource planning and management, urban development and environmental management, water and wastewater engineering, bioprocess technology, and others. Additional search at various universities (e.g., China, Japan, and S. Korea) did not reveal any information mainly because of the language barrier. At the University of Tokyo, EE programs exist through the Department of Urban Engineering and through the Department of Chemical System Engineering. However, courses were not listed.

TABLE 1. The Environmental Engineering Degree at the University of Florida [5]

REQUIRED COURSES	ELECTIVES
General chemistry	Energy and environment
Physics with calculus	Modeling environmental systems dynamics
Analytical geometry and calculus	Water analysis
Differential equations	Public health engineering
Computer programming for engineers	Env. Meteorology and oceanography
Engineering mechanics - Statics	Ecological and general systems
Engineering mechanics - Dynamics	Env. Toxicology
Thermodynamics	Pollutant transport
Computer Assisted Drafting/Design	Air sampling and analysis
Computational methods	Design of air pollution control systems
Wastewater microbiology	Radiological health
Water chemistry	Nuclear power radioactive waste technology
Elements of atmospheric pollution	Solid waste containement design
Hydrodynamics	Water treatment process design
Air pollution control design	Potable water system design
Water and wastewater treatment	Concepts of wastewater treatment
Env. Chemistry of carbon components	Wastewater system design
Materials science and engineering I	Industrial wastewater treatment
Elements of electrical engineering	Industrial air pollution analysis
Engineering statistics	Solid waste treatment design
Environmental hydrology	Solid waste containment design
Hydraulic system design	Design nutrient control and water reuse
Env. Resources management	Environmental policy
Solid and hazardous waste management	Atmospheric dispersion modeling
Environmental biology	Basic surveying and mapping
Environmental biology laboratory	Engineering hydrology
Environmental engineering ethics seminar	Hydraulics

2.5 Programs in various European countries

Several European programs were studied from the UK, Sweden, the Netherlands, Germany and Italy. Information regarding UK universities was obtained from [9]. There is no EE department listed and in the summary tables the subject "Environmental Engineering" does not occur (although the subject "Environmental Science" does in most universities). Most EE programs are under a civil or chemical engineering department, therefore, they have similarities to the respective US programs. However, one program was found through the Internet, at Napier University [10]. This university offers a BE degree in energy and environmental engineering. The coursework is based on a combination of mechanical,

electrical and control engineering fundamentals, along with understanding of economics, accounting and management. Because of its goal, this program is not considered representative of the ones we study here. The University of Nottingham also offers a degree in Environmental Engineering and Resource Management through the Institute of Environmental Engineering [11]. Typical programs in Environmental Science in Sweden (e.g., Lund University [12]) include courses such as: sustainable development, human health, environmental pollution, environmental law and policy, environmental economics, systems analysis, energy and the environment, urban systems and the environment, industry and the environment, and others (at the graduate level). A similar program (Human Ecology) is offered at the Free University of Brussels, Belgium, with concentration on sustainable development, environmental management, policy and law (at the graduate level). Coursework related to water and environment (at the graduate level) exist also at Delft International Institute for Infrastructural, Hydraulic and Environmental Engineering, in the Netherlands [13]. Typical courses include: hydraulic engineering, hydrology, sanitary engineering, environmental science and technology, water quality management, environmental sanitation and management, water resources management, anaerobic wastewater treatment, low-cost water supply and sanitation, water quality management and decision-makers, environmental resource management and impact assessment, environmental ecotechnology, groundwater flow and transport, irrigation systems, groundwater pollution modeling, unsaturated zone modeling, GIS, etc. Some of these courses would also apply to the undergraduate curriculum.

EE programs in Germany include the ones at the Technological University of Berlin [14], the University of Stuttgart [15] and the University of Clausthal [16]. For example, at the University of Stuttgart, there is no EE department. However, the department of civil engineering offers an EE diploma degree. Courses are common with civil engineering up to the 4th semester. The 5th and 6th semesters offer courses such as: environmental chemistry, environmental biology, and administrative law, and environmental and natural resources economics, environmental measurements, mechanical and thermal processes, biological-chemical and physical engineering, environmental fluid mechanics, water resources management, sanitary engineering, water quality and waste disposal technology, energy and environment, environmental planning. The 7th and 8th semesters offer specialization with advanced courses in the above subjects and additional courses such as: groundwater resources management, industrial water technology, solid waste management, air pollution control, traffic and environment, motor vehicles and environment and others. An EE department also exists at the University of Cagliari, Italy [17], which also is part of the European Community Course Credit Transfer System. The emphasis of this program is the geo-engineering area with courses in hydrology, excavation, land planning, geophysics, sanitary engineering, solid wastes, soil protection, geo-resources, mining, and several others. This curriculum is not considered typical.

2.6 Programs in Greece

A review of the various EE programs in Greece has been presented by Panagiotakopoulos [18], Gregoropoulos et al. [19] and Eliou [20], among others. Generally, civil engineering departments in Greece offer similar programs to the type 1 in the USA (i.e., civil engineering diplomas with some EE courses). However, there exist now two EE departments (at the Democritus University of Thrace [21] and the University of Crete [22]) and one environmental science department at the University of the Aegean. The first two offer 5-year engineering degrees and closely follow a similar curriculum. The last one is a 4-year science degree program.

3. A FIVE-YEAR CURRICULUM

Courses in the afore-mentioned curricula were summarized in a common database. Most commonly offered courses, and groundwork on course clusters by Panagiotakopoulos [21] have been used to

produce the current course offerings at the Department of Environmental Engineering, Democritus University of Thrace, which is summarized in Table 2. In addition, this curriculum contains adequate number of courses from the other engineering disciplines (electrical, mechanical, chemical and particularly civil) to defend the professional rights of the environmental engineers. Such courses include those in the areas of structural analysis, reinforced concrete design, steel structures, soil mechanics, etc. which have been imposed by the requirements in the Presidential Decree of 1993 establishing the department. One of these requirements states: "...to produce high quality technical experts, able to plan, design, manage and administer programs, projects and policies regarding the environment." This curriculum has the following characteristics: (1) 10-semester duration with a total of 208 credit units which include 20 units of Diploma thesis; (2) the curriculum contains 23 credits in humanities and social sciences, 55 credits in basic sciences, 45 credits of engineering sciences, 39 credits of environmental engineering core courses, and 12 credits of environmental engineering electives. (3) 13 weeks of classes per semester and an additional 2-week examination period; (4) approximately 30 hours of classroom contact hours per week, which include teaching, tutoring and problem solving, laboratories and field assignments. Finally, this curriculum contains modern courses not found in many other programs, such as concepts of systems analysis, theory of chaos, sustainable development, ecological engineering, eco-auditing/ecomanagement, and others.

TABLE 2. The curriculum of the Department of Environmental Engineering at Democritus University of Thrace.

SEMESTER	COURSE LISTINGS
1	Calculus; Env. Chemistry I; Env. Physics; Env. Biology; Computer science; Drafting/CADD; Ecology; Environmental ethics.
2	Linear algebra/Multivariate analysis; Env. Chemistry II; Thermodynamics; Computer networks/ Information management; Env. Geology; Introduction to Env. Engrg.; Ecology lab.; Systems theory.
3	Differential equations; Engineering mechanics; Fluid mechanics/Applied hydraulics; Probabilities and statistics; Environmental economics I; Engineering biochemistry; Numerical analysis; Social science II
4	Strength of the materials; Technical and environmental law; Env. Microbiology; Mathematics of optimization; Environmental economics II; Social science III; Hydrology and groundwater; Sociology/ risk assessment.
5	Operations research; Structures III; Electrical systems I; Air pollution; Physical processes; Public health/ occupational health; Transport phenomena.
6	Chemical and biochemical processes; People management and communication; Industrial production and impacts to the environment; Electrical systems II; Forms of energy; Solid waste management I; Theory of chaos; Social science IV.
7	Wastewater management I; Structures IV; Engineering economics; Project management; Theory of sustainable development; Ecological engineering/Ecosystem management; Civil engineering elective.
8	Wastewater management II; Solid waste management II; Structures V, Civil engineering elective; Air pollution control technology; Environmental auditing.
9	Bioclimatic design of buildings; Environmental impact assessment; Soil treatment/toxic waste management; Analysis and management of env. systems; Env. engineering design project; Civil engineering elective.
10	Diploma thesis

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USE OF SOFTWARE MODULES, CASE STUDIES AND THE INTERNET IN ENVIRONMENTAL ENGINEERING TEACHING

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ABSTRACT

An effort is described in developing and using a case study on the Everglades module and software modules for the pieces of software StormCAD, HEC-2 and HEC-6 in Environmental Engineering class instruction. The case study on the Everglades, along with lecture notes, homework solutions and projects for the class Water Resources Engineering, have been included in the Internet for easy access and use by all students. Software modules contained detailed descriptions of use of the software along with manuals, step-by-step examples and tutorial video tapes. Evaluation of the effectiveness of the modules was made by the instructor and students through specially developed questionnaires and by assessment of student performance after multiple class application.

ΧΡΗΣΗ ΠΑΚΕΤΩΝ ΛΟΓΙΣΜΙΚΟΥ, ΕΝΔΙΑΦΕΡΟΥΣΩΝ ΠΕΡΙΠΤΩΣΕΩΝ ΚΑΙ ΤΟΥ INTERNET ΣΤΗΝ ΔΙΔΑΣΚΑΛΙΑ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗΣ ΜΗΧΑΝΙΚΗΣ

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ΠΕΡΙΛΗΨΗ

Παρουσιάζεται η ανάπτυξη και χρήση της ενδιαφέρουσας περίπτωσης των βιοτόπων Everglades και των πακέτων λογισμικού StormCAD, HEC-2 και HEC-6 στην διδασκαλία Περιβαλλοντικής Μηχανικής. Υλικό για την ενδιαφέρουσα περίπτωση των Everglades, μαζί με σημειώσεις, λύση προβλημάτων και εξαμηνιαία θέματα για το μάθημα Μηχανική Υδατικών Πόρων, έχουν αποθηκευτεί στο Internet για εύκολη χρήση από φοιτητές. Τα πακέτα λογισμικού περιέχουν λεπτομερείς περιγραφές της χρήσης, βήμα-προς-βήμα παραδείγματα και διδακτικές ταινίες video. Η αποτελεσματικότητα των παραπάνω στην διδασκαλία κρίθηκε μέσω ειδικών ερωτηματολογίων μετά από πολλαπλή εφαρμογή στην τάξη.

1. INTRODUCTION

This paper describes development, application and evaluation of the project "Shared Resources Modules to Support Environmental Engineering Education" which is an initiative within the Gateway Coalition, funded by the US National Science Foundation. This coalition comprises ten universities in the east and south-east USA with the purpose to redesign engineering education to meet the challenges of the 21st century.

The project is a collaborative effort of seven out of the ten universities of the coalition. It was envisioned in early summer 1995 by participants from the following universities: Case Western Reserve University, Ohio State University, Polytechnic University of Brooklyn, The Cooper Union, New Jersey Institute of Technology, University of South Carolina, and Florida International University (FIU). At that time, faculty and administrators from each institution established the project vision by defining project criteria, guidelines for funding and administration, and project implementation, evaluation and assessment methods.

The main idea of the project was to utilize resources and expertise available among the Gateway universities and participating faculty, to prepare modular instructional tools that cover a wide variety of applications in environmental engineering courses at all levels of undergraduate education. These would be placed in a central library and be shared among coalition member universities, to aid in the teaching of environmental and water resources engineering courses, and/or to add an environmental component to other courses. As a course module was defined a package of information that would regularly require one to two weeks of instruction (3 to 6 hours) within a class period, in addition to extra time by the students to complete assignments and projects. The modular instructional tools would have a focus or component, such as:

(1) environmental case studies;
(2) environmental software analysis packages; and
(3) environmental databases.

A pilot application of the idea was completed by August 1995. A workshop was then organized where faculty by the afore-mentioned universities presented their pilot modules, discussed their ideas and came to conclusions on how to fully implement the project. Main conclusions were the following:

(1) although a module can have a main focus (i.e., case study, software or database) most modules should incorporate all three of these to some degree. For example, application of a software module would require use of a database and need to present examples, i.e., case studies.
(2) The component databases was found not to require as much development as the other two components, therefore, was not emphasized, and the concentration was directed to case studies and software modules.
(3) Four impact areas were selected to prepare case study and software modules on. These were the:
    (a) solid and hazardous wastes;
    (b) water/wastewater treatment and environmental chemistry;
    (c) air pollution; and
    (d) environmental hydraulics and water resources.
(4) Evaluation of the modules was decided to be done in three steps:
    (a) peer review: the written part and the contents of the module would be reviewed by the project team members and Gateway, in a way similar to a journal paper peer-review;

(b) alpha-testing: multiple in-class application and review of the results and student comments by the developer; and
(c) beta-testing: out-of-class application and review by at least one team member at another university of the coalition.

(5) Innovative ways of instruction should also be utilized in the process, for example use of the Internet.

The author, developed the part of Florida International University, and concentrated on impact area (d) (environmental hydraulics and water resources). A case study on the Everglades was developed and tested and also modules for the following three pieces of software: StormCAD [1], HEC-2 [2] and HEC-6 [3]. The application of a module of the software HEC-1 [4], developed by The Cooper Union, was also tested. The case study on the Everglades, along with lecture notes, homework solutions and projects for the class Water Resources Engineering, have been included in the Internet for easy access and use by all students. Software modules contained detailed descriptions of use of the software along with manuals, step-by-step examples and teaching video tapes. In-class applications of the above mentioned case studies and modules at FIU was made in Fall 1996, Spring 1997 and Summer 1997 semesters. Evaluation of the effectiveness was made by the instructor and students through specially developed questionnaires and by assessment of student performance. The paper describes the project development, the modules, the case study, the use of the Internet in class teaching, and generally its application in the classroom and evaluation of its effectiveness.

2. DEVELOPMENT AND APPLICATION

2.1 The case study development and application

The Everglades ecosystem is one of the most important in the world. Before human settlement in Florida, the Everglades used to cover approximately the southern 1/3 of the Florida peninsula, extending over a 100-mile long and 40-mile wide area. After the man came to Florida, the need for urban and agricultural development greatly impacted the Everglades significantly encroaching its area and altering its hydrology [5,6]. Among others, impacts include: (1) freshwater wetlands: reduction in flow quantities and hydroperiods, deterioration of water quality due to nonpoint source pollution, and reduction of bird populations and biodiversity; and (2) Florida Bay and other coastal areas: hypersalination of the Bay, water quality deterioration, and impacts on seagrass and marine life. The example of the Everglades can offer a unique opportunity to teach engineering students through both: (a) comprehensive large-scale case studies that address impacts to the entire ecosystem, and (b) isolated small-scale case studies that address either individual components, i.e., sub-areas or sub-basins of the ecosystem, or individual physical or other processes.

For the development of the case study two steps were taken: (1) prototype pilot case study (summer 1995) and (2) final case study (September 1995 till August 1997). For the pilot case study, the first approach, i.e., item (a) above, was followed which was deemed more appropriate to introduce the Everglades ecosystem. The prototype pilot case study included description of the historic natural Everglades, time evolution of settlement and development in South Florida, impacts of urbanization and agriculture on water deliveries, hydroperiods and water quality, subsequent impacts on biological indicators, and a prospect on current and future restoration efforts. This pilot case study did not present all aspects in detail, but rather samples of the work, a prototype, to be further polished in the future. In addition, socio-economic aspects (e.g., tourism or battle between agricultural productivity and ecosystem health) were not there.

The final case study followed and included the following descriptive material, supported by graphs, pictures, tables in a textbook format. Several chapters identified the various aspects of the impacts to the ecosystem and its restoration for both large-scale and small-scale cases. To prepare this material books on the Everglades, reports of engineering and other studies by local agencies and various scientists, published scientific papers, and related sites on the Internet were reviewed. All this descriptive material was incorporated as one site on the Internet for easy central access by all GATEWAY university students and instructors and better dissemination and evaluation, so that it is used as a shared resource.

The final case study can be found at the following address on the Internet: *www.eng.fiu.edu/evrglads/* [7]. It includes the following main chapters or sections:

(1) descriptive information on the Everglades National Park (ENP), its wetlands and other neighboring national parks, sanctuaries, natural preserves and coastal protected areas;
(2) historical overview of the Everglades and its morphology and ecology;
(3) a general section on wetlands and comparison of inland and coastal systems;
(4) Everglades wetland types, ENP flora and fauna;
(5) Engineering related topics of the Everglades such as hydrology, water demand, water data, sustainable development, restoration programs;
(6) Sample engineering projects conducted by the author;
(7) Surface water improvement plans for the Everglades and other neighboring areas, prepared by the South Florida Water Management District;
(8) Description of various restoration programs, such as the Everglades Nutrient Removal Project and the restoration of the Kissimmie River;
(9) Results of model predictions on the historic and existing hydrologic conditions of the Everglades;
(10) Representative pictures of the ecosystems, maps, graphs, figures, references and other related sites on the Internet.

One can see that the case study has a holistic and multi-disciplinary view of the Everglades that addresses both engineering issues and ecological ones. Appropriate classes that can possibly use this case study within the Environmental Engineering or the Civil and Environmental Engineering curriculum are the following: Water Resources Engineering; Introduction to Environmental Engineering; Environmental Impact Assessment; Open Channel Hydraulics; Environmental Hydraulics; Groundwater Hydrology; Fundamentals for Environmental Engineers; Environmental Planning; Environmental Modeling; Water Quality Modeling; Independent Study; Special Topics in Environmental Engineering. Several classes can also be identified within other related curricula including engineering departments, and landscape architecture, biological science, environmental science, environmental studies, and geology departments.

In addition to the above described case study, at the same address on the Internet but as a separate folder, was included material for the class Water Resources Engineering, taught by the author, which is the first class that utilized the case study. The class material included the following:

(1) the syllabus of the class;
(2) eight homework assignments and solutions;
(3) two term projects with all the supporting material (i.e., maps, pictures, etc.)
(4) thirteen lectures, each one covering approximately a two-week time period, with the following subjects (Introduction to water resources engineering; meteorology and hydrologic cycle; precipitation: formation and measurement; infiltration; evapotranspiration; urban drainage systems; storm and sanitary sewers; pressure flow system; pumps; streamflow measurement; hydrographs; unit hydrograph; reservoir routing; storage and control structures);
(5) sample quizzes.

The case study was tested in the class Water Resources Engineering at FIU, by its author, in Fall 1996 and Spring 1997 semesters. The students were assigned the project that is summarized in Table 1. The project counted 10% of the final grade and was required. Students could work in teams of up to three. They were also required to return a written summary on their view of the use of the Internet in class instruction. The project was also accompanied from a detailed set of guidelines on how to prepare the term paper.

Table 1. Assigned project related to the Everglades case study.

Prepare a term paper on any Everglades-related subject you may choose. Subjects may include the following general areas: historic Everglades, drainage and impacts, today's problems, pollution, ecology, and any other related. The rules are attached.

2.2 The software modules

The following software modules were prepared by the author at FIU:

1. Use of StormCAD, developed by Haestad Methods. This software is user-friendly and can be easily learned and applied by students. It provides an interactive application of the Rational Method in hydrology studies.
2. Use of the hydraulic software HEC-2 developed by the Corps of Engineers. This software is the most well-known and commonly used software for water surface profiles in open channels.
3. Use of hydraulic software HEC-6 developed by the Corps of Engineers. This software is the most well-known software for sediment transport in open channels.

In addition, the software module HEC-1, which was prepared by The Cooper Union, was beta-tested at FIU.

3. RESULTS AND EVALUATION

3.1 The case study

A total of 28 papers were returned in Fall 1996 and 26 in Spring 1997 semesters. Fall 1996 projects are summarized in Table 2. Most of them were prepared carefully and following the guidelines. Most of the project also used material from the Internet site to set the idea and conduct the initial search. Then they collected some references from the library or visited the ENP and the South Florida Water Management District and talked to the researchers there. Some students also said that the project was a great chance to visit and spend time in the Everglades.

To evaluate the project a questionnaire with 19 questions (16 of them required "ranking" between poor, fair, good, excellent and outstanding, 2 required yes or no answer and 1 had space for comments). The questions were regarding the site, the use of the Internet, if the project is worthy having it and so on. Most answers to the questions ranked excellent to outstanding indicating general satisfaction of the project by the students.

Regarding the use of the Internet, not only for the case study but also the class material, the students had comments such as:

(1) Students saw the effort as positive. Some also said it brought them closer to computers and the Internet and that they had no chance to use this tool in the past. Some even mentioned that bought a computer or ordered Internet service at home for their family.

Table 2. Sample student projects.

#	Title for Fall 1996
1	Wetlands of South Florida and Impacts
2	Everglades Nutrient Removal Project
3	The Loss of Biological Diversity: A Human Impact on the Everglades
4	History of the Everglades and the Impact of Man
5	Stormwater Runoff into Lake Okeechobee
6	Everglades: Water Resources-Ecosystem
7	Everglades Restoration: Time is Running Out for South Florida
8	The Everglades: A Beginner's Guide
9	History of the Everglades
10	Man's Environmental Effects on the Everglades
11	Environmental Impacts on the Everglades
12	Big Cypress National Preserve
13	Water Conservation Areas
14	Events Affecting Inflow to Florida Bay
15	SWIM: The Surface Water Improvement and Management Act: A Plan for the Restoration of the Everglades
16	The Evolution of South Florida's Hydrology on the Everglades
17	Mercury Contamination in the Everglades: The Extent of the Problem and Steps Taken to Ratify it
18	Importance of Wetlands in the Everglades
19	Our Withering World
20	A History of the Area Covered by the Everglades
21	The Everglades Flora
22	Amazonia
23	Constructed Wetlands and the Everglades Nutrient Removal Project
24	The Everglades - History and Drainage Analysis
25	The Restoration of Taylor Slough
26	An Overview of the "Everglades Forever Act"
27	The Truth about Big Sugar
28	Development and the Everglades

(2) They liked the idea of the lecture notes on the Internet because it allowed them to prepare ahead for the following lecture and they did not have to take notes during class but pay attention to the instructor. Also if they missed a class they still had the notes.
(3) Sample quizzes made them more confident when taking exams.
(4) They also liked interaction with the professor by e-mail to ask questions and get quick answers.
(5) They also liked the additional Internet sites that were linked to the Everglades site.

Suggestions on the use of the Internet had mostly to do with the speed of the system to load and print, a few problems of availability (it was down sometimes), and that some students had advantage having a computer at home. All these problems were positive critique that helped improve the service the next time the class was offered.

3.2 The software modules

StormCAD was alpha-tested in Spring 1996 and Fall 1996 and Spring 1997 in the class Water Resources Engineering. Approximately 35 students participated in the class each semester. StormCAD was

assigned as an individual required project, worthy 10% of the class points, which was placed on the Internet. The project involved application of this software to an actual site in South Florida to complete the hydrologic and hydraulic design. Close to 100 reports were returned during these three semesters. Evaluation of the software was done each time based on a 14 question questionnaire which generally ranked the module good to excellent on a 5-point scale poor, fair, good, excellent, outstanding. This module can be made a part of any hydrology or hydraulics class.

The module HEC-2 was alpha-tested in Spring 1996 in the class Engineering Sediment Transport and in Summer 1997 in the class Senior Design Project at FIU. It can also be made part of at least two classes: Water Resources Engineering and Open Channel Hydraulics. The module HEC-6 is more advanced. It was alpha-tested in Spring 1996 in the class Engineering Sediment Transport. It can also be made part of the Open Channel Hydraulics class. Application of these two pieces of software were limited to about 10 students. The module was ranked excellent on a 5-point scale poor, fair, good, excellent, outstanding.

HEC-1, prepared by The Cooper Union, was used in class Senior Design Project during Summer 1997. It can also be used in any hydrology class. Application of this software module was limited to about 2 students. The module was ranked good on a 5-point scale poor, fair, good, excellent, outstanding. The modules StormCAD, HEC-2 and HEC-6 and the Everglades case study were also beta-tested at other universities of the coalition. However, the results of this evaluation are not available yet.

4. CONCLUSIONS

The experience of teaching using the Internet, and introducing case study and software model modules, was very rewarding. Students responded positively on these new ideas as their comments and answers on questionnaires state. A measure of class performance is the average class grade of all students which was not increased compared to previous classes taught by the same instructor where the modules were not used. Therefore, one cannot conclude whether or not average class performance was increased. Retention of the material is another measure of the success of new teaching methods. Evaluation of retention is very difficult and requires studies with the same students in future classes. Again, one cannot conclude whether or not average class retention was increased. However, the volume of knowledge directed to the students was significantly increased if one compared the same course taught by the same instructor before and after application of the described innovative ways of teaching. In addition, student research and technical writing skills were tested and they became familiar with the Internet and application of theory in real projects through models.

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CYCLES OF THE NATURAL ENVIRONMENT

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ABSTRACT

This paper presents in brief the reasoning and the findings of a new (original) theory, which considers the antagonism in Nature as a result of accumulated deficit or surplus of the thermodynamic work enclosed in biomass. The work is computed and an endless diagram is produced showing the connection of input and output during the period from 6635 B.C. to 23625 A.D. A study of the diagram shows that the total Earth environment is recycled every 315,1123, 1575,17645, and 25994 years. Finally, some original equations are provided for economic considerations.

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ΠΕΡΙΛΗΨΗ

Αυτή η εργασία παρουσιάζει περιληπτικά τον τρόπο σκέψης και τα ευρήματα μιας νέας θεωρίας, η οποία θεωρεί τον ανταγωνισμό στη Φύση ως το αποτέλεσμα συσσώρευσης ελλείμματος ή πλεονάσματος θερμοδυναμικού έργου που εμπεριέχεται στη βιομάζα. Υπολογίζει πρωτότυπα αυτό το έργο και, πρωτότυπα επίσης, παράγει ένα ατέρμον διάγραμμα που δείχνει τον τρόπο διασύνδεσης της εισροής και εκροής αυτού του έργου σε παγκόσμια κλίμακα, για την περίοδο από το 6.635 π.Χ. έως το 23.625 μ.Χ. Η μελέτη του διαγράμματος έδειξε ότι: Το γήινο περιβάλλον ανακυκλώνεται κάθε 315, 1123, 1575, 17645 και 25994 χρόνια. Δίνονται μερικές πρωτότυπες εξισώσεις για χρησιμοποίηση σε οικονομικές αναλύσεις.

1. INTRODUCTION.

This work is a brief presentation of the thermodynamic operation in the natural environment, through some innovative ideas of a new theory by the author, named Forest Utilization Theory of Ecological Balance. The theory was developed during a period of 25 years and, so far, more than twenty publications have been produced [4 to16]. The subjects discussed cover the following topics of the conference: Design for the environment, Environmental impact assessment and risk analysis, Environmental economics, and Global climatic changes.

2. METHOD AND MATERIALS.

a) Land use and the whole history of a human ecosystem show to go together as a tug of war from forest to agriculture and vice versa. This introduces the idea of an environmental recycling.

b) According to the above incentive, war and peace in a closed human ecosystem are the result of antagonism between forestry (action) and agriculture (reaction). The action could be attributed by biomass accumulation (input of thermodynamic work) and the reaction by biomass consumption (output of thermodynamic work). At any moment, there is a difference between input and output creating either surplus or deficit. The existence of such a surplus or deficit could be developed within various size ecosystems ranged from the whole Earth up to an individual land property .

c) The work input through biomass could be computed through estimation of its part actually manifested as work. The new theory has estimated it through the average annual yield (Σ) of one of the main biomass products of the examined human ecosystem. Main product investigated was wheat according to official data in Greece. In order to find the part of Σ actually manifested as work, the theory introduced the land use law $\Sigma/P=1.8819$, where P is the marginal productivity, i.e., the unused part of the work remaining in the soil [4,13]. Figure 1 shows that the work input follows a cyclic course ranged between minimum (P) and maximum (Σ max) rates in a time period of T=44.8975 years. The current chronological points of two minima and one maximum have been localized. Consequently, anyone could easily make an endless diagram of the quantity Σ-P to compute the under curve area $E\delta'$, if the period T were considered to be a natural constant.

d) In order to find the course of output of the above input work, the theory introduced a quantity named "new variable n", defined by temperature data in the following formula:

$$n=\frac{\text{Mean absolute temperature of warmest month-Mean absolute temperature of coldest month}}{\text{Mean absolute temperature of warmest month}}$$

The central idea of this suggestion is the so - called homeopathy principle "Biomass, as a form of heat energy, suffers the same loss (%) as the heat energy of the ambient atmosphere, when both appear as work" [8]. Figure 2 based on officia Greek data shows that the work output follows a cyclic course ranging between minimum and maximum rates in a time period $T\alpha = 35.07919$ years. The current chronological points of two minima and one maximum are localized. Consequently, anyone could easily make an endless diagram of n and compute the under curve area $E\alpha'$, if the period Ta were considered a natural constant.

e) The periods T and $T\alpha$ have the following impressive properties:
   (1) They approach the length of two well known cycles. That is the economic cycle of Kondratieff of about 50 years [21] and the climatic cycle of Bruckner of about 35 years [3].

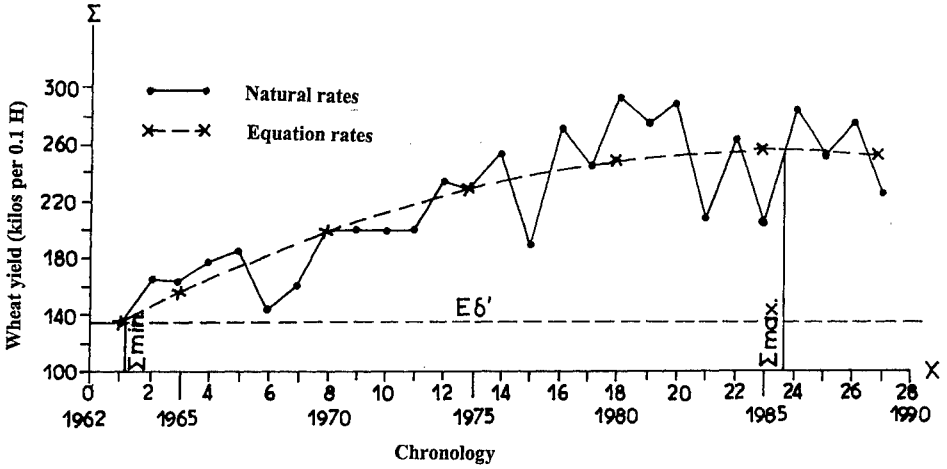


Fig. 1. Average annual wheat yield per stremma (o.1 Hect.) in Greece. Source: [13, 16]

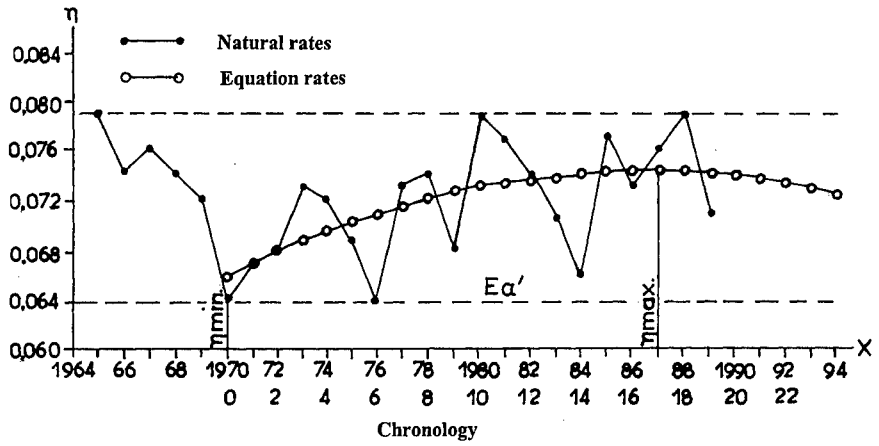


Fig. 2. Change of the "new variable n"in Northern Greece. Source: [11]

(2) The analogy $\frac{T^2}{Ta^2} = \frac{Ta^2}{T^2 - Ta^2}$ (1) is valid . It means that there is a geometrical balance between economic and climatic conditions considering that the above analogy is classically well known as "golden section" [16].

(3) The difference T - Tα = 44.8975 - 35.07919 = 9.81831 is lying within the limits of the absolute rates of the acceleration of gravity, i.e., g = 9.80 ± 0.5% [1]. The role of gravity is a subject of constant inquiry.

(4) The Greek human ecosystem is shown to be a very good indicator of the average Earth environment. That is, the new theory found to be valid for the whole Earth $\frac{T}{Ta}=\frac{E\delta'}{Ea'}=c=\frac{1}{1-4.624.n}$=1.27825 (2a) [4,8], and the findings here show also $\frac{T}{Ta}=\frac{44.8975}{35.07919}$=1.27989 (2b). The difference between (2a) and (2b) is only 0.1%.

All these coincidences give us the right to consider the periods T and Ta as very good approaches of natural constants. Therefore, anyone could use them to make a common endless diagram for the quantities Σ - P and n on a system of axes X and Y.

f) In making the common endless diagram, the mathematically accepted view was adopted that both the areas, Eδ' and Eα', could be expressed as triangles. The base of the first triangle should be T= 44. 8975 years and that of the second one Ta = 35.07919 years. In such a construction, it is valid $E\delta'=\frac{1}{2}.T.\bar{Y}_1$ (3) and $Ea'=\frac{1}{2}.Ta.\bar{Y}_2$ (4).

g) The equals of Eδ' and Ea' in (3) and (4) replace them in the analogy $\frac{T}{Ta}=\frac{E\delta'}{Ea'}$ (5), which analogy is a part of the(2a). It produces Eδ' . Tα = Eα'.T (6), or $\frac{1}{2}.T.Ta.\bar{Y}_1=\frac{1}{2}.T.Ta.\bar{Y}_2$ (7), or finally $\bar{Y}_1=\bar{Y}_2$ (8). The meaning of the latter equation is that it is mandatory to use equal heights in drawing the triangles.

h) The developed common endless diagram has covered a period 30,260 years, from 6635 B.C. to 23625 A.D., to be investigated. Some fragments of it are shown in Figure 3.

3. CONCLUSIONS.

3.1. Design for the environment.

a) The common endless diagram shows successive surpluses and deficits with a trend to neutralize each other. Mathematically, perfect neutralization is realized within a period of T.Tα =44.8975x35.07919=1574.9679 years. This happens, because $\frac{1}{2}.T.\bar{Y}_1.\frac{T.Ta}{T}=\frac{1}{2}.Ta.\bar{Y}_2.\frac{T.Ta}{Ta}$, as $\bar{Y}_1=\bar{Y}_2$ in accordance to equation (8).

b) There is a clear tendency for recycling every 315,1123, 17645, and 25994 years (Figure 3). These four numbers are approximately common multiples of T and Ta. It is proved, that the least difference between work of action and work of reaction lies in the cycle of 17645 years. This cycle consists of about 56 cycles of 315 years. Each 57th cycle is very similar to each 1st one. Furthermore, each cycle of 315 years is like its former and next one, but this likeness is gradually destroyed and tends to become a catoptric symmetry after 56/2=28 cycles. The last is evident by comparison of the 1st and 29th cycles. The conclusion is that the cycle of 17645 years operates as a loop, that is as an imperfect circle. The cycle of 1123 years looks to be independent of those of 315 and 17645 years. Independent to any other is also the cycle of 25994 years, but it has the impressive feature to coincide to the well known cosmic cycle of about 26000 years of the precession of the equinoxes. This was a serious incentive for the new theory, additional to the four mentioned above (see Chapter 2, paragraph e), to expand the limits of the natural

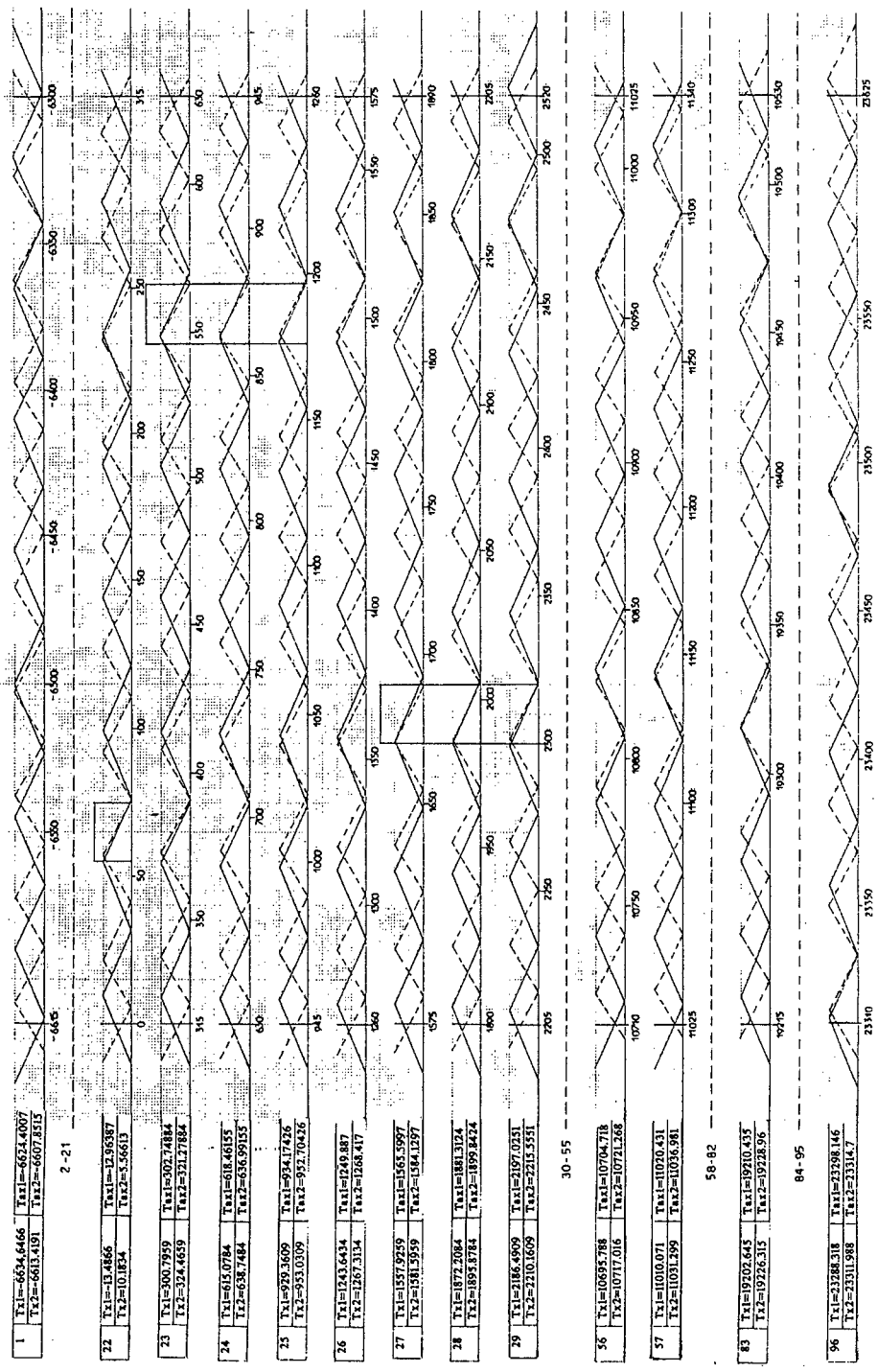


Fig. 3. Endless diagram of the biomass thermodynamic work.

environment beyond the forest, deeply in Space, and define it. A relative chapter is entitled "The Space limits of the natural environment. Gravity and Counter - gravity. Micro - universe" [15].

c) The two triangles seem either to attract (contraction) or to repel (expansion) each other as a pulse. It should also be stated, that the endless diagram is a system of two oscillations and the discontinued appearance of surplus reminds the discontinued emission of energy from the "black body" of the Nobelist Planck. Perhaps, his Quantum Theory is also valid in the macrocosme of the Earth environment. Let's remember that Physics are ever open in revision [1,2,18,19,23].

d) The recycling in Forestry is one of the main inquiries of the current research program "COST" of the European Union. Therefore, the above cycles are provided as a first relative contribution.

3.2. Environmental impact assessment and risk analysis.

a) Any surplus in a closed ecosystem presupposes an equal deficit elsewhere within it. Consequently, either a big deficit or surplus could cause a war. The endless diagram (Figure 3) shows such an international situation around 1915 and 1935, when World Wars I and II started. The present time verifies no deficit no World War. In addition to the above, the diagram indicates the present history to be similar to that of 315 years ago, and same is the opinion expressed by others [22], concerning the likeness of the current events to those around the so - called "Thirty Years War of Europe" during the 17^{th} century. Finally, the diagram shows some serious World War events to be expected during the second half of the 21^{st} century, and again about the same is the opinion of others [2].All the above comments indicate, that the endless diagram could be useful to historians to explain and foresee World History.

b) To explain and foresee war or serious phenomena of disorganization in local levels, appropriate is the criterion $\frac{E\delta}{Ea} \geq c$ (9), where Eδ = Forest land area and Ea = Sum of agricultural and urban land area [4,5,7,9,13]. This arises from the analogy (2a) and the proposed theory agrees; moreover, it constitutes an improvement of the well known Malthus' theory [13, 21]. The following events could be explained through the above criterion:

(1) The participation of Germany in the European Union has improved its own bad ratio Eδ/Eα and eliminates the start of a new World War again from that country [13].

(2) The current political decline in the countries of Eastern Europe is the result of wrong use of their lands. It may be argued, that the application of extensive agriculture (large Eα) by them has induced the ratio Eδ/Eα to more or less critical points [11,17].

(3) Forest fire outbreaks all over the world during the past 25 years is, for the most part, the result of unsuccessful politics on the rotation of crops, i.e., it has put strong barriers to change Agriculture to Forestry and vice versa [9,12,14,16]

3.3. Environmental economics .

The general conclusion from the endless diagram is that input and output compensate each other. Based on this idea, the proposed theory provided enough equations to help environmental economics. The main of them are as follows:

$\Pi xo = \frac{1062.8.b.\Sigma.t.X}{100+E.X}$ (10) [4,13,16]

$\Pi x = 10.628.b.\Sigma.t.X$ (11) [4,13,16]

$Za = \frac{\Pi x - \Pi xo}{t}$ (12) [9,12,14,16]

$b = 1-6.0858.n$ (13) [8,10,16]

$\Pi A = 100.b$ (14) [8,10,16]

$$A=\frac{10^4.b.\Sigma.t}{E(100+E)} \quad (15) \quad [6,7,9,15,16]$$

Where: Πxo = Marginal productivity per hectare in money units, Πx = Πxo plus its simple interest (r) for accidental time period (X), Za = Work deficit (or surplus) in money units equal to simple interest (r) of Πxo in time (X), Σ = The annual yield per stremma (0.1 hectare) of the more interesting product as an average of the last three years, t = Current average price per unit of Σ, E = Current average simple interest rate (%), n = Average of the "new variable n", ΠA= The human participation (%)on any kind of forest biomass under sustainable development, and A = Market value of forest land per stremma (0.1 hectare).

All above equations gave impressive results, when applied to various forestry practices, and their application to other sciences (e. g. Agriculture) is also expected to be successful [7,13,15].

3.4. Global climatic changes.

1) The cycles of 315, 1123, 17645 and 25994 years are approximate multiples of the climatic cycle of Bruckner. This means, that the weather of the Earth, as a total phenomenon of any year, is about the same, to one before or after 315, 1123, 17645 or 25994 years. The same is valid for small time periods too. Therefore, anyone could reasonably suppose, that the weather phenomena of the current period 1985 - 2005, such as El Ninio, Greenhouse effect and Ozone hole, have their correspondents in both past and future. This is a subject to be investigated. Some periods in Figure 3, enclosed in rectangles, show a similarity to the present and should also be investigated.

2) Furthermore on above subject, the picture of the period 1985 - 2005 in the diagram shows a coincidence of accumulation (more or less summer work) to consumption (more or less winter work).It happens, because the Earth environment pulse is in contraction phase (see Chapter 3.1, paragraph c). Theoretically, the above period should show "weather confusion" and "seasonal confusion". As a fact, this is the main feature of current weather. However, such an idea harmonizing the opposites in Nature is not new; it may be traced to the following view of the ancient Greek philosopher Heraklitus [20]: "God is day - night, winter - summer, war - peace, satiety - starvation....". It is a fact, that the proposed theory found its first incentives and was built on the ideas of this "obscure" philosopher, but it was also able to unify to a large extent the ideas of other philosophers [9,13,16,17].

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WOMEN AND ENVIRONMENTAL ACTIVITY

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ABSTRACT

The purpose of this paper is to present an overview of the contributions which women around the world have made to the protection of the environment and the factors that persuaded them to get involved. Many people become interested in environmental care only when the quality of the changes affect them personally. We all want clean air, drinkable water and a flourishing wilderness but we haven't decided on what price. In our attempt to control the world it seems that we are loosing control of our future. This "future" is what makes women more sensitive to environmental issues. Biological reproduction involves the integrated production of the species. Women's shared experiences of, and potential for, childbirth unify them in their concern for the quality of life for future generations and for the survival of humankind which as it has been recognized is totally dependent on a healthy environment. Women are themselves painfully aware of the threat to their own lives and those of their children from onslaughts of the environment and consequences of the environmental changes.

ΓΥΝΑΙΚΕΣ ΚΑΙ Η ΠΕΡΙΒΑΛΛΟΝΤΙΚΗ ΚΙΝΗΣΗ

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ΠΕΡΙΛΗΨΗ

Ο σκοπός αυτής της μελέτης είναι η παρουσίαση της παγκόσμιας συμβολής των γυναικών στη προστασία του περιβάλλοντος και οι λόγοι που συνέβαλαν σε αυτή την ανάμιξη. Πολλοί ενδιαφέρονται για την φροντίδα του περιβάλλοντος μόνο όταν προσβάλλεται η ποιότητα της ζωής τους. Όλοι θέλουμε καθαρό αέρα, νερό και μια ανέπαφη φύση, αλλά δεν είμαστε έτοιμοι να απαρνηθούμε τις ανέσεις. Οι φόβοι για τις συνέπειες της περιβαλλοντικής καταστροφής στις επόμενες γενιές βρίσκουν τις γυναίκες πιο ευαισθητοποιημένες.

1. VOICES FROM THE DEVELOPED WORLD

1.1 The United States

Toxic waste disposal has been a central focus of grassroots environmental activism in the United States.[1,2,3,4] Toxic waste facilities are predominantly sited in working-class and low-income communities of communities of color, reflecting the disproportionate burden placed on these communities by a political economy of growth that distributes the costs of economic growth unequally.[5,6,7,8,9,10] Spurred by knowledge of the threat that toxic wastes pose to family health and survival, grassroots women activists have assumed the leadership of community environmental struggles. This conclusion is confirmed by case studies of numerous sites [1,3,5,11,12,13] as well as by observations of the leaders of national organizations, especially the Citizen's Clearinghouse for Hazardous Wastes and the Environmental Health Network (EHN).[3,14] As part of a larger movement for "environmental justice," women activists comprise a diverse constituency, including working-class housewives and secretaries, rural black farmers, urban residents, Mexican-American farm workers, and Native Americans.

Working-class women of diverse racial and ethnic backgrounds identify the toxic waste movement as a women's movement, composed primarily of mothers. In communities of color, it is women (especially pregnant and older women) and children who suffer disproportionately from the ill effects of environmental contaminants. "One of the most sobering aspects of the ecological degradation we endure is the impact on our capacity to bear healthy children." [15] Much of the environmental epidemiological literature has addressed reproductive outcomes, many of which have been attributed to toxins. [16] Recognized by environmental historians as the watershed event in women's grassroots environmentalism, Love Canal is a story of how lower-middle-class women who had never been environmental activists became politicized by calamitous issues directly affecting their children and their homes. In 1977, Native American women organized WARN, Women of All Red Nations, to protest high radiation levels from uranium mining tailings on their reservations and to call attention to the high rates of aborted and deformed babies. Other issues included loss of reservation lands and the erosion of the family. Lorelei Means and Winona LaDuke are two WARN members who speak out nationally on behalf of Native American people and environmental issues.[17] Cathy Hinds, whose well water in East Gray, Maine, was contaminated by chemicals from a nearby industrial clean-up corporation became "fighting mad" when she lost a child and her daughter began to suffer from dizzy spells. She eventually founded the Maine Citizens' Coalition on Toxics and became active in the national Toxics Campaign. Her motive was to protect her children. Women, she says, "are mothers of the earth."[18]

Despite high levels of participation by women in toxic waste activism, gender and the fight against toxic hazards are rarely analyzed together in studies either on gender or on environmental issues. The absence of rigorous analysis of gender issues in toxic waste activism is particularly noticeable, since many scholars of toxic waste activism often note, in passing, that women predominate in this movement. [19] One of the newest grassroots environmental groups is the Great Lakes Women's Leadership Network (GLWLN), a broad based, multicultural, intergenerational organization which targets women willing to work together, share information and focus on crafting a future for the Great Lakes ecosystem. [20] The network is the dream of two women activists, Jan Conley and Debbie Ortman. In 1996, they received an 18 month grant from the Kellogg Foundation to establish GLWLN as a central provider of skills training and support for Canadian and American women environmental leaders around the Great Lakes Basin.

1.2 Canada

The Canadian Environmental Network staff is made up mostly of women, as is much of the volunteer leadership nationally, provincially and territorially.[21] Some of the Canadian organizations which can boast of women in key positions are Toronto's Solid Waste Environmental Assessment Program (SWEAP), Citizens for a Safe Environment and Canada's National Packaging Task Force.[22]

Fredelle Brief is a member of one of five advisory groups within SWEAP which meet regularly to consider a new "garbage plan" for Metro Toronto. Metro generates one ton of garbage per capita each year, which means it must find ways to deal with three million tons of garbage annually. But Metro was quickly running out of landfill space. It was predicted that by 1992, the two existing landfill sites would be full. It makes good sense, then, that the first priority of SWEAP was to reduce the amount of garbage that coming into the waste stream. Reuse and recycling are second and third in order of priority. Aine Suttle is frank about her anger. A few years ago her son Brendan was discovered to have high lead levels in his blood. Suttle became very involved in the lead poisoning issue in her community of South Riverdale, working first with the South Riverdale Community Health Center and then with Citizens for a Safe Environment. She was told that there was not a problem with lead in the environment and that she was just "hysterical." She knows better now. "As women, trust your instincts and remember scientific knowledge is not always an advantage."[22]

Innu women in Labrador and Quebec have been protesting their government's decision to allow NATO countries to practice low-level flight testing over their native lands. Environmental impact studies have documented the harmful effects of these flight patterns on social, environmental and cultural health. Dubbed "Innu and Earth," this female-sponsored campaign has utilized public outreach through the media, and non-violent protest by occupying the planes' runways.[23]

1.3 Sweden

Swedish critic and reformer Elin Wagner wrote in 1941, "It is beginning to dawn on women that they must assume the responsibility for housekeeping nature."[24] Since that time, women in Sweden have campaigned more vigorously than men against industrial and agricultural pollution. According to the National Institute of Environmental Medicine, 59% of Swedish women polled were concerned about the health risks of air pollution from an aluminum factory, while only 36% of the men were equally concerned. A women-dominated protest succeeded in forcing the factory to adhere to strict guidelines for discharge of particles into the air, and stopped a planned expansion of the factory. In a protest against the use of herbicides on food crops, Marit Paulsson and a group of women initiated a nationwide movement to convince politicians to ban the use of herbicides in all forests in Sweden. As a result, the parliament passed a law in 1979 prohibiting herbicide use by the forest industry.

A national referendum on nuclear power, held in 1980, revealed that 43% of Swedish women oppose the use of nuclear power, more than twice the proportion of men. Following the referendum, Birgitta Ohlsson organized a group to protest the location of nuclear disposal sites near populated areas in central Sweden. The swift popular support they received resulted in an abandonment of the plan.[17]

1.4 Australia

In Australia, women are the leading environmentalists. More Australian women than men belong to environmental and conservation organizations. Surveys of those under age 50 reveal that women are more concerned than men about environmental issues, nature conservation, and pollution.[17] In a comprehensive survey of the residents of Queensland published in 1990, women were shown to have greater support for every environmental issue mentioned: ending uranium mining, logging on Fraser Island, rainforest protection, and voting along environmental protection lines. The researchers found that the gender difference was highly statistically significant.[25]

Australia is one of the developed world's most vulnerable areas in terms of de-certification, the most widespread form of global land degradation. At least 50% of Australia's dry land is moderately to severely desertified.[26] One of the most prominent ways in which women have impacted the environmental movement in Australia is through the government sponsored "Decade of Landcare," a national effort to reduce desertification begun in the early 1990s. Women comprise more than 85% of the Australian Toxics Network, a grassroots organization devoted to the clean-up of pesticide and petrochemical industry residues.[27] The Australian chapter of the Women's Home Environment Network (WHEN) was started by Mina Sirianni, an immigrant from Canada who had been active in the Vancouver chapter of WHEN. She organized the first chapter in Melbourne in 1990 with the goals of: encouraging conservation, recycling, buying organic food, protecting trees, using environmentally friendly means of transportation, making households toxic free, shopping locally, using cloth diapers, creating no garbage, and protecting the rights of indigenous people. As a result of her efforts to publicize WHEN, several new satellite chapters have been formed in other areas of Australia.[17]

1.5 Japan

The environmental movement in Japan can be described as almost exclusively grassroots. There are approximately three thousand active grassroots organizations spread throughout the country, but no large, well-financed groups acting on a national level.[28] Most of the grassroots groups are small, numbering no more than a few hundred members, and managed by housewife volunteers out of their homes.

The Seikatsu Club is a consumer group founded in the 1970s by women in Japan who were concerned about Minimata disease, a fish-borne mercury poisoning that causes neurological damage, paralysis and death. Using the purchasing power of 210,000 housewives, the club promotes organic, ecologically sound farming. After the Chernobyl nuclear disaster, the Seikatsu Club created the Radiation Disaster Network to monitor radioactive substances in food imported from Europe.[23]

A graduate of an arts college, Kado Akiko is a Japanese housewife who is active in a local recycling group which she helped found in Ishikawa Prefecture in 1990. Together with another woman, she established the Carton Association, which has collection boxes for used milk cartons at 30 sites in a town of only about 10,000 people. They expanded their recycling efforts to include aluminum cans and styrofoam. Whatever small monies they earn by recycling are sent to Midori Ippon, a United Nations based group which promotes reforestation in Africa.[28]

2. VOICES FROM THE DEVELOPING WORLD

The principal victims of environmental degradation are the most underprivileged people, and the majority of these are women in developing countries. Their problems and those of the environment

are very much interrelated. Both are marginalized by existing developmental policies. And because of the complex cycles of poverty, inappropriate development and environmental degradation, poor people have been forced into ways of living which induce further destruction.[29] Women possess unique knowledge and experience to help maintain the world's biotic wealth, but the hardships and constraints they face remain unbridled. Tackling those unmet needs will enable women to participate more effectively and efficiently in all conservation and development activities -- participation that will improve the welfare of both humans and the environment.[30]

In all the tasks of environmental protection women play a vital role, and for many different reasons. First, in many areas of the world women are the main environmental managers. In Africa, women grow most of the crops, and are traditionally responsible for a great deal of conservation activity. They protect soils, trees, and water resources. They carefully select the seed corn for planting. The women know, for example, much better than imported "experts" which trees make the best fuel wood, which wood dries faster and burns well, which plants retain moisture in the soil, and which ones provide the best foliage for fodder or fertilizer.[31] Secondly, women have a remarkable ability to work together. The evidence from many women's groups is that women can share their skills and resources to take effective action. Some of the most successful examples of sustainable development are built upon women's initiative: in the Chipko movement of northern India and in the Kenyan Green Belt Movement. Many women are experienced in cooperative working, something that male-dominated governments and multinational corporations have yet to learn.[32] Finally, and perhaps most important of all, it is likely that restoring women's capacity to care for the environment will be associated with improvements in their independence and status. There is a major convergence of interest between environmentally sound and sustainable development, and the development of women.

2.1 Poland

A pilot project, called The Environmental Management and Leadership Training for Women, has begun in Silesia, one of the most environmentally degraded regions in Poland. The program's goal is to increase the effectiveness of women's activities in the spheres of environmental protection and environmental health.[33]

Dr. Maria Guminska, a professor of biochemistry at Krakow Medical University, helped to found the 4,000 member Polish Ecology Club and served as one of its vice-presidents. She prepared a critical report on the air pollution of Poland's largest aluminum smelter and was active in the effort to reduce toxic pollutants from a Krakow pharmaceutical plant.[34] The PEC sponsored a program in which food grown in industrial areas of environmental degradation is tested for contaminants before being delivered to consumers. The program is implemented by the supervision of retail stores by the PEC; setting up distribution systems so that high quality foods go to day care centers and hospitals; and sponsoring environmental educational activities for community groups.[35]

2.2 The Former Soviet Union

At an international symposium on women, politics, and the environment, held in Moscow in 1994, Alexei Yablokov [36] described the environmental situation as "critical." He stated that the average lifespan in Russia had decreased by two years in 1992 and again in 1993, and attributed at least 30% of the reduction in life expectancy to environmental factors. He cited several disturbing facts: (1) The Kara Sea is the most radioactive sea on earth; (2) St. Petersburg is the largest megalopolis in the world without water purification facilities; (3) Severonickel has the most polluted air on the planet, and (4) Western Siberia is the brightest place on earth due to the hundreds of thousands of oil torches burning on its plains.[36] The rate of birth defects was higher in the most contaminated

areas of Moscow, and environmental monitoring studies showed a significant accumulation of heavy metals in children's hair and PCBs in human breast milk.[37]

The nuclear disaster in Chernobyl is usually cited as the salient event which launched women's environmental activism in the Soviet Union in the 1980s.[38] Recognized as the world's most severe technogenic catastrophe, the 1986 Chernobyl nuclear reactor accident resulted in radioactive contamination of several Soviet states. Soil, food products and water were poisoned with radionuclides. Even eight years after the accident, many regions of the Ukraine, Belorus and Russia continued to register elevated levels of background radiation.[39] In 1990, a women's group called Zhynocha Hromada Rukhu actively picketed the Parliament building in the Ukraine , demanding the closing of all Chernobyl reactors. This same group supported the students' hunger strike which finally led to the resignation of the entire government in the Ukraine.

2.3 Central America

Of all the countries in the Americas, El Salvador has suffered the greatest environmental degradation. Much of the devastation is a result of a lengthy civil war, but extensive cultivation for export products and lack of environmental regulations have also played a role.

The National Coordinating Committee for Salvadoran Women (CONAMUS) was founded in 1986. It organizes women at the grassroots level, sponsoring health programs, tree planting in war-ravaged areas, and the use of natural medicinal plants.

2.4 Kenya

Kenyan women's access to firewood and water for subsistence was the primary motivation underlying the women's Green Belt movement. According to its founder, Professor of Biology Wangari Maathai, the movement's objective is to promote "environmental rehabilitation and conservation and... sustainable development." Maathai had observed the desert expanding when trees removed for fuel were not replaced. Without the trees, springs dried up and ground water levels dropped. Using the trees as a focal point for environmental protection, she began a movement that has involved school children and 15,000 small scale farmers, most of them women. Collectively, they planted more than two million trees between 1977 and 1983.[40]

2.5 India

In the Reni forests of the Chamoli district, Utter Pradesh, in northern India, in 1974, women were confronted with the prospect of losing 2,500 trees to a commercial enterprise. Clearcutting and forest pillaging had been common practices for years. In fact, the destruction of the Himalayan forest had become the major cause of ecological instability in the region, bringing the losses of forage and fuel and repeated catastrophic flooding. The women were alone, for their men had left home. When the contractors arrived, the women went into the forest, joined hands, and encircled the trees: hence the movement called "chipko" (to hug). The protesters told the cutters that before any tree could fall, they would first have to cut off the heads of the women. The contractors withdrew, and the forest was saved. This type of protest was to be repeated: women fasted, guarded forests, and wrapped themselves around trees destined for the woodcutters axe. As a result of women's actions to preserve their environment, Prime Minister Indira Gandhi issued a fifteen-year ban on commercial felling the forests of Utter Pradesh.[30]

The Chipko Andolan movement grew out of these initial protests. It is a movement in which both men and women participate as leaders. The movement has extended beyond Utter Pradesh to encompass the entire Himalayan region. On their march through the mountains in India, Nepal and

Bhutan, Chipko activists come into contact with the societies of the remote hill areas. Their message of anguish about the ecological situation of the region has spread as more and more people and villages have become involved in the issue. The Chipko movement has attracted worldwide attention. The image of poor, rural women in the hills of northern India standing with their arms around trees to protect them from the woodcutter is a romantic and compelling vision. The reality, in many ways, fits the image: the Chipko movement can indeed be considered an important success story in the fight to secure a higher status for women, in the process of local community development through forestry and in environmental protection.

2.6 Taiwan

The price of rapid industrialization in Taiwan during the 70s and 80s was enormous, and a heavy toll was extracted from the environment. Highly polluting industries in Japan moved their operations to Taiwan after public pressure from the Japanese people forced them out of their own country. Taiwan become yet another victim of the powerful industrial polluters of the developed world. Grassroots protest movements sprung up during the 1980s, but did not gain a real voice until martial law was lifted in 1987. Since then various groups have formed to target specific environmental issues: water resource protection, nuclear power, industrial pollution, conservation of endangered species, and so on. One of the most prominent groups is the Women's Alliance for Environmental Protection (WAEP).

Most members of the WAEP are housewives and mothers. They are involved in protests and demonstrations on behalf of environmental protection, but also advocate for "green" living, waste recycling, and consumer education. The group encourages manufacturers to produce safe and pollution-free products. In 1993, the growing influence of women environmental activists was evident when many housewives in the movement were elected to borough leadership positions.[41]

3. CONCLUSION

Around the globe, women are shaping the environment -- and caring for it. Women's environmental groups in the industrialized countries of the world are more effective and visible than ever before. Collectively, their actions are changing the lives of people in households, communities and societies on every continent. Women in the poorest countries have organized movements, institutes, and businesses to transform maldevelopment into sustainable development. They are often at the forefront of change to protect their own lives, those of their children, and the life of the planet. For most of the women in developing countries, especially the poorest, a healthy environment is fundamental to their survival. The natural environment is not just an aesthetic backdrop for their activities -- it is vital to their livelihoods and the welfare of their families. While the modern environmental movement has always stressed the concept "think globally and act locally," it has become crucial to learn to think locally and act globally. Especially in the developed world, we must understand the implications of our everyday actions not only on our own environment but also on the environments and people in other parts of the world. We are connected in more ways than our ancestors ever imagined.

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INCORPORATION OF SOCIAL ACCEPTANCE IN THE SANITARY LANDFILL SITING SELECTION PROCEDURES IN GREECE

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ABSTRACT

One of the major problems in waste management concerns the selection procedure for an appropriate sanitary landfill site. The public acceptance of sanitary landfill selection studies in Greece is very low. It is not possible to have a universally accepted selection procedure, but people would like to express their opinion, especially concerning the relative weight of the criteria that will be used for sanitary landfill selection. Inhabitants of Thessaloniki and Volos were interviewed. The results of the polls showed that inhabitants of both cities give a higher level of significance to environmental impact than to economic or social acceptance criteria. They also showed eagerness to undertake the cost for a properly operating sanitary landfill.

ΔΙΕΡΕΥΝΗΣΗ ΤΟΥ ΡΟΛΟΥ ΤΗΣ ΚΟΙΝΩΝΙΚΗΣ ΑΠΟΔΟΧΗΣ ΣΤΗΝ ΕΠΙΛΟΓΗ ΧΩΡΟΥ ΥΓΕΙΟΝΟΜΙΚΗΣ ΤΑΦΗΣ ΣΤΗΝ ΕΛΛΑΔΑ

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ΠΕΡΙΛΗΨΗ

Η επιλογή κατάλληλων χώρων για υγειονομική ταφή είναι από τα μεγαλύτερα περιβαλλοντικά προβλήματα. Πολλές μελέτες προτείνουν αντικρουόμενες λύσεις, ενώ το κοινό εμφανίζει μία δυσπιστία απέναντι σε αυτές. Προτείνεται να ενισχυθεί η συμμετοχή του κοινού στη λήψη αποφάσεων, μέσω κατάλληλων δημοσκοπήσεων, τα αποτελέσματα των οποίων θα δείξουν στους ειδικούς τα βάρη που δίνουν οι κάτοικοι μιας περιοχής σε κριτήρια περιβαλλοντικά, οικονομικά και κοινωνικής αποδοχής. Κάτοικοι της Θεσσαλονίκης και του Βόλου έδωσαν μεγαλύτερο βάρος στα περιβαλλοντικά κριτήρια και δέχθηκαν κατά πλειοψηφία να αναλάβουν το κόστος μιας άριστα λειτουργούσης υγειονομικής ταφής.

1. INTRODUCTION

In the last decade, selection of an appropriate landfill site has become a significant environmental and social issue in Greece as well as in other countries. Sanitary landfilling is the most common way of disposing municipal solid wastes. In Greece its role is dominant, since other methods such as incineration of wastes or composting are very little used. A great number of studies regarding landfill siting took place, but the public acceptance of them is very low. Among other reasons, this is also due to the fact that methods used by different researchers usually lead to contradicting conclusions. In future, the dimensions of the problem are expected to grow, since sanitary landfill space near the heavily developed municipalities is becoming scarce [1].

The inappropriate selection of a cite and the lack of acceptance of the nearby communities can contribute to environmental problems, increased cost and public disorder. In the area of Athens there have been cases of studies by different researchers leading to contradicting results. Such incidents greatly affect the trust of the people on the so- called environmental experts. One of the most important differences in the methods investigating the selection procedure of landfill sites, is the level of significance given to selection criteria. It is worth noticing that not only the level of significance but even the classification of criteria is different for different environmental specialists. As an example, Prefecture of Thessaloniki classifies the criteria as operational criteria (20 % level of significance), regional planning criteria (30 %), environmental criteria (35 %) and economic criteria (15 %) [2]. Frantzis has classified as environmental criteria, engineering criteria and economic criteria [3]. Yhdego and co- workers have classified the factors affecting selection of a sanitary landfill site as political and environmental [4].

Diamadopoulos and co-workers (unpublished data) have advocated the incorporation of social acceptance criteria together with environmental, technical and economic ones. They suggest that multicriteria decision analysis [5] be used for the selection of a landfill site. According to their suggestion ELECTRE III method should be used for the evaluation and selection procedure of a specific landfill site with analysis based on the interaction of four groups of people, environmental experts, local authorities, residents of the urban area responsible for the generation of the solid wastes and residents of the areas located near the potential sites. The four interacting groups give different relative weight to the basic criteria involved in the selection procedure. In the area concerning environmental subjects, implementation of multiple criteria analysis has been limited [6]. Characteristic problems that have been dealt with multicriteria decision analysis techniques include the choice of a solid waste management system in Finland [7] and in Ontario, Canada [8].

In the last decade many researchers have published various approaches in the problem of sanitary landfill selection. Noble [9] published a method for a three- stage selection of an appropriate site. Narayanaswamy and Kennedy [10] published one algorithm to locate solid-waste disposal site considering as major factors environmental and health risks, economic issues, social issues and political issues. Other researchers who have worked on methods for selection or case- studies include Kao and Lin [11], Nieves et al. [12], Renn et al. [13] and Siddiqui et al. [14].

2. RESULTS AND DISCUSSION

Polls were conducted in two major urban areas of Greece, Thessaloniki and Volos, in order to investigate the attitude of people towards sanitary landfill. Thessaloniki is the second biggest city of Greece with a population close to one million people. The currently used sanitary

landfill site in Tagarades is getting saturated and new sites have been suggested. There have been quite some reactions of the residents of the areas located near the potential sites and municipal waste management is expected to cause problems in Thessaloniki in near future. Volos urban area has a total population approaching 150,000 people. The currently used sanitary landfill site in Kakkavos is far from being saturated and is expected to be able to receive the municipal solid wastes of Volos for 20- 30 more years. The sanitary landfill site in Kakkavos is far from any inhabited area and its social acceptance is quite good.

People interviewed in both coties were aged between 25 and 55, University or Technical College graduates, residents of urban areas responsible for the generation of solid wastes. Fifty- six inhabitants of central Volos and fifty inhabitants of thessaloniki were interviewed. The questionnaires contained some information about sanitary landfill siting emphasizing that proper sanitary landfill refers to:
- Selection of the most appropriate place, through environmental impact assessment studies accomplished by environmental experts.
- Protection of public health by means of solid waste compression and covering with soil.
- Protection of underground water.
- Managing the produced biogas.

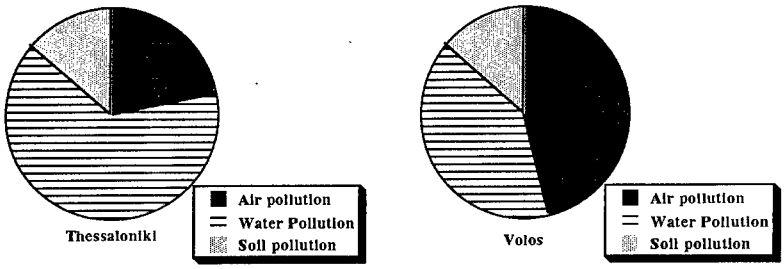


Fig.1. Relative importance given to air, water and soil pollution problems by inhabitants of Thessaloniki and Volos.

The first question asked to inhabitants of Thessaloniki and Volos was whether they consider air pollution caused by cars, factories and central heating, water pollution caused by wastewater or soil pollution caused by industrial and municipal solid wastes as most serious environmental problems in their respective prefectures. The answers to this question are shown in Fig. 1. In both prefectures the seriousness of the solid wastes problem ranked third after gas and liquid wastes. Only 14 % of Thessaloniki inhabitants and 13.9 % of Volos inhabitants consider soil pollution caused by municipal and industrial solid wastes as the top environmental problem in their prefectures. An explanation for this is that air and water pollution problems have been more discussed in the mass media until recently. However, it is believed that with scarcity of available land for sanitary landfill increasing, solid wastes disposal problems will come to surface in future. The only difference that was observed in the answers from Thessaloniki and Volos was that Thessaloniki inhabitants are more concerned about water pollution, while Volos inhabitants are more concerned about air pollution. This is a natural consequence of the fact that water resources in Thessaloniki (Thermaikos Gulf, Koronia lake) are more heavily polluted.

The inhabitants of Thessaloniki and Volos were asked about the relative level of significance that they would give to economic criteria, social acceptance criteria and environmental impact

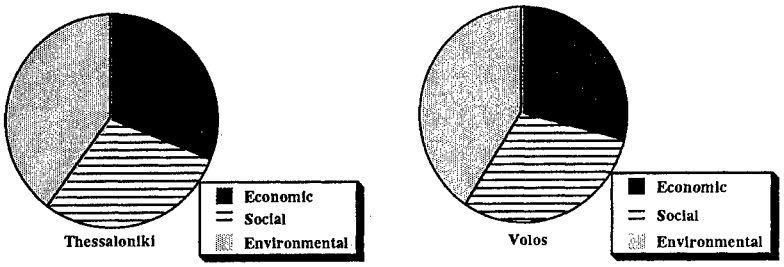


Fig. 2. Relative level of significance given by inhabitants of Thessaloniki and Volos to economic, social acceptance and environmental impact criteria.

criteria. The answers to these questions, after data analysis, are shown in Fig. 2. People were not asked about technical criteria, because such concepts are not easily understood by the public. Inhabitants of both cities gave higher importance to environmental impact criteria, without neglecting economic and social acceptance criteria. It is noteworthy that there was no difference in the answers between the two prefectures. Both inhabitants of Volos and Thessaloniki gave roughly a 40 % level of significance to environmental impact criteria and 30 % each to economic and social acceptance criteria. If we add the technical criteria, which are not included in the questionnaire, and give them a 25 % level of significance, then the overall level of significance should be 30 % for environmental impact criteria, and 22.5 % each for economic and social acceptance criteria. However, it has to be emphasized that the results of the polls presented in this study concern only one specific group of people. The opinions of other groups of the population (i.e. primary and secondary education graduates), as well as of the residents of the areas near the potential landfill sites should be taken into account. The authors of this study suggest that an extensive study of public opinion be made, before the level of significance of each group of criteria is determined.

It is a common belief among authorities and environmental specialists in Greece that the concept of sanitary landfill is misunderstood by the public. This is due to the fact that it is often confused with the concept of simple disposal, where no special care is taken to protect public health, underground water and to manage the biogas produced. As a result of this misunderstanding, a lot of people consider that major environmental problems are caused by the sanitary landfill of solid wastes. Surprisingly, however 82 % of interviewed people in Volos and 84 % of interviewed people in Thessaloniki answered that a properly operating sanitary landfill does not cause environmental problems (see Fig. 3). Of course it must be pointed out that the questionnaires were given to University and Technical college graduates. Also the basic concepts about a properly operating landfill site were summarized on top of the questionnaire. It can be concluded that, with proper information and continuous environmental education by the authorities, the negative attitude of people towards sanitary landfill can be reversed.

One very crucial question concerning the capacity of a prefectural authority to create properly operating sanitary landfill sites has to do with the eagerness of the public to pay for the expenses. The majority of people in both Thessaloniki and Volos answered that they would pay a reasonable amount per month for a sanitary landfill operating under optimal conditions. One thousand drachmas per family per month was considered a reasonable amount in both cities.

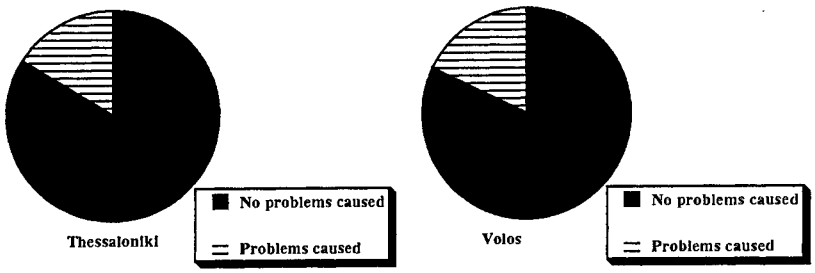


Fig. 3. Opinion of inhabitants of Thessaloniki and Volos concerning problems caused by a sanitary landfill site operating properly.

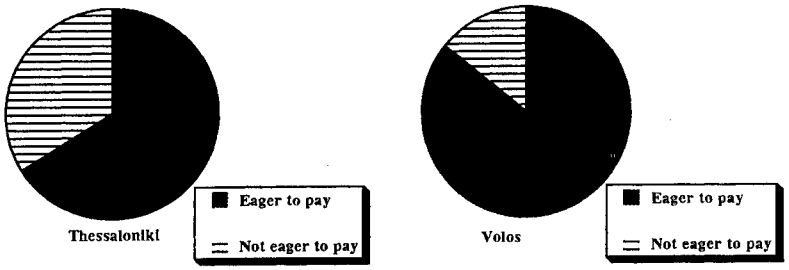


Fig. 4. Relative eagerness of inhabitants of Thessaloniki and Volos to pay a reasonable amount of money per month for a sanitary landfill site operating under optimal conditions.

Surprisingly, the eagerness to pay, as it can be seen in Fig. 4, was higher in Volos (85 %) and lower in Thessaloniki (66 %). A probable explanation for this response is that the inhabitants of the center of Thessaloniki consider that the proper operation of the sanitary landfill is a distant problem for them, since they know that it can only be located far from the city center. It can even be assumed that some of Thessaloniki inhabitants do not trust their authorities for proper use of municipal funds. Still, the main point is that the majority of people in both prefectures are eager to pay for a cleaner environment.

CONCLUSIONS

It has been a fact neglected by authorities that inhabitants of urban and rural areas would like to play a more active role in sanitary landfill siting selection. Educated people of Thessaloniki and Volos give higher level of significance to environmental impact criteria than to economic and social acceptance criteria, without neglecting the role of the latter. A big majority of educated people in both areas accept that a properly operating sanitary landfill site would not cause problems to the environment. It is clear that, through proper environmental education, the negative attitude of the public towards sanitary landfill can be reversed. Most of inhabitants of Thessaloniki and Volos are eager to pay a reasonable amount of money per month, in order to assure proper operation of the sanitary landfill site.

It is not possible to suggest a universally accepted selection procedure for sanitary landfill siting. Different communities might give different relative weight to environmental, technical,

economic and social criteria involved in the selection procedure. The authors of this study suggest that the authorities should investigate the opinions of residents, before assigning a proper level of significance to environmental, technical, social and economic criteria. This way the public will be involved in the selection procedure and it will more easily accept the site suggested by the environmental specialists.

ACKNOWLEDGMENT

The authors of this study want to express their thanks to associate professor of Demography at Thessaly University Dr. V. Kotzamanis for his contribution in forming the questionnaire used in this study. We also thank the inhabitants of Thessaloniki and Volos who participated in the poll for their contribution to the completion of this study.

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ENVIRONMENTAL IMPACTS OF MINING AND SOCIAL ATTITUDE: A VIEW THROUGH THE RECORDS

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ABSTRACT

Mining is an activity with serious environmental impacts affecting society as a whole. This paper presents the evolution of the relation between mining, environment and social perception, during the past thirty years, by studying methodically numerous of publications, accusations, official records, maps and aerial photographs in a characteristic case.

ΠΕΡΙΒΑΛΛΟΝΤΙΚΕΣ ΕΠΙΠΤΩΣΕΙΣ ΤΗΣ ΜΕΤΑΛΛΕΥΤΙΚΗΣ ΔΡΑΣΤΗΡΙΟΤΗΤΑΣ ΚΑΙ ΚΟΙΝΩΝΙΚΗ ΣΥΜΠΕΡΙΦΟΡΑ : ΜΙΑ ΜΑΤΙΑ ΜΕΣΑ ΑΠΟ ΤΑ ΑΡΧΕΙΑ

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ΠΕΡΙΛΗΨΗ

Η μεταλλευτική δραστηριότητα αποτελεί μια κατ' εξοχή δραστηριότητα με σημαντικές επιδράσεις στο περιβάλλον και κατ' επέκταση στο κοινωνικό σύνολο. Το παρόν άρθρο στοχεύει στη μελέτη της σχέσης μεταλλεία - περιβάλλον - κοινωνική αντίληψη, κατά τη διάρκεια των τελευταίων τριάντα χρόνων, ερευνώντας συστηματικά, μέσω ενός πλούσιου αρχείου δημοσιευμάτων, επίσημων εγγράφων, χαρτών και αεροφωτογραφιών της περιοχής, την χαρακτηριστική περίπτωση των λατομείων Καρέα Υμηττού.

1. INTRODUCTION

For thousands of years, mining has gone hand in hand with human evolution. During this period, gigantic quantities of minerals and building stones have been produced for civilization development, economic welfare, and technological progress. However, it is also an activity with serious environmental impacts. Thus, mining is rightly characterized by some as the only activity that can combine disaster and development to such a degree[1].

The relationship between mining, the environment and social perception seems to have passed through many stages. For centuries, denuded landscapes, fouled streams and dirty air were accepted by society as part of the price that has to be paid for mineral production [2]. This was a widespread impression until the last years of the sixties. From the beginning of the next decade, a radical change in dealing with environmental problems emerged.

This paper presents the case of the Kareas quarries, an aggregate exploitation within the capital city of Greece. It concerns an expanded exploitation that caused serious environmental impacts affecting directly thousand of people.The study of files including publications, accusations and official records, the examination of maps and aerial photographs of the site as well as on-site research, composed the basis for a historical approach to the continuously changed relationship between mining and social behavior at the determinative period of the past thirty years.

2. THE CASE OF THE ABANDONED QUARRIES OF KAREAS.

Kareas quarries are situated to the east of the Attica basin, at the edge of the city, on the west slopes of Hymettus mountain. Their distance is about 6 km from the center of the city and 1 km from the Katechaki-Alimos peripheral motorway. The quarries surroundings (at a distance of 1-2.5 km) are the inhabited areas of Vironas, Kareas, Kesariani and Ilioupoli.

The abandoned Kareas-Hymettus quarries are also known as "the ancient quarries" of Hymettus, due to the quarrying activity which took place in the same site in ancient times [3].

The intense exploitation of the limestone deposits of the area for the production of aggregates, turned the Kareas quarries into one of the main quarrying centers which, during the period 1960-1979, provided a basis for the rapid but disorderly urban development of the Attica basin. The easy and economical aggregates transportation from the quarries to the urban areas of Attica basin, contributed to the extensive exploitation in Attica.

Quarrying was officially terminated in 1979, due to the degradation of quality of life in the surrounding areas (vibrations, materials' flinging, noise, dust), as well as the extensive aesthetic depreciation of the mountainous area. Substantially the area exploitation was carried on until 1993, since the state made use of the area as a place of uncontrolled landfill of debris and wastes.

In order to comprehend better the facts that have been correlated with quarries history, three periods are distinguished:

2.1 First period: 1960 until 1969

The exploitation method until 1965, was that of inclined benches with pits excavated in unsettled direction and depth. In 1967 the distance between the quarries and the houses was about 600 m [4]. The aerial photo of 1960 shows that in the territory, before the beginning of workings, luxuriant vegetation existed (Fig. 1)[5]. The basic characteristic of the landscape is the big number of streams.

In 1969 (Fig. 2) a single slope without ranks and with height of about 1000 m, had been formed. The distance of the quarry site and the Petraki Monastery, which is one of the most historically significant monasteries in Greece, has been reduced to about 400 m.

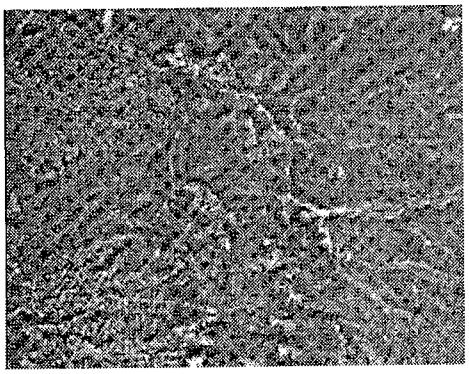


Figure 1. The area of Kakorema before the beginning of the mining operation (scale 1:30.000)

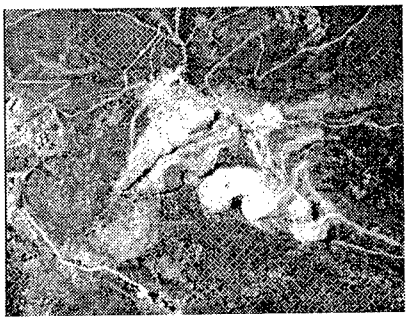


Figure 2. The quarrying site in 1969 (scale 1:15.000)

At this period the reactions of the inhabitants and the local associations were becoming intense because of the serious health and safety problems. However, the substantial reactions broke out at the end of the sixties. In May 1968, people complained about the raw materials that were blowing up to their yards, because of blasting. In January 1969, due to the exploitation extension towards the adjoining, under reforestation, areas the Bureau of General Forest Management requested from the Ministry of Industry the protection of Kareas[6]. Six months later and after the complaints of the inhabitants and the associations of Kareas region, about "annoyance, fissures and subsidence caused from blasting vibrations", the Inspection of Mining examined the safety rate of the exploitation workings[7].

The inhabitants reactions, until the end of the sixties, concerned only the impacts of mining affecting them directly (materials ejection, vibrations, fissures). The devastation of the visual scenery was not thought to be something of a problem until then. The bad living conditions did not allow people to see the long-term impacts on the environment in which they would continue to live.

2.2 Second Period : 1970 to 1979

The public response went through a radical change from the beginning of that period. The fact that the advent of the'70s was marked by the global change of route with reference to environmental issues (NEPA 1970, Conference of the United Nations on the Environment (Stockholm, 1972), etc.), it is not considered as accidental.

The number of people developing an awareness increased and they got actively involved. This became apparent also from the daily press of that period, concerning the quarry activities, and which were frequent and intense in nature. In the summer of 1970, articles were focused on the severe problems generated in the areas adjoining the quarries. A relevant article in a popular newspaper[8], a year later, pointed out that "the quarries blatantly disregard both the State and the public". As a matter of fact, it went on to refer to the "Stone Jungle of Athens" and made a special reference to the quarries of Kakorema. The public became aware of the severity of the problem and achieved to put forward, for the first time, the relocation of the quarries.

The dimensions that the issue gained, forced the government to take a stand to the problem and to provide necessary measures. From the beginning of 1972, all mining work at the quarries of Karea were banned (Royal Decrees No 770,771 and 773) on the grounds of public benefit (protection of the landscape, public health, etc.), as the company itself had never taken any preventive measures to deal with the problems (rehabilitation/visual pollution, etc.).

However, few months later, in July 1972, the companies of "Hymettus Quarries - K.Polydoros S.A." and "Quarrying Products Extraction LTD" signed a 5 year contract with the Greek State for the lease of the quarry site in Kakorema. In this contract, it was mentioned for the first time, the obligation of the quarries'owners to pay for the rehabilitation of the quarrying sites. It is also asked from them, to comply with the instructions of the Department of Mines for the accomplishment of some basic works : slopes excavation and shaping, banking up the area, reforestation, smoothing out of the old rough quarrying fronts, etc. In the context of this contract, a relocation of the mining fronts was effected at a distance of about 1500 m from their old location, so that the distance from the closest residential community would be more than 2 km. Initial planning provided the exploitation of the quarries to follow the method of vertical benches. However, the final method employed was the one involving the horizontal blastholes, which is strongly illegal (Regulation of Mining and Quarry Operation art. 80, par.3). Furthermore, this relocation marked the commitment of a new and larger in proportion crime against the environment, as the quarrying was relocated inside the mainstream of Kakorema, a region of inestimable ecological value and of vital importance for the safe drainage of the waters, resulting in high risk of floods and extensive disasters.

The total non-existence of any environmental planning, leaded, in 1975, to the first uncontrolled disposals within the quarry area. In the end of '75, some local associations accused in black and white the quarrying owners for "the uncontrolled debris' transfer and disposal in order to cover the old fronts"[9]. In December 1975, the Ministry of Public Services with its document to Attica's Prefecture, complained for the unhealthy state of the area, due to the operation of the quarries and the disposal of the municipal solid waste in the same location [10].

In 1976, the law 386/76 ceased all the quarries' exploitation in the area of Athens and Piraeus, which, despite its controversial results, indicated the explosive dimensions of the problem. The Inspection of Mining gave them a three year working extension, in order to prepare the quarry site for restoration. In 1979, the operation of Karea's quarries came finally to an halt. In the aerial photo

of 1979 (Fig.3), we can distinguish four working fronts with S-W direction and three steep slopes of disposals in the south area of the quarries.

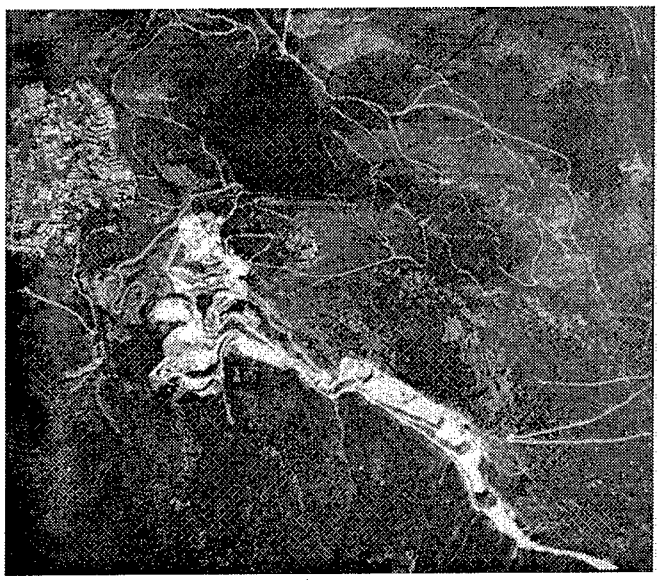


Figure 3. Aerial photograph of Kareas, towards the end (1979)of the quarrying activity (Scale 1: 15000).

Comparing the data of the 3-D digital reproduction of the quarry's contour in 1979 (before landfilling started) (Fig. 4) and the results of the drilling research, it is found out that there was a difference, approximately 10-15 m, in the estimation of the quarry's bedrock placement, between the results given by the drilling and the one given by the use of fotogrametry software. This obviously means that the exploitation of the quarry has gone on long after its official closure, magnifying, in an extreme point, the social suspicion against the mining activity.

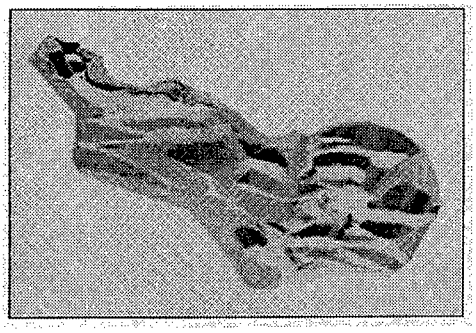


Figure 4. 3D digital reproduction of the quarry's state in 1979, using fotogrametry and G.I.S. (ARC/INFO™)

2.3 Third Period: 1979 to 1993

In the name of "environmental protection" and more specifically, in an effort to reform the area by covering the quarrying craters, a new calamity occured: from the year 1979, the area was covered uncontrollably with waste and debris. From 1985 and up to February 1993, the area was being used to dispose excavation and demolition materials under the supervision of the Ministry of the Environment, Spatial Planning and Public Works, while at the same time, the landfilling of municipal solid waste (MSW) was going on by the surrounding Municipalities. In this way, the quarry site was turned into the biggest uncontrolled landfill site in Greece, comprising of about 8.500.000 m^3 of debris and MSW. Therefore, new and more intense problems occured: visual pollution, landslide phenomena, biogas emmision, ground water pollution, etc.

While the management of the area had passed on from the private companies to the public agencies, no environmental protection seemed to be achieved. The state, which should represent the public interest, actually tolerated a new environmental disaster. In essence, the concept of environmental protection has not been incorporated as a permanent social value and a standard behavior.

Today, the rehabilitation of the area has come again to occupy the foreground as it could offer a significant opportunity to upgrade the whole area. The Ministry of Agriculture thinks that the full reforestation of the area is the only accepted scenario. The rest of the agencies are open to the possibility of application of some new uses provided that they would be of low intensity and compatible with the protection status. The Municipality of Vyronas expresses its concern on the hazardous nature of the landfill in Kakorema and is lobbying in the Ministry for Environmental Planning and Public Works for its rehabilitation. The latter assigned, in 1995, a contract for the Environmental Impacts and Rehabilitation Study of the area to the National Technical University of Athens (Laboratory of Mining Technology). Two alternatives have been proposed; a complete natural restoration with establishment of reformed landscape and a partial natural rehabilitation combined with some recreation uses. Unfortunately, this study has not yet put in practice.

3. CONCLUSIONS

The quarrying activity in the region of Kareas is strongly indicative of the relation between mining and society. Looking back at the activity's long history, a retrospection of such a relation could be formed, as follows:

- In the 1960s, mining still enjoys the privileges of complete "immunity" because of its vital importance, especially to the economic growth of the country. The reactions of the residents and especially those living in the surrounding area are limited and concerning exclusively health and safety problems.

- In the beginning of the 1970s, radical changes in the behavior of the citizens take place, as regards environmental matters. People begin to realise the necessity of a healthy environment in order to improve their life quality. However, the legal context stays behind in adapting the arising changes. The administrative measures taken, in the late 1970s, are incapable of protecting the environment adequately. The policy chosen, even in the middle of the '80s, is basically defensive and by being of a repressive character, can not achieve neither prevention, nor protection of the environment.

- In the 1990s, the environmental protection still doesn't constitute a deeply established social value as it is indicated by both the use of the place as an uncontrolled landfill and the inexcusable delay to apply the existed rehabilitation study.

- The relation between mining and society follows, in general, the social changes concerning environmental issues. However, the irrational exploitation, for many years, has resulted in a strongly negative social perception, as regards mining. Mapping an environmental policy and acquisition of objective responsibility are still the necessary requirements for the optimisation of the relations between society and mining.

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LOW-LEVEL CHEMICAL SENSITIVITY: AN EMERGING OCCUPATIONAL AND ENVIRONMENTAL HEALTH PROBLEM

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ABSTRACT

There is increasingly evidence that human exposure to levels of chemicals once thought to be safe--or presenting insignificant risk--are, in fact, harmful. So-called low-level exposures are now known to be associated with adverse biological effects through endocrine disruption, chemical sensitivity, and cancer. This requires that we change both (1) the way we think about chemicals and health, and (2) the solutions we devise to address chemically-caused injury. The new and emerging science of low-level exposure to chemicals requires appropriate social policy responses which include regulation of toxic substances, notification of those exposed, and compensation and reasonable accommodation to those affected.

ΧΗΜΙΚΗ ΕΥΑΙΣΘΗΣΙΑ ΧΑΜΗΛΟΥ ΕΠΙΠΕΔΟΥ: ΕΝΑ ΑΝΑΠΤΥΣΣΟΜΕΝΟ ΕΡΓΑΣΙΑΚΟ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΙΚΟ ΠΡΟΒΛΗΜΑ ΥΓΕΙΑΣ

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ΠΕΡΙΛΗΨΗ

Υπάρχει αυξανόμενη ένδειξη οτι έκθεση του ανθρώπου σε επίπεδα χημικών ουσιών που κάποτε θεωρούσαμε ασφαλή η χαμηλής επικινδυνότητας, είναι στην πραγματικότητα επιβλαβής. Σήμερα είναι γνωστό οτι η χαμηλού επιπέδου έκθεση συνδέεται με επιβλαβείς βιολογικές επιπτώσεις, όπως ενδοκρινική παρεμπόδιση, χημική ευαισθησία και καρκίνο. Αυτό απαιτεί αλλαγή 1) του τρόπου αντιμετώπισης των χημικών και υγείας, και 2)των μεθόδων αντιμετώπισης βλαβών που προκαλούνται από χημικές ουσίες. Χρειάζεται κατάλληλη κοινωνική αντιμετώπιση που συμπεριλαμβάνει έλεγχο τοξικών ουσιών, πληροφόρηση, αποζημίωση και φροντίδα όσων εκτίθενται

1. INTRODUCTION

While sensitivity to low levels of chemical exposures is not a new problem, it has been approached with renewed interest, and controversy, in the last decade, first in North America and more recently in Europe. The Canadian government first examined the problem of chemical hyper-reactivity in 1985 in its Thomson Report [1] and has since sponsored several workshops to help define a research agenda in this area. In the United States, the issue has been discussed and examined by state governments [2, 3], federal agencies, [4], the National Academy of Sciences [5], and a number of professional organizations through workshops, conferences, and position papers [6, 7, 8]. Chemical hyper-reactivity continues to engender scientific debate and controversy around issues relating to etiology, diagnosis, and treatment. While an increasing number of patients voice their concern and dissatisfaction with the response of the medical community and government to their illnesses which they believe are caused by exposure to low levels of chemicals in their environments, the scientific debate rages on; and the medical community continues to engage in sometimes acrimonious discussions about the nature of the problem.

As a result of an overview of the problem in North America [9], it is increasingly clear that low-level chemical sensitivity, rather than a clearly-defined disease entity, might be more correctly described as a class of disorders--like infectious disease--the members of which may present with similar symptoms, but which have a myriad of precipitating agents and pathophysiological pathways. Chemical sensitivity may be viewed as the *consequence* of a variety of disease processes resulting from "Toxicant-Induced Loss of Tolerance" (TILT). TILT is a new theory of disease providing a phenomenological description of those disease processes [9, 10].

In both the lay and scientific literature, a certain illogic attends the many observations made and approaches taken to unravelling this problem. Errors in logic confuse information relevant to cause, presentation and the evaluation of interventions related to the condition. The purposes of this paper are to draw upon recent work and observations in order to (1) contribute to a clearer way of thinking about chemical sensitivity and (2) to underscore the value of narrowing the focus of future enquiry to observations of event-driven studies, rather than concentrate on characterizing collections of patients who present with chemical sensitivity which they identify as having originated with a myriad of different exposure events and at varying times in the past.

2. DISTINGUISHING DIFFERENT TYPES OF SENSITIVITY

The different meanings of the term *sensitivity* are at least partially responsible for the confusion surrounding chemical sensitivity. Chemical sensitivity encompasses three relatively distinct categories:

1) The response of *normal* subjects to known exposures in a traditional dose-response fashion. This category includes classical allergy or other immunologically-mediated sensitivity.

2) The response of *normal* subjects to known or unknown exposures, unexplained by classical or known mechanisms. This category includes:

a) Sick building syndrome in which individuals respond to known or unknown exposures but whose symptoms resolve when they are not exposed to the building.

b) Sensitivity, such as that induced by toluene di-isocyanate (TDI), which begins as specific hypersensitivity to a single agent (or class of substances) but which may evolve into non-specific hyper-responsiveness described in category 3) below.

3) The heightened, extraordinary, or unusual response of individuals to known or unknown exposures whose symptoms do not completely resolve upon removal from the exposures and/or whose "sensitivities" seem to spread to other agents. These individuals may experience :

a) a heightened response to agents at the same exposure levels as other individuals;
b) a response at lower levels than those that affect other individuals; and/or
c) a response at an earlier time than that experienced by other individuals.

Patients suffering from what North Americans call multiple chemical sensitivity (MCS) [11] exhibit the third type of sensitivity. Their health problems often (but not always) appear to involve a two-step process. The first step originates with some acute or traumatic exposure, after which the triggering of symptoms and observed sensitivities occur at very low levels of chemical exposure (the second step). The inducing chemical or substance may or may not be the same as the substances that thereafter provoke or "trigger" responses. (Sometimes the inducing substance is described as "sensitizing" the individual, and the affected person is termed a "sensitized" person.) Acute or traumatic exposures are not always necessary. Repeated or continuous lower-level exposures may also lead to sensitization.

These "sensitized individuals" are not those on the tails of a *normal* distribution. They are thought to make up a distinct subset of the population. The fact that normal persons do not experience even at higher levels of exposure those symptoms that chemically-sensitive patients describe at much lower levels of exposure probably helps explain the reluctance of some physicians to believe that the problems are physical in nature. To compound the problem of physician acceptance of this illness, multiple organ systems may be affected, and multiple substances may trigger the effects. Over time, sensitivities seem to spread, in terms of both the types of triggering substances and the systems affected [9, 12].

Avoidance of the offending substances is reported to be effective but much more difficult to achieve for these patients than for classically sensitive patients because symptoms may occur at extremely low levels and the exposures are ubiquitous. *Adaptation* to chronic low-level exposure with consequent "masking" of symptoms is alleged to make it exceedingly difficult to discover these sensitivities and unravel the multifactorial triggering of symptoms [9].

Mechanisms to explain this third type of chemical sensitivity range from psychological to physiological--including neurological, immunological, and biochemical (or endocrinological) pathways [9]. Odor conditioning, perhaps involving both psychological and physiological mechanisms, has also been suggested [13].

This paper focuses for the most part on type 3 sensitivity, although hypersensitive sub-cohorts of individuals affected in tight buildings from traditional sick building syndrome (type 2a)--that is, those individuals who might not have recovered, but who experienced subsequent sensitivities--were thought to constitute a potentially useful group who could provide important information on low-level chemical sensitivity and overlap with other conditions such as chronic fatigue syndrome [14].

3. SEPARATING CAUSE AND EFFECT: DISTINGUISHING CAUSES, EFFECTS AND THE RESULTS OF INTERVENTIONS

In researching the presentation and characterization of low-level chemical sensitivity, it is useful to distinguish contrasting ways in which observations might be recorded. First, physician reports of individual patients can be examined. Since chemical sensitivity was first "discovered" by observant physicians, this might seem like a useful place to start, but there are difficulties with this approach. While physician reports contain much information about the patient's symptoms and complaints, they usually contain inadequate information about possible *initiating exposures or events* and *outcomes* of various interventions--both clinical and non-clinical. Moreover, information differentiating initiating events/exposures from subsequent sensitivities is often lacking or conceptually muddled. Since the precise nature of and mechanisms for chemical sensitivity remain ill-defined, information on possible initiating factors and effective interventions is crucial to improving our understanding of this somewhat bewildering condition. Also, each of the more prevalent effects can be caused by a multitude of biological mechanisms and environmental exposures. Therefore, the symptoms do not indicate the nature of the causality, which may be multifactorial.

Most physicians do not usually obtain occupational or environmental histories on their patients, and the patients themselves may not be fully aware of possible precipitating events or exposures. Moreover, physicians approach patients with their own disciplinary orientations and biases, making it difficult to compare reports on individual patients from different physicians. (Of course, different patients with their own convictions about the cause of their condition may also influence their physician's diagnosis.) For example, pulmonary physicians will tend to focus on respiratory symptoms and airborne contaminants, perhaps overlooking or discounting the more subjective (and possibly equally bothersome) central nervous system (CNS) complaints. Indeed, chemically-sensitive patients often go from physician to physician, acquiring different diagnoses and labels -- from organic brain syndrome to chronic fatigue syndrome to psychosomatic disease. Since there seems to be few proven effective medical interventions for these patients, the eventual outcome of the condition and possible success of various interventions (such as avoidance, food rotation, or simply just letting time pass) may not be known to the diagnosing physician or clinic.

Finally, isolated case reports suffer from being symptom/syndrome-focused in patients with health problems that might be induced by a wide variety of different initiating exposures or events. This has compounded the difficulty in understanding the origins of chemical sensitivity. We have earlier suggested that low-level chemical sensitivity might be more correctly described as a class of disorders, like infectious diseases, the members of which may present with similar symptoms, but whose different causes and pathways need to be particularized to successfully address them. The different forms of chemical sensitivity may be differentially precipitated by psychosocial events or stress, or by different physical or chemical exposures. The presenting symptoms--whether objective or subjective--are not necessarily indicative of etiology.

Causes, symptoms, and interventions can each be characterized as physiological (**P**) or psychological. Both physiological and psychological stressors can precipitate either physiological or psychological symptoms, or both. Psychological interventions (such as biofeedback and social support) can alleviate some aspects of physical disease. Neither the nature of symptoms, nor the successes of interventions, are dispositive of the origins of a condition. Schematically, the three factors -- causes, symptoms, and interventions -- can be represented as separate "dimensions" of illness (Figure 1). Physicians and researchers may operate in different "quadrants." For example, a physician may believe that the cause of a particular patient's chemical sensitivity is physiological,

observe CNS (psychological) symptoms, and treat with biofeedback or other coping (i.e., psychological/behavioral) interventions. In contrast, a researcher may assume stress as the "cause," observe asthma as a consequence, and investigate the use of new drugs to alleviate the symptoms. What is disappointing in much of the literature is the continuing failure to distinguish causes and symptoms of the condition and unjustified conclusions drawn from successes or failures of possible interventions. Although lip service is given to making these distinctions, at the end of the day, the failure to find consistent objective markers of disease [15] or the finding of a history of childhood abuse in some patient groups [16] lead the authors to lean very heavily in the direction of psychogenic causes and the recommendation of psychological interventions, rather than physiologic causes and the avoidance of future exposures as a treatment modality. Even a recent review of some of the literature on low-level chemical sensitivity [17], while acknowledging the multifactorial origins of this condition, ends up recommending psychological interventions as the only acceptable treatment modality. Inasmuch as great uncertainty continues to characterize this condition, these views are premature and perhaps even harmful to patients [18]

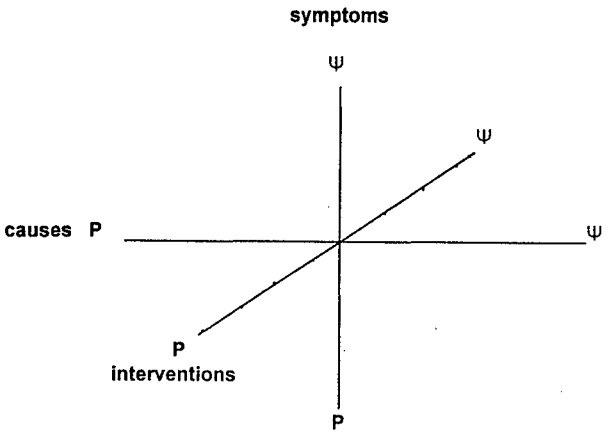


Figure 1. Schematic Representation of the Three Dimensions of Illness

4. EMPIRICAL APPROACHES TO UNRAVELING THE MYSTERIES OF LOW-LEVEL CHEMICAL SENSITIVITY

The need to distinguish information that might elucidate causes, presentation and the success of interventions having been discussed above, physicians' observations may be more helpful when: 1) the physician sees a large number of chemically-sensitive patients, takes a complete exposure history; and recognizes subgroups that give clues to different origins and successful interventions of each; 2) the physician happens to see a group of patients who have experienced the same or similar events or exposures, such as living in the same neighborhood or apartment building or using the same type of product, such as new carpets; 3) the physician specializes in occupational or environmental medicine and sees patients with similar exposures, occupations, or environmental histories; or 4) the physicians are specialists -- for example, pulmonary or ear, nose and throat physicians -- who concentrate on specific organ systems and are more likely to recognize subsets of patients who present with

problems uncharacteristic of the majority of patients with the same illness. For example, patients whose asthma is precipitated by perfumes, detergents, and clothing stores may constitute a chemically-sensitive subgroup of special interest. In order for these types of fortuitous observations to provide clarification of chemical sensitivity, the occurrence of some of the different presentations of chemical sensitivity would have to be reasonably large.

Perhaps more informative would be observations on the natural history of chemical sensitivity associated with particular *incidents* or *exposure events* rather than isolated case reports. Event-driven information includes both 1) disease or symptom outbreaks in particular communities, buildings, workplaces, or occupational groups and 2) events/scenarios reported as related to chemical exposures commonly found in certain occupations and those from particular building materials, consumer products, anesthetics, and ethical drugs. Studies of collected case reports or multiple case reports linked to specific incidents or exposure events might be particularly useful. Identification of events or exposures that could be followed over time may be more likely to be reported by public, environmental, or occupational health authorities, compensation or disability agencies, affected individuals, trade unions, and patient associations rather than by physicians. While retrospective investigations may be helpful, prospective studies (for example of greenhouse workers or occupants of newly-renovated office buildings) might yield useful perspectives, especially if the cohort is followed for a sufficiently long period of time.

Already mentioned is the necessity of accounting for adaptation or the masking of symptoms in observing the symptoms of patients with alleged low-level chemically sensitivity, the possible confounding of observations resulting from the use of therapeutic drugs, and the failure to investigate food intolerances in patients with possible low-level chemical sensitivities [9]. Researchers and clinicians who ignore these concerns, and then find no consistent markers, symptoms, or success in chemical avoidance can not rightfully claim to have tested or investigated the many hypotheses suggested for this condition [19].

5. COMPARISON OF EUROPEAN AND NORTH AMERICAN EXPERIENCES WITH LOW-LEVEL CHEMICAL SENSITIVITY

The limited data available at this time from North America and Europe suggest that low-level chemical sensitivity is *not* a single, distinct clinical entity. Clinical presentations are extraordinarily diverse, a major reason why consensus on a case definition for the illness has been so difficult to achieve despite numerous attempts [9, 20]. Symptoms appear to involve any and every organ system or several systems simultaneously, although central nervous system symptoms such as fatigue, mood changes (irritability, depression), and memory and concentration difficulties predominate. Even among persons who have shared the same initiating exposure, symptoms and severity differ markedly. Ultimately, chemical sensitivity may be more accurately characterized as a *class* of disorders, like infectious diseases, which share a common general mechanism, yet within the class, particular members may involve different symptoms, agents, and specific mechanisms.

From European [21] and North American observations [9], a wide range of environmental exposures appear able to initiate the problem. While implicated chemicals are structurally diverse, certain ones appear again and again on both continents:

1. Pesticides are frequently cited in North America and Europe, with the exception of Sweden, Finland, and the Netherlands, where indoor use of pesticides may be less frequent as a consequence of cooler temperatures and reduced insect populations. Organophosphate and carbamate pesticides

are those most often reported as causing illness in the United States, but this may simply reflect the fact that these are among the agents most commonly applied. The greater symptom severity reported by chemical sensitivity patients exposed to organophosphates versus remodeling, summarized earlier in this paper, suggests that some compounds in this class might be especially potent sensitizers, at least for a subset of the population.

2. Organic solvent exposure was cited in every European country surveyed and is commonly cited in North America. Such exposures frequently occur in the workplace and are more often chronic than acute in nature.

While there are consistent observations regarding causes of chemical sensitivity between continents, there are also notable differences, for example, the so-called "wood preservative syndrome" associated with pentachlorophenol use in Germany [22].

Although Sick Building Syndrome (SBS) is widely recognized in the Scandinavian countries where a number of internationally-known researchers are engaged in its study, instances of SBS *per se* did not generally reveal chemically sensitive subgroups. Conceivably, preoccupation with immediate effects may have obscured their discovery. Certainly, there was no indication of a large problem in those instances. Initiating experiences with carpets were noted, however. If future inquiry were to reveal that chemical sensitivity does not occur in even a subset of individuals in European SBS episodes, this finding might suggest the importance of other factors, for example, the use of wall-to-wall carpeting (common in the United States and relatively infrequent in Europe), or use of certain fragrances, air fresheners, cleaners, and/or extermination practices.

In both Europe and North America, patients report spreading of their sensitivities to an array of common exposures, including fragrances, cleaning agents, engine exhaust, alcoholic beverages, foods, and medications they formerly tolerated without difficulty. The fact that many of these individuals voluntarily forego pizza, chocolate, beer, or other favorite foods because they make them feel so ill warrants consideration—there is little secondary gain to be garnered from such forbearance. Many participants in North America reported that drugs, ingestants containing chemical additives (monosodium glutamate, chlorinated tap water), and food-drug combinations (alcoholic beverages or xanthine-containing foods) made them ill, a finding consistent with a hypothesis that these individuals exhibit amplified responses to pharmacologic doses of a variety of substances [23].

Generally speaking, awareness of chemical sensitivity may be greater in countries with more environmental activism, but illnesses resembling chemical sensitivity were described in every European country that was studied [21]. The practice of clinical ecology, a homeopathic, naturalistic, and holistic medical approach to chemical exposures, had it's origin in the United States. The fact that it has spread to other English-speaking nations, including Canada and the United Kingdom, no doubt have influenced the numbers of patients receiving a diagnosis of chemical sensitivity in those countries. Discord among physicians as to what constitutes appropriate diagnostic and therapeutic approaches in these countries permeates professional meetings, medical journals, and court proceedings. Where patients must "prove" a particular exposure caused their illness in order to receive worker's compensation or reimbursement for medical expenses (as in the United States where there is no national health care system), disputes between medical practitioners (who may testify on opposing sides) are most contentious.

Cultural practices may affect the prevalence of chemical sensitivity. In some European countries, people typically spend several hours each day out-of-doors, for example, walking to work or shopping, and windows in homes and offices may be left open part or most of the day. In contrast, on average, Americans spend 90% or more of the day indoors, often in tightly-sealed structures, where levels of certain volatile organic air contaminants can be orders of magnitude higher than out-of-doors.

Choices of building construction materials and furnishings also vary greatly between countries, including use of wall-to-wall carpeting versus washable throw rugs or no floor coverings at all; solid hardwood furnishings versus particle board or pressed wood; paint, wallpaper, and adhesive constituents; office equipment, including photocopiers and computers, etc.

Ventilation practices may be similarly diverse. Tightly-constructed buildings with little fresh make-up air built in North America since the oil embargo of the mid 1970's could be a factor that explains the apparent increase in chemical sensitivity cases over the past two decades in the United States and Canada. The experience with SBS, but not chemical sensitivity, in Scandinavia merits closer examination to determine whether the latter condition has thus far escaped attention or whether environmental or perhaps genetic or cultural differences may prevent development of the condition.

Use of chemicals also varies from country to country, in particular, pesticides, cleaners, and personal care products, including fragrances. Comparing differing rates of consumption of these products, as well as pharmaceuticals, and the incidence of chemical sensitivity among countries, could provide further clues.

6. CONCLUSION

Complex questions concerning the origins and mechanisms of chemical sensitivity will not be resolved by retrospective survey studies--indeed, probably not by retrospective studies of any kind. Perhaps more informative would be prospective observations on the natural history of chemical sensitivity associated with particular *incidents* or *exposure events* rather than isolated case reports. (See especially a recent comparison of persons identifying the onset of their chemical sensitivities from organophosphate pesticides with persons identifying newly- remodeled building environments as the origin of the onset of their sensitivities [24]). In addition, enlightening similarities and instructive differences can be gleaned from future, more directed cross-country comparisons of experiences with chemical sensitivity.

In the past five years in the United States, controversies surrounding chemical sensitivity have exploded far beyond the narrow confines of a medical debate into a national debate with far-reaching policy and regulatory implications. Most recently, a number of U.S. Persian Gulf veterans have reported multi-system health problems and new-onset intolerances to chemicals, foods, and other substances since returning from the war [9, 25]. Some have received a diagnosis of chemical sensitivity from private physicians and now seek medical care and compensation for the condition. Such trends in North America could be mirrored in European countries over the next few decades.

Understanding chemical sensitivity is pivotal to establishing sound environmental policy. If there is a subset of the population that is (or can become) especially sensitive to low-level chemical exposures, a strategy for protecting this subset must be found. If it were to be determined that certain chemical exposures can lead to sensitization, then perhaps these exposures could be avoided. Perhaps by preventing chemical accidents, prohibiting occupancy of buildings prior to finish-out or completion,

avoiding use of certain cholinesterase-inhibiting pesticides indoors, etc., society could protect more vulnerable individuals from becoming sensitized in the first place. It would make little sense to regulate chemicals at the parts per billion level or lower if what was required was to keep people from becoming sensitized in the first place. Indeed, by understanding the true nature of chemical sensitivity and who is at risk, we may prevent unnecessary and costly overregulation of environmental exposures in the years to come.

Chemical sensitivity could be the result of a new mechanism/paradigm of disease--Toxicant-Induced Loss of Tolerance--that has the potential to explain many chronic and costly illnesses, including fatigue, depression, headaches, and asthma, or it could continue to elude definition. By not understanding chemical sensitivity, we take an immense gamble. But knowledge will not come cheaply. Future studies on chemical sensitivity that involve double-blinded, placebo-controlled challenges in a controlled environment, that utilize brain imaging, state-of-the-art immunological testing or other sophisticated tests, and that compare adequate numbers of patients and controls, will be costly, but necessary. Funding agencies will need to invest adequate sums to acquire answers in this area as they have for other diseases, such as breast cancer and AIDS. Until sufficient research funds become available, chemical sensitivity no doubt will continue to pit physician against physician, perplex both scientists and policy makers, and frustrate patients and corporations alike.

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CONSEQUENCES OF NUCLEAR ACCIDENTS IN KOZLODUY SITE-DECIDING ON STABLE IODINE TABLETS DISTRIBUTION

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ABSTRACT

Amongst the major problems in making decision immediately after a nuclear accident are the countermeasures to be taken by the authorities to avoid contamination of the people, particularly of the youngest ones. Stable iodine tablets distribution could be an action of preference. Estimations of total thyroid doses in Greece and neighboring countries through COSYMA code from a potential accident that occurred in Kozloduy nuclear power plant, are given. These estimations can be used to support the decision makers on the advisability of use of stable iodine tablets as a relevant countermeasure.

ΣΥΝΕΠΕΙΕΣ ΠΥΡΗΝΙΚΩΝ ΑΤΥΧΗΜΑΤΩΝ ΣΤΟΝ ΠΥΡΗΝΙΚΟ ΣΤΑΘΜΟ ΚΟΖΛΟΝΤΟΥΙ - ΠΙΘΑΝΗ ΧΟΡΗΓΗΣΗ ΧΑΠΙΩΝ ΙΩΔΙΟΥ

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ΠΕΡΙΛΗΨΗ

Από τις σημαντικότερες αποφάσεις που πρέπει να ληφθούν από τις αρχές μετά από πυρηνικό ατύχημα, ώστε να αποφευχθεί ραδιενεργός μόλυνση του πληθυσμού και ειδικότερα των νέων, είναι τα μέτρα έκτακτης ανάγκης. Μεταξύ των μέτρων αυτών περιλαμβάνεται η διανομή χαπιών ιωδίου. Με τον κώδικα COSYMA υπολογίσθηκαν, για τις γειτονικές χώρες και την Ελλάδα, οι δόσεις στο θυροειδή ως αποτέλεσμα ατυχημάτων στην πυρηνική εγκατάσταση του Κοζλοντούι. Οι εκτιμήσεις αυτές μπορούν να υποστηρίξουν αποφάσεις χορήγησης χαπιών ιωδίου.

1. INTRODUCTION

The Kozloduy nuclear power station is the nearest one to Greece. Its site is at the northern border of Bulgaria, by the river Danube, at a distance of about 225 km from the nearest border of Greece, about 360 km from the city of Thessaloniki and 640 km from the city of Athens. The station is composed by six pressurized water reactors, four of them of WWER-440 type, and the other two of WWER-1000 type. National and international attention in improving the safety of these reactors has resulted in substantially safety enhancement. Nevertheless, the fact that it is the closest nuclear power station to Greece, creates a big concern for the Greek population about the possible effects of a nuclear accident in one of these reactors, particularly to one of the biggest.

Owing to the fact that stable iodine tablets distribution is helping to prevent high doses from inhalation of the radioactive isotopes of iodine, releases of radioactive nuclides of iodine only have been considered. The scenario considered is a reference one [3]. Estimations of the consequences were made by using the PC COSYMA [1] accident consequence assessment code. These estimations can support decisions on the use of stable iodine tablets, in Greece or neighboring countries, in case of such an accident. PC COSYMA is a code developed over a period of ten years by the EU and it is used to perform deterministic and/or probabilistic calculations of potential off-site consequences of atmospheric releases of radioactive material. It simulates the progression of the radioactive cloud released from the reactor in the event of an accident and predicts its interaction with and influence on the environment and human beings.

2. REACTOR CORE INVENTORY, RADIOACTIVE RELEASES CHARACTERISTICS AND DATA USED

The radioactive inventory source of the WWER-1000 reactor unit with thermal power rating of 3000, was estimated by linear scaling of a WWER-440 inventory with a thermal power of 1375 MW, at the end of its cycle [2-3]. The radioactive iodine isotopes inventory is presented in Table 1. The accident chosen involves releases of these isotopes in two phases, of the duration of one hour each, at a height of 10 m, beginning 4 hours after shutdown. The heat content of the effluents amounts to 28 MW/h for a total of 56 MW. The characteristics of this release are presented in Table 2.

TABLE 1. Radioactive iodine isotopes inventory in Bq.

I-131	2.930E18
I-132	4.327 E18
I-133	6.192 E18
I-134	6.672 E18
I-135	5.832 E18

TABLE 2. Characteristics of the release of the reactor effluents.

Type of accident	Core melt
Time before release (hr)	4
Duration of release (hr)	2
Release height (m)	10
Total rate of release (MW)	56

A release fraction equal to 1.0E-01 has been considered. The deposition velocity was taken equal to 0.001 m/s. A constant washout coefficient of 8.00E-05 has been taken into consideration. The reactor building is about 76.4 m high and 156 m wide [4].

A Hungarian meteorological file typical of Central Europe meteorological conditions has been used. The meteorological record consists of 8760 hourly observations of wind speed, atmospheric stability, mixing height and accumulative precipitation. The atmospheric turbulence is classified by the empirical turbulence - typing scheme of Pasquill and Gifford [5], which assigns the grade of

atmospheric stability to six diffusion categories (category A for very unstable conditions, category B for moderately unstable conditions, category C for slightly unstable conditions, category D for neutral conditions, category E for moderately stable conditions and category F for very stable conditions). Pre-selected mixing height values have been used, depending on the stability class (1600 m for category A, 1200 m for category B, 800 m for category C, 560 m for category D, 320 m for category E, 200 m for category F). A probabilistic run has been undertaken using a stratified sampling scheme [6] in which sequences of conditions on the meteorological data file for which the consequences are likely to be similar are combined into groups. Sequences are then chosen at random from those within each of the groups, and assigned a probability based on the number of sequences allocated to each group and the number selected from within each group.

The demographic data utilized are those included in COSYMA population data bank. For Bulgaria and Rumania they are taken by atlases edited at the beginning of 1980 while for EU countries the data are much more recent [7]. For Greece the 1991 national census data were used, providing for the area under study to about 10.244.042 inhabitants [8]. PC COSYMA default values have been used for the rest of the parameters. The latter include the meteorological parameters such as the wind profile exponents by stability category, sigma -y, sigma-z and horizontal standard deviation by stability category and by height, and various dose related parameters such as the breathing rate, dose response factors, cancer risk factors (factors according to ICRP-60 [9] have been chosen), various re-suspension parameters, etc.

The distribution of stable iodine tablets is considered as the means of reducing both early and late health effects. Early effects in this case mainly include skin burns and hypothyroidism and late effects include fatal and non fatal cancers in the thyroid, lung and other parts of the body and hereditary effects. Two strategies have been analyzed: 1) Iodine tablets are distributed to all persons within a circle of a certain radius, or 2) iodine tablets are distributed only if the estimated integrated thyroid dose from inhalation over a time period of 365 days exceeds a given value. The reduction of dose achieved depends on the relative timing of taking the tablets and the inhaling material from the plume. It was assumed, in both strategies, that the tablets are taken by the population 4 hours after the accident. In all cases the time for the integration of the thyroid dose was assumed 365 days and the dose threshold for tablets distribution was set equal to 0.2 Sv.

3. RESULTS

Five scenarios have been considered. The first, base case, assumes no iodine tablet distribution and serves as a comparative base. The next three scenarios assume iodine tablet distribution to the population inside a circle of radius 5 km, 10 km, 15 km, respectively. Finally a fifth scenario assumes distribution of iodine tablets only to those individuals expected to receive a dose exceeding 0.2 Sv, regardless of the distance from the plant. The long term mean collective doses to the thyroid, in manSv, for each of these scenarios have been calculated and are presented in Figure 1.

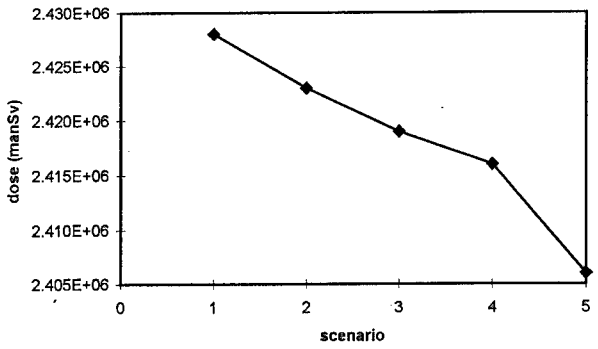


Figure 1. Mean collective dose to the thyroid for different cases of iodine tablet distribution to the population.

Figure 2 presents the excess late health effects (mortality from thyroid cancers) in 50 years with respect to the fifth scenario. These results indicate that "maximum" protection (scenario #5) achieves a reduction of 18 late health effects over scenario #1 that assumes no iodine-related protective measures. Corresponding reduction of late effects for the other scenarios (2,3, and 4) are also indicated. It is noteworthy that the variation between the various cases is not substantial.

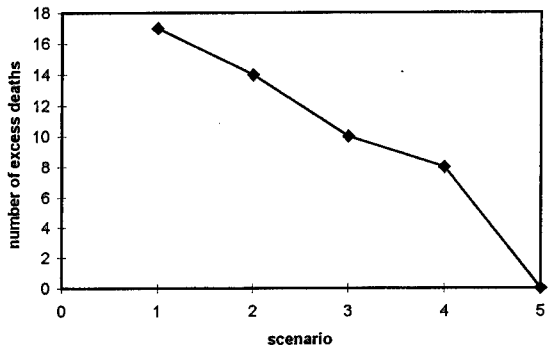


Figure 2. Number of excess deaths from thyroid cancers in 50 years.

Figure 3 gives the number of persons receiving stable iodine tablets immediately after the nuclear accident as a function of the scenario.

Results given in Figures 1 and 3 indicate that the high number of persons receiving tablets according to the scenario # 4, does not result in a substantial reduction of collective doses. In Figure 4 the area (in km^2) affected by stable iodine tablets distribution is presented for all the scenarios.

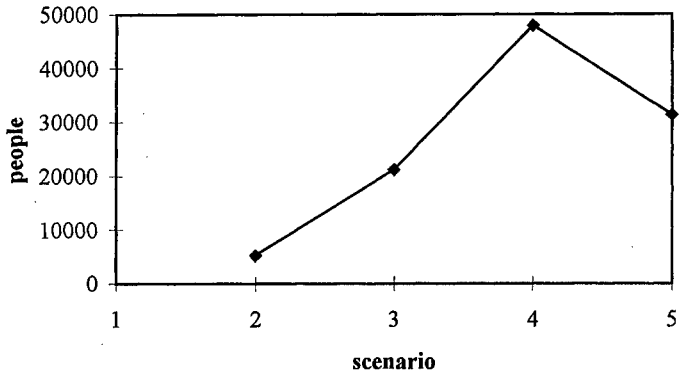


Figure 3. Number of persons receiving stable iodine tablets.

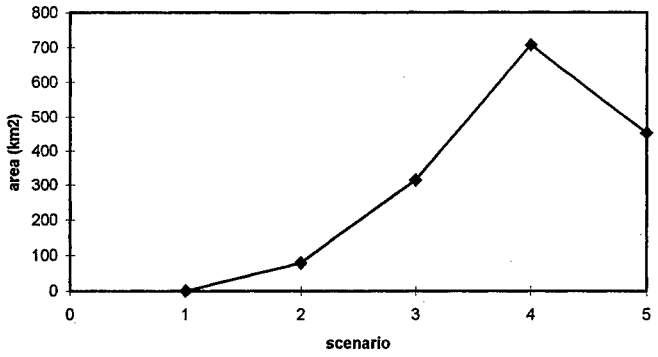


Figure 4. Areas in km^2 affected by stable iodine tablets distribution.

4. CONCLUSIONS

Stable iodine tablet distribution does not have a significant impact on the collective doses and the resulting health consequences. In case of the serious accident considered, it is evident that the population of south Romania and north Bulgaria would principally suffer of the consequences. It could be protected against high thyroid doses, through stable iodine tablets distribution up to a distance of 5 km. Within this distance the number of people that have to receive iodine tablets is relatively small, so that quick administration is achievable. Beyond that distance the protection with tablet distribution in various areas around the site of the nuclear power plant should not result in a significant gain in reduction of late effects.

5. ACNOWLEDGMENTS

We acknowledge Dr. I. A. Papazoglou for his helpful remarks.

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Poster presentations
(summaries)

HOW GOOD THE ESTIMATE OF THE DAILY MEAN AIR TEMPERATURE IS, IF BASED ON DAILY MIN-MAX AIR TEMPERATURE DATA?

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ΠΟΣΟ ΚΑΛΗ ΕΙΝΑΙ Η ΕΚΤΙΜΗΣΗ ΤΗΣ ΜΕΣΗΣ ΗΜΕΡΗΣΙΑΣ ΘΕΡΜΟΚΡΑΣΙΑΣ, ΠΟΥ ΥΠΟΛΟΓΙΖΕΤΑΙ ΑΠΟ ΤΙΣ ΜΕΤΡΗΜΕΝΕΣ ΗΜΕΡΗΣΙΕΣ ΑΚΡΑΙΕΣ ΤΙΜΕΣ;

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1. INTRODUCTION

The mean air temperature is an important meteorological and climatological parameter, especially for environmental studies. The main fear from the green house effect, due to the growing concentration of the CO_2 gas in atmosphere, is the raise of the mean temperature on the surface of the globe. Apart from pure climatological use, the daily mean air temperature is used in many sequential estimates of practical interest, as that of evapotranspiration, heating energy needs, snow melting etc. [1].

The Class I meteorological stations measure continuously temperatures by thermographs (mechanical, electric or electronic) and daily min-max temperatures by minimum thermometers and maximum thermometers. The number of these stations is quite limited, as the standards of operation and the relative cost are quite important. A very large number of Class II and III meteorological stations exists, where only the daily extremes (min-max) are recorded, by simple, though very precise, min-max thermometers.

The common practice, when a thermograph is not in use, is the estimation of the daily mean temperature as the mean of the daily extreme min and max temperatures. The analysis of a continuous temperature data series from an electronic thermograph proves that this practice is not a reliable technique. This remark underlie also in some remarks considering the homogeneity of mean daily temperature time series [2].

2. THE DATA ANALYSIS

The data used for the analysis of the reliability of the estimation of the mean air temperature based on the daily min-max temperature data are the 5′ mean temperature recording by a Davis automatic meteorological station. The precision of the data has been controlled by comparison with the equivalent data from the Aristotle University official Meteorological Station that uses classical mechanical instruments.

The mean daily temperature from continuous recordings is computed by:

$$T_{dmean} = \frac{1}{n}\sum_{i}^{n} T_i \quad , \quad n = \frac{24 \times 60}{\Delta\tau} = 288 \quad , \quad \Delta\tau = 5' \qquad \text{Eq. 1}$$

The mean daily temperature based on min-max data is computed by:

$$T^{*}_{dmean} = \frac{T_{d\max} + T_{d\min}}{2} \qquad \text{Eq. 2}$$

Where:

T_{dmean} = 24 hours (daily) mean air temperature
$T_{d\min}$ = 24 hours (daily) min. air temperature
$T_{d\max}$ = 24 hours (daily) max. Air temperature
T_i = Instantaneous or brief time interval ($\Delta\tau$) air temperature

It is obvious that not only the recording of two values (min-max) is simpler, but also the computation of T^{*}_{dmean} instead of T_{dmean} from the 288 daily values is by no means easier to do by hand. If we use digital recording and automatic computer computation, then neither the continuous recording or the computation of the mean poses any problem. The main difference lay on the cost of equipment needed in each case. The simple min-max thermometer costs from 10 US$ (for consumer, not approved for Scientific use, thermometers) to 300 US$ (for high precision thermometers). The cost for a small automatic electronic digital recording weather station starts from 2500 US$.

3. RESULTS AND CONCLUSIONS

A year of recorded temperatures (Mars 1997- April 1998) has been analyzed. The computation of the mean daily temperature, based on the daily min-max temperatures, proved that an overestimation of + 1.5° C or an underestimation of - 0.5° C was common, especially for the summer. The study of the published data of the Meteorological Institute of the Aristotle University [2] gives similar results. These results generate some questions on the reliability of studies that use min-max temperature series from local stations. For example, the basic scenario for Climatic Change effect is a +1.0° C mean temperature raise. That is less than the range of the error on mean daily temperature, if computed from the minimum and maximum temperatures.

The question that comes next is whether any correction procedure could give more precise estimation of the daily mean temperature, when no continuous recordings are available. This study is continuing on in an effort to determine corrections based on season and temperatures of the fore and after days.

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IMPROVING ENVIRONMENTAL IMPACT ASSESSMENT IN GREECE

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ΠΡΟΤΑΣΕΙΣ ΓΙΑ ΤΗ ΒΕΛΤΙΩΣΗ ΤΗΣ ΕΚΤΙΜΗΣΗΣ ΠΕΡΙΒΑΛΛΟΝΤΙΚΩΝ ΕΠΙΠΤΩΣΕΩΝ ΣΤΗΝ ΕΛΛΑΔΑ

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ABSTRACT

The Environmental Impact Assessment (EIA) process is a tool that integrates environmental considerations into decision making and thus can contribute significantly to the protection and restoration of the environment and to sustainable development. Strengthening the public participation and improving the quality of Environmental Impact Statements (EISs) are considered to be of major importance for improving the EIA process in Greece. This paper is based on work undertaken for EIA in Manchester University and Aristotle University of Thessaloniki and practical experience from working on a Greek NGO, the Hellenic Ornithological Society.

The public participation stage is probably the most sensitive issue for Greek EIA. One of the reasons is that the concept was just introduced in 1990, when the EIA directive 85/337/EEC was activated by Greek legislation. Before that time, there was a type of environmental assessment in operation in Greece, but it did not involve any public participation. However, the preparation of environmental statements for industrial projects goes back to the early 80's.

An evaluation of the quality of a sample of 12 Greek EISs was undertaken using the Environmental Statement Review Package, developed by Lee and Colley in 1992. According to the assessment results only 17% of the EISs in the sample were assessed as of "good" quality, 33 % were "borderline" and 50% "poor". However, given that the sample of the EIS evaluated was small and not representative, the results should only be considered as providing an indication of overall EIS quality in Greece. Deficiencies identified in Greek EISs, which in part relate to incomplete legal requirements, include: lack of non technical summary, very weak or no consideration of alternatives, lack of methods for determining the magnitude and significance of impacts, poor commitment to mitigation and lack of consideration of the general public's opinion.

Some of the weaknesses of the EISs are obviously related to poor public participation in the EIA process in Greece which in turn may influence significantly the quality of the Greek EISs. The main

problems of public participation stage in Greece are related to : the lack of public participation requirement during siting approval, the limited period allowed for the public's response, the reduced availability of the EIS and relevant information and the lack of the necessary experience and training on public participation for all parties involved.

The improvement of these two important stages of the EIA process requires changes to the legislation, preparation of guidelines for the environmental assessment of different types of projects and promotion of short term training courses for all groups of people involved.

Despite of improvements to the stages of the EIA process, project-level EIA has limitations that can be resolved by Strategic Environmental Assessment (SEA). However, SEA is absent in the Greek EIA system. This is probably related with problems in acceptance of public participation on a higher level but also, in several occasions, with the lack of concrete policies, plans and programmes which should be assessed by SEA. The importance of SEA is currently recognised by several countries and the European Commission. Future SEA provision should be made which, inter alia, could contribute to the promotion of sustainable development in Greece.

The poster presentation will both elaborate on the review of the current Greek EIA situation and on proposals for its improvement.

ACKNOWLEDGEMENTS

This work was based on the MSc dissertation on "The Environmental Impact Assessment Process in Greece : Analysis of Stages and Evaluation" (Vareltzidou, 1996) which was completed under the joint supervision of Dr. Despoina Vokou, Assistant Professor of the Biology Department at Aristotle University of Thessaloniki and Dr. Norman Lee, Senior Lecturer and Co-Director of the EIA Centre at the University of Manchester.

THERMODYNAMIC ASPECTS IN ENVIRONMENTAL CALCULATIONS

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ΥΠΟΛΟΓΙΣΜΟΙ ΙΣΟΡΡΟΠΙΑΣ ΦΑΣΕΩΝ ΣΕ ΠΕΡΙΒΑΛΛΟΝΤΙΚΑ ΣΥΣΤΗΜΑΤΑ

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In a variety of applications of environmental significance it is required to consider thermodynamic information mostly in the form of phase equilibrium data. Such applications include the transport of chemicals to the environment, occupational risk assessment, partitioning of the chemicals in the various ecosystems, risk analysis and design of separation - waste-treatment methods such as carbon adsoprtion and the novel supercritical fluid extraction.

Due to the importance of water in most studies, physical chemical relations and interactions between pollutants and water are of utmost importance. Risk analysis require that the partitioning of pollutants in the various ecosystems are known. This partitioning is traditionally expressed in environmental science with the various distribution (equlibrium) coefficients of which the octanol-water one (Kow) is the most important. The importance of Kow lies in two reasons:

i. All other partition coefficients e.g. organic carbon or soil-water can be expressed as a function of Kow
ii. The bioconcentration factor i.e. the accumulation of a pollutant in the lipid phase of an aquatic organism is a relation of Kow

The literature of Kow values is extended for simple pollutants. However, the data for complex pollutants (containing at least two functional groups) are scarce. Since the experimental determination of Kow may be cumbersome and time-consuming / expensive for structurally complex pollutants, predictive computational techniques are required.

Thermodynamics offers relationships usually in the forms of equations of state and activity coefficient models which can, in principle, be applied in the equilibria water / octanol / pollutant and thus assess Kow. The most important problem here is that since traditional phase equilibrium models were designed for chemical rather than for environmental engineers, they were addressed to the problems of chemical, oil and petroleum industry. In the latter, relatively simple systems of the type gas (e.g. methane, carbon dioxide) and hydrocarbons are involved. Thus most models applicable to the problems of oil and related industries cannot be extended to environmental systems. One exception is the UNIFAC activity coefficient model which was originally proposed in 1975 by Fredenslund and co-workers. UNIFAC is based on the group-contributions concept and is able to predict activity coefficients for complex systems. In particular the recent extension of UNIFAC to environmental systems by introducing new parameters based on phase equilibrium data for water

systems (Chen et al., 1993, Chemosphere, 26(7): 1325) yields improved Kow predictions. Still, an inherent limitation of group-contribution principle on which UNIFAC is based is in the treatment of chemicals with more than two functional groups such as OH, COOH, etc. in which the so-called proximity effects are very strong. Additive methods cannot adequately account for these effects often present in the many environmental systems.

In this work sample Kow calculations are reported for selected hydrocarbon pollutants with UNIFAC, UNIFAC-water by Chen et al., and the novel equation of state abbreviated as sCPA developed by IGVP. sCPA stands for simplified Cubic Plus Association and represents an equation of state suitable for associating fluids where strong hydrogen bonding effects are present (for example alcohols, phenols, water, acids, glycols, amines, etc. as well as those chemicals including hydroxyl and other similar groups). The importance of such compounds in environmental discipline is obvious since both water and a large number of pollutants are included in this family. sCPA is capable of treating these systems since, in addition to the usual term for the physical interactions, it contains an extra term based on perturbation theory (Statistical Mechanics) which accounts for the hydrogen bonding interactions. Different association sites and schemes are employed for each associating compound depending on the physical picture. For example, acids which are known to dimerize have one association site, alcohols and phenols form multi-chain oligomers and have two sites while water forming three-dimensional networks has four association sites. The implementation of the association term in sCPA is done in a rigorous but still simple from the application and industrial points of view methodology.

sCPA equation of state has been proposed Kontogeorgis et al. (Kontogeorgis et al., 1996, Ind. Eng. Chem. Res., 35: 4310) and has been already applied to a wide range of applications including alcohols/ hydrocarbons vapor-liquid equilibria (Yakoumis et al., 1997, Fluid Phase Equilibria, 130: 31), and liquid-liquid equilibria (Voutsas et al., 1997, Fluid Phase Equilibria, 132: 61) and more recently water/alkanes (Yakoumis et al., 1998, Ind. Eng. Chem. Res., accepted). On the course of a project funded by Shell Research and Technology Center (Amsterdam), sCPA was for the first time extended to ternary and multicomponent systems containing water, alcohol and one or more hydrocarbons (Kontogeorgis et al., 1998, Fluid Phase Equilibria, submitted). Very satisfactory predictions were obtained for these systems which can be considered as simulating the complex cases of environmental significance.

sCPA is extended here to systems containing water / octanol / hydrocarbon pollutants and the prediction of the constituent octanol-water partition coefficients. Both classical -in oil and chemical studies- n-alkanes and some aromatic and chlorinated hydrocarbons are considered. Binary parameters are based on existing phase equilibrium data. Very satisfactory Kow results are obtained which are favourably compared to the classical UNIFAC methods. Unlike the latter, however, sCPA can be extended to any type of pollutants provided that some binary experimental phase equilibrium data are available.

STUDY OF THE POLLUTION OF THE MARINE ECOSYSTEM OF THERMAIKOS GULF THROUGH METAL ACCUMULATION IN ORGANISMS (*Mytilus galloprovincialis*)

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ΜΕΛΕΤΗ ΤΗΣ ΡΥΠΑΝΣΗΣ ΤΟΥ ΘΑΛΑΣΣΙΟΥ ΟΙΚΟΣΥΣΤΗΜΑΤΟΣ ΤΟΥ ΘΕΡΜΑΪΚΟΥ ΚΟΛΠΟΥ ΜΕΣΩ ΤΗΣ ΒΙΟΣΥΣΣΩΡΕΥΣΗΣ ΒΑΡΕΩΝ ΜΕΤΑΛΛΩΝ ΣΕ ΟΡΓΑΝΙΣΜΟΥΣ (*Mytilus galloprovincialis*)

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1. INTRODUCTION

Benthic organisms and particularly mussels were considered as advantageous biological indicators for the study of metal pollution in the sea (Phillips D.J.H., 1976). Mussels are sedentary organisms and filter feeders. Metal concentrations in their tissues reflect, through bioaccumulation, levels of pollutants in the marine environment.

There are many mussel-farms in Thermaikos gulf, particularly along west coasts. This gulf represents a complex and interesting marine ecosystem. Pollutants enter in the gulf via rivers (due to industrial and agricultural activities) and from the city of Thessaloniki. Metal levels estimation in mussel tissues and metal geographical distribution was the scope of this preliminary study.

2. METHODOLOGY

Mussels (*Mytilus galloprovincialis*) were collected along the west coasts of Thermaikos gulf, from mussel-farms at station 1 (Halastra) and at station 2 (Makrigialos) and along the east coast at station 3 (Mihaniona) (Fig 1). Pooled samples were prepared from the soft part of 6 individuals each. Microwave-assisted digestion was provided and the determination of heavy metals (Cr, Ni, Cu, Zn and Fe) was made by atomic absorption spectroscopy (UNEP, 1984). Accuracy and precision of the analytical methodology was tested with the reference material BCR No 279 (*Ulva lactuca*). The size of individuals was almost the same at all (6-7 cm). For the statistical analysis (analysis of variance) the software package STATGRAPHICS PLUS was used. Data were log transformed before statistical treatment.

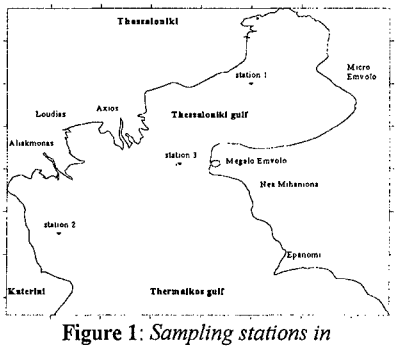


Figure 1: *Sampling stations in Thermaikos gulf (September 1997)*

3. RESULTS-DISCUSSION

The results of the metal analysis are presented in Table 1 (average, standard deviation, minimum and maximum values). Concentrations of Cr, Ni, Cu, Zn and Fe are expressed in μg of metal per g of dry weight of the tissue (ppm). These are comparable to those found in other Greek and Mediterranean areas.

Table 1: *Metal concentrations in mussels in Thermaikos gulf (μg/g dw)*

	Cr	Ni	Cu	Zn	Fe
Halastra	1,98±0,37	0,94±0,41	2,54±0,41	136,61±17,68	231,87±113,49
st1	(1,70-2,62)	(0,47-1,46)	(1,90-2,94)	(118,15-167,38)	(125,09-435,73)
Makrigialos	2,55±0,37	1,15±0,24	3,21±0,37	119,22±26,9	131,10±30,82
st2	(2,14-3,13)	(0,91-1,47)	(2,79+3,76)	(82,70-161,35)	(89,36-175,47)
Mihaniona	2,27±0,38	2,71±0,28	5,0±0,7	216,80±36,6	254,22±50,09
st3	(1,63-2,63)	(2,41-3,19)	(3,89-6,04)	(186,51-273,96)	(205,37-333,2)

Metal concentrations seem to differentiate stations. Namely Ni, Cu and Zn values at stations 1 and 2 were statistically significant lower than those at station 3 (Fig. 2). On the contrary no significant differences were detected among stations for Cr and Fe.

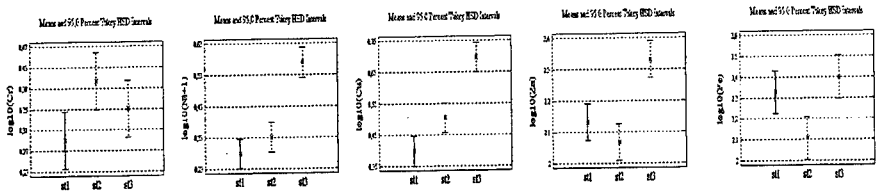


Figure 2: *Average values of metal concentrations in mussels in Thermaikos gulf.*

Metals binded from *Mytilus galloprovincialis,* continually removed by their transportation to the market, mainly from west-coast farms. Furthermore, rapid growth and large amounts of mussels, perhaps are contributing to the removal of the "metal load" of the particular area. Marine molluscs accumulate and detoxify metals in intracellular granules and excrete them via the gut and faecal pellets. Granules in the faecal pellets will become part of the sediment. It is possible that metals remain biologically unavailable when returned to the external environment (Nott J.A. and A. Nicolaidou, 1993). In conclusion it can be assumed that molluscan metal detoxification is effective on an environmental scale, especially when the abundance of the organisms is large enough. Furthermore, complexation with a variety of organic ligands can affect the availability and toxicity of metals in marine environment. Estimation of "organic load" of studied area, probably would give more information and explanations.

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HEAVY METALS IN MARINE BIOTA FROM THE NORTH-EAST COASTS OF RHODES ISLAND

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ΒΑΡΕΑ ΜΕΤΑΛΛΑ ΣΕ ΘΑΛΑΣΣΙΟΥΣ ΒΕΝΘΙΚΟΥΣ ΟΡΓΑΝΙΣΜΟΥΣ ΑΠΟ ΤΙΣ Β.Α. ΑΚΤΕΣ ΤΗΣ ΡΟΔΟΥ

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1. INTRODUCTION

Heavy metals were monitored in phytobenthos *(Padina pavonica)* and zoobenthos (the gastropod *Patella sp.)* species, collected in June and October of 1996 from a station in the North-East coast of Rhodes island, for the purposes of the MED-POL. programme, in order to provide information about heavy metals content in benthic organisms in an area which is considered to be unpolluted.

2. METHODOLOGY

Pooled samples from the soft tissues of 4 to 10 individuals of *Patella sp.* and the thallus of *Padina pavonica* were prepared. All samples were transported to the laboratory at -10oC. Samples were dried by lyophilisation and then homogenised. Approximately 0.5 gr of dried tissue was digested with 5 ml of nitric acid into teflon vessels under pressure at 120 oC for 10 h. Determination of copper, chromium, nickel and zinc was made using an air-acetylene flame spectrophotometer (UNEP, 1984). The accuracy and precision of the analytical methodology was tested with the reference material of BCR No 279 (*Ulva lactuca*). For the statistical analysis (analysis of variance) the software package STATGRAPHICS PLUS was used. Data were log transformed before statistical treatment.

3. RESULTS-DISCUSSION

The levels of the metals ranged between 1.98 and 9.94 ppm for Cu, between 4.97 and 16.97 ppm for Cr, while Ni values varied from 3.82 to 28.09 ppm. Levels of Zn (for *P. pavonica*) are higher and ranged between 46.04 to 65.28 ppm. Average, standard deviation, minimum and maximum values for each species are given in Table 1. Generally, levels of metals in marine flora and fauna were low and similar to other clean areas (Catsiki et al, 1991).

Table 1: Metal concentrations in *Patella sp.* and *P.pavonica* from NE coasts of Rhodes island (Ladiko) during 1996, (μg of the metal/ g dry weight) -(upper line: mean value ± SD, lower line: ranges of values).

P.pavonica

June Cu	Cr	Ni	Zn
2,29±0,1	10,45±3,3	20,19±4,2	52,42±5,7
2,01-2,5	6,68-17	14,95-28,1	46,04-64,4
October Cu	**Cr**	**Ni**	**Zn**
2,34±0,4	10,17±3,1	18,26±3,9	49,75±2,9
1,98-3,0	6,44-15,1	13,04-24,21	47,16-55,64

Patella sp.

June Cu	Cr	Ni	Zn
5,58±0,8	7,58+2,6	8,32+4,5	57,28+3,6
4,45-7,1	5,05-14	3,82-22,3	51,12-65,3
October Cu	**Cr**	**Ni**	**Zn**
6,68±2,1	7,17±3,1	6,43±1,4	51,84±4,5
4,02-9,94	4,97-13,14	4,16-7,97	47,77-58,03

The average concentration of Zn and Cu are higher in *Patella sp.* than in *P. pavonica*, while the opposite occurs for Ni and Cr. Generally samples of both species collected in autumn seemed to present lower metal levels (Figure 1).

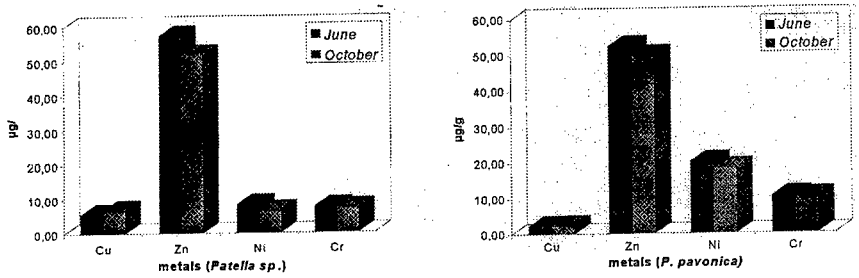


Figure 1: Mean metal concentrations in *Patella sp.* and *P. pavonica* from the NE coasts of Rhodes island (Ladiko) during 1996.

In order to find out if the differences between species and seasons are statistically significant we performed analysis of variance (Figure 2). In this study, species were the more important factor which influenced metal bioaccumulation by the tested biota for most of the studied metals; significant differences are observed between species for Cu, Ni and Cr when for Zn differences do not seem to be statistically significant.

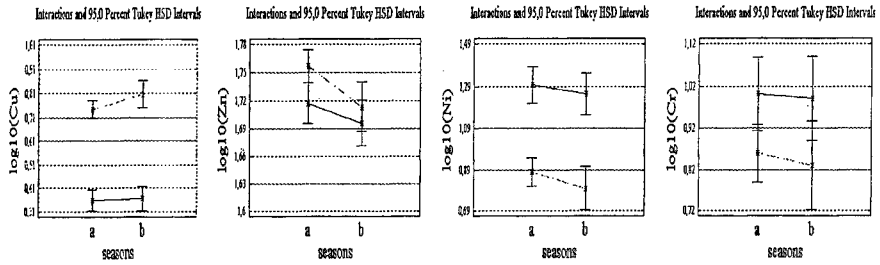


Figure 2: Average values of metal concentrations in *P. pavonica* (solid line) and *Patella sp.* (dotted line) from the Island of Rhodes (Ladiko), during 1996 (a: summer and b: autumn)

These results suggest that *Patella sp.* seems to be a better indicator for Cu while *P. pavonica* for Ni. However, different species accumulate different metals to a different extent and assessment of pollution effects should take this into account.

Regarding the variation of metals throughout the year, no significant differences between seasons seem to exist in the bioaccumulation rate for both species.

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THE ENVIRONMENTAL IMPACT TO THE HERACLION GULF, THROUGH THE GEOCHEMICAL STUDY OF SEDIMENTS

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Η ΠΕΡΙΒΑΛΛΟΝΤΙΚΗ ΕΠΙΒΑΡΥΝΣΗ ΤΟΥ ΚΟΛΠΟΥ ΤΟΥ ΗΡΑΚΛΕΙΟΥ ΜΕΣΩ ΤΗΣ ΓΕΩΧΗΜΙΚΗΣ ΜΕΛΕΤΗΣ ΤΩΝ ΙΖΗΜΑΤΩΝ

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1. INTRODUCTION

The clear environment plays an important role for the development of an area, because it increases the number of tourists and is the basic factor for a safe and healthy residence. Particularly at the Mediterranean coasts, which offer hospitality to millions of tourists every summer, the pollution control of the sea environment is a main priority and survival prerequisite for tourism industry.
The pollution derived from the human activities and the products of the land erosion end up into to the sea environment and finally to the bottom surface sediments (heavy metals, urban sewage, industrial sewage, petroleum leak, e.t.c.).
These pollutants through the nutritive chain or through water, solved in high concentration, enter the human body and provoke injuries. Ministries of Environment and local authorities usually measure only the microbes contained per litre in the sea water of the beaches.
This study shows the necessity of the monitoring, measuring the pollution in the sea regions with tourism, fishery and other activities. One way, is the study of the bottom sediments because they are the final termination of the pollutants. The geochemical study of the sediments, in correlation with the results from the grain size analysis, is possible to drive us into useful conclusions concerning:
a. the sedimentation conditions
b. the movement of the sediments
c. the distribution and the origin of the pollutants.
d. the transport and the absorption of the metals into the sediments
An example of a coastal urban centre with rapid development for three decades, is Heraklion - Crete and the surrounding area. In the framework of the conduct of my Ph.D research, the sea area of the gulf was studied concerning the sedimentation, the geochemistry, the mineralogy, with conclusions for the pollution level and the source of the pollution.

2. MATERIALS AND METHODS

For the sampling of 29 sediment samples, the sampler Dietz la font was used as well as the oceanographic ship NAYTILOS of the Greek Hydrographic Service.
By the geochemical study of the sediments, the percentage of 23 main and minor elements was measured at 29 stations of the gulf and the carbon dioxide: Fe, Al, Mg, Na, K, Ca, Si, Hg, Mn, Ag,

Ba, Sr, Mo, P, Zn, Cu, Co, Ni, Cd, Ti, Cr, Pb, organic carbon and calcium carbonic. Some of them are toxic heavy metals:
Co, Ni, Cr, Pb, Hg, Cu, Cd.

The chemical analysis was realised by the solution of the sample (reaction with $HCL+HNO_3$) and the measurement of the concentration of the metals by atomic absorption. Also, the XRF method was used. The calcium carbonic was defined by the measurement of the pressure of CO_2, after the reaction of carbonics with HCL. Hg was measured with the pyrolitic method. The organic carbon was defined by parching and reaction with H_2O_2 .
These measurements were correlated with the concentrations of the heavy metals in other Hellenic gulfs. Maps were designed with the surface distribution of each element concentration in the gulf (until Dias island). Diagrams were planed showing the relation between Aluminum and the other elements, as well as their relation with the statistical grain sized parameters in order to study : the origin of the elements - the way of movement/deposit and their absorption to the sediment (Aluminum part). For studying the environmental impact at the sediments, the Mueller method (1979) was used which is based to the calculation of the geo-accumulation index for some heavy metals.
In order to separate the gulf into zones, depending on the concentration level of the main elements, we used the cluster analysis in geochemical data from 29 stations. As a result we had 6 zones.

3. CONCLUSIONS

The sea area of the gulf accepts the products of the erosion/weathering of the rocks as well as the urban and industrial sewage. Some elements are associated with the aluminium phase of the sediments (Al, Ba, K, Fe, Ti, Cr, Co, Mn), are derived from the land and their concentration increases with the depth of the sea. These elements are absorbed on the surface of aluminium minerals or resume nexus positions to the nexus of the aluminium elements or subside as hydroxides and oxides.
Another group of elements (Ni, Zn, Cu, Ag, P, Na, Mo) are associated with the coarser fraction of the sediment and their concentration increases near the coast. The third group of elements is associated with the organic fraction of the sediment (Corg , Pb, Mo, Hg). Calcium carbonic is biogenic and is derived from the carbonic rocks of the land. The organic carbon increases with the fine grain aluminium material and with the depth in the continental shelf. In the central part of the gulf the percentage is high (>4%).
The environmental impact of the sediments is characterised as ''minimum - until light '' for all the regions of the gulf . The degree of the impact decreases concerning the concentration of the main metals as follows: Mo>Cr>Ni>Co>Pb>Cu>Zn.
A medium level of pollution was located near the coast of Alikarnassos (due to the Municipal slaughter-house), into the port and at the South West gulf (due to petrolleum transport). Comparing this level of pollution with other Hellenic gulfs, we found lower or the same concentrations except Saronicos gulf.

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CHEMICAL COMPOSITION OF AEROSOLS COLLECTED IN ATHENS-GREECE

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ΧΗΜΙΚΗ ΣΥΣΤΑΣΗ ΑΕΡΟΛΥΜΑΤΩΝ ΣΥΛΛΕΓΕΝΤΩΝ ΣΤΗΝ ΑΤΜΟΣΦΑΙΡΑ ΤΩΝ ΑΘΗΝΩΝ

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1. INTRODUCTION

It is known that particles which are formed in the atmosphere from gaseous precursors have their size distribution in the fine mode (diameter less than 2.5μm) show a marked seasonal variation and cause numerous environmental and human health effects (1).In the present study atmospheric aerosols are collected at two sites in Athens region, Patision (center of Athens) and Rentis (semi-industrial region). Concentrations of the main anions and cations were determined for the period March 1995-March 1996 in 224 samples (Patision 187 and Rentis 37 samples). Seasonal variation of the major conmponments of aerosols and correlation between the ion concentations were examined.

2. EXPERIMENTAL

Sampling. Aerosol samples were collected at Patision station almost every day except weekends and at Rentis station only two days per week. The Harvard Impactor System (HIS) was used for collection of fine particles mass on 24-hr basis on a 47 mm diameter 2 μm pore PTFE teflon mebrane. The HIS protects the aerosol sample from neutralization (2).

Sample analysis. Measurements of H^+ were carried out using an WTW_2pH-meter with a Ross combination semimicro-electrode .The major cations NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} and the major anions Cl^-, NO_3^-, SO_4^{2-} were analyzed by ion chromatography technique using a Universal Ion Cromatograph available from Alltech and conductivity detector under computer control.

3. RESULTS AND DISCUSSION

Several studies have examined the chemical composition of wet and dry precipitation in the atmosphere of Greece (3,4,5). The results from the twelve months study show seasonal variations in aerosol strong acidity concentrations. Aerosols were more acidic in Patision station in the winter. Sulfates did not appear seasonal variation as was expected for the winter when the central heating is opperated but this may be confess sulfate transportation in combination with the fact that sulfates remain in the atmosphere for seven days. The two stations had similar sulfate meadian concentrations and acidity measurements (Table1).

TABLE 1: Chemical composition of aerosols collected in Athens for one year period (Number of samples: 224)

Sampling site		**Patision**	**Rentis**
ION	**N**	**x ± s**	**x ± s**
Cl^-	29	108 ± 89	78 ± 58
SO_4^{2-}	28	105 ± 41	110 ± 44
NO_3^-	28	38 ± 33	40 ± 32
H^+	28	19 ± 22	15 ± 16
NH_4^+	28	124 ± 80	117 ± 87
Na^+	25	117 ± 136	99 ± 59
K^+	8	34 ± 23	35 ± 31
Ca^{2+}	25	25 ± 19	22 ± 13.4
Mg^{2+}	13	5.7 ± 2,7	6.5 ± 3.0

The average molar ratio of $[H^+]/[SO_4^{2-}]$ is equal to 0.12 in Patision station and 0.13 in Rentis station which means that sulfate composition is usually in the range between ammonioum sulfate $(NH_4)_2SO_4$ and ammonioum bisulfate NH_4HSO_4 .The existence of transportation of sulfates and nitrates must be examined more thoroughly. The concentrations of the determined ions must be compared to meterological data to describe in detail the origin of aerosols constituents.

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OPERATION OF WASTEWATER TREATMENT FACILITIES IN NORTHERN GREECE

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ΛΕΙΤΟΥΡΓΙΑ ΕΓΚΑΤΑΣΤΑΣΕΩΝ ΕΠΕΞΕΡΓΑΣΙΑΣ ΛΥΜΑΤΩΝ ΣΤΗ ΒΟΡΕΙΑ ΕΛΛΑΔΑ

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Today in Greece, most of the cities (equivalent population > 50,000) have or construct wastewater treatment plants (WWTP). On the contrary, there is lack of such facilities for small towns and communities. In the next few years, according to the EU directives, the pressure for implementing water pollution control projects is expected to be significant. Although there are Greek scientists and engineers who are experts in wastewater treatment, there is lack in properly trained technical and labor personnel. The operation of incomplete WWTP, or the non proper operation (mainly in small or medium size facilities) does not contribute to the abatement of the pollution, but rather to the deterioration of the receiving water bodies. This situation is extremely important especially for the sensitive coastal areas.

In this poster, design and operation data of WWTP in Northern Greece are given and evaluated. Moreover, characteristic photographs of the examined WWTP are presented and measures for improving the situation are discussed and proposed. Due to the limited space provided in the Proceedings for the presentation of this study, it is not possible to include here either tables of design parameters and operational data or figures concerning the examined correlations.The 10 WWTP for which design and operation data are presented and evaluated are the facilities of Thessaloniki, Aggelochori (touristic regions of Thessaloniki), N. Madytos-Modi, Katerini, N. Moudania, Pefkochori, Agios Nikolaos, Kavala, Alexandroupoli and Ioannina, although design data there are also for other WWTP [1,2]. The applied method of treatment is the activated sludge (usually extended aeration) except the N. Madytos-Modi facility where constructed wetlands are used.

It must be pointed out the difficulty which exists in obtaining, especially, operation data of the Greek WWTP [1,2]. However, to evaluate the environmental impacts of WWTP, the existence of proper national data base, related to the applied technology in various WWTP, their operational characteristics, and effluent quality, is required. Moreover, this data base is considered indispensable for better programming and the future design and operation of the Greek WWTP. Also, the relative EU data base suffers from a relatively low response ratio for completion of input questionnaires, and there is a need for developing guidelines for the preparation of the corresponding reports from the member states in order to make the data comparable [3].

From the analysis of existing data, local visits, and interviews (not only in the afore-mentioned facilities) the following problems have been found [1,2,4,5]:

1. Poor design and/or construction combined with operators that lack or have only limited experience, especially in the medium and small WWTP.
2. Local communities are asked to highly invest in order to preserve and protect the environment without having adequate funds and personnel.
3. In the small WWTP there is lack of skilled operators.
4. In many WWTP sites there are obvious signs of negligence.
5. There is lack of infrastructure in the greater area of many WWTP.
6. Illegal septage and industrial wastes dumping into the sewers is observed, especially during the summer, from regions where there are not sewerage systems.
7. There is lack of adequate screens and oil-grease traps, especially in pumping stations.
8. Some WWTP suffer from limited or terminal capacity during the summer months.
9. Bulking and foaming is observed in activated sludge plants.
10. Saltwater intrusion is observed in the coastal groundwater aquifers, and the WWTP.

To improve the current situation, among others, the following measures are suggested:

1. The need for at least secondary treatment combined in some cases with nitrogen and/or phosphorus removal is indisputable, especially in sensitive coastal areas. Moreover, effluent reuse and beneficial biosolids management must be examined and encouraged.
2. Activated sludge may be not a good choice for many small WWTP. Where do not exist land limitations, climate or other constraints, design engineers must consider alternative simpler, economic, low technology treatment processes.
3. WWTP inflexibility undermines operability. Designers should conscientiously build flexibility, especially into small systems.
4. Small WWTP have head-works/grit removal and sludge handling problems. If they do not have primary clarifiers, the entire plant (pumps, piping, and aeration systems) should reflect this design and should be able to accommodate increased solids in the system. Moreover, operators need to remove the floating debris that pass primary screening.
5. Hydraulic and organic overloading of small WWTP can confound underskilled operators. Design engineers and community administrators must discuss during planning process and agree on realistic loading levels for the facility (i.e infiltration/inflow).
6. Sludge bulking and foaming is a fact for many Greek WWTP. Attention should be given to the correlation between the particular types of filamentous microorganisms and process parameters. Moreover, the experience of experts in this field is valuable.
7. For permanent and continuous scientific and technical support of the small and medium size WWTP of broader regions central laboratories must be established.

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THE 'IN SITU' PURIFICATION METHOD OF THE LEACHATES FROM A LANDFILL

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Η ΜΕΘΟΔΟΣ ΤΟΥ ΕΠΙΤΟΠΟΥ ΚΑΘΑΡΙΣΜΟΥ ΤΩΝ ΣΤΡΑΓΓΙΣΜΑΤΩΝ ΑΠΟ ΤΙΣ ΧΩΜΑΤΕΡΕΣ

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1. INTRODUCTION

The most important problem of the waste disposal is the treatment of the high organic load leachate from sites of sanitary landfilling. The research for the development in Greece simple, low cost and efficient methods is very interesting.

Taking into account the above we have developed the 'in situ' purification method for the leachates. In this method a number of independent purification units is developed in the landfill. Each unit consists of a small well where the leachates are collected. This well also suplies a trickling filter equipped with filling material where air is circulating. In Figure 1 the process is schematically represented.

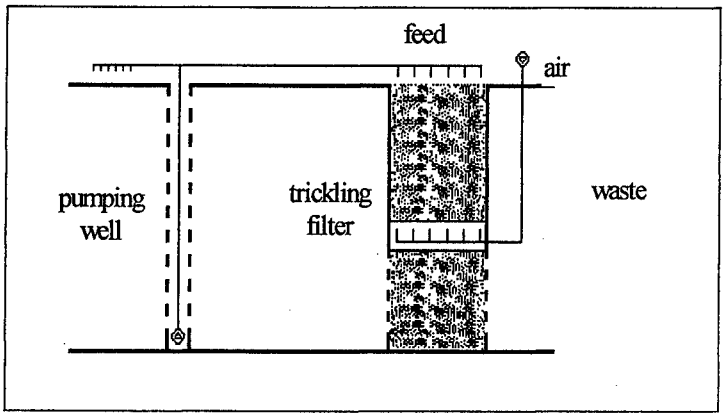


Figure 1.Schematic representation of the 'in situ' purification method.

2. MATHEMATICAL MODEL

The mathematical model was developed for the estimation of the BOD and COD removal rate versus time. The model was solved in a computer and special effort was made for taking into the account all the fundamental parameters of the procedure. In Table 1 the input data of the model are given.

TABLE 1. Input data of the model.

	Symbol	Units	Value
Depth of the landfill	α	m	20
Hydraulic conductivity of the landfill	κ	Darcy	0.05
Temperature of the landfill	T	^{0}C	35
Coefficient of the surface of the landfill	c	-	0.5
Humidity of the wastes	hum	%	50
Production rate of pollution	μ'	kgO_2/tn .d	0.001
Concentration of biodegradable carbon	C_{or}	kg/tn	6.26
Equivalence coefficient of the pollution/biogas	ξ	KgO_2/Nm^3	1.6812
Viscosity of the leachates	μ	Pa.s	3
Height of the leachate's column	x	m	0.15
Radius of the well collecting leachates	r_w	m	101300
Hydrostatic pres. in the well collecting leachates	P_a	Pa	1
Diameter of the trickle filter	δ	m	10
Effective Radius	r_e	m	10
Arrangment of the purification unit	-	TRI/TETR	TETR
Deposits of the leachates	ρ	tn/m^3	0.8
Maximum organic load per volume	B_r	KgO_2/m^3d	0.4
Minimum hydraulic load of the surface	q_A	m^3/m^2d	19.2
Initial organic load of the leachates	COD	KgO_2/m^3	30
	BOD_5	KgO_2/m^3	18

The removal of BOD and COD from leachate as a function of time are given in Figure 2

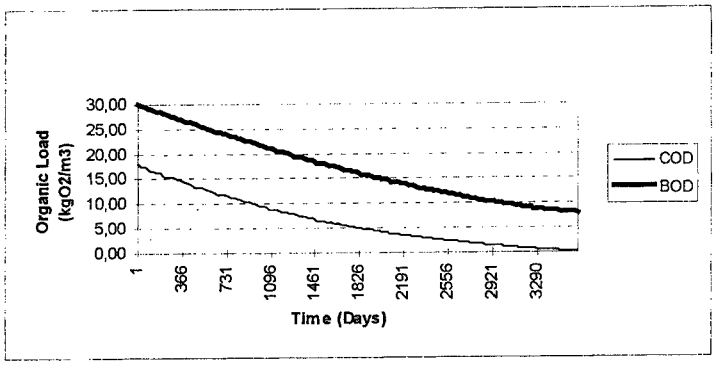


Figure 2. The removal of BOD and COD from leachate as a function of time

3. CONCLUSIONS

By applying the 'in situ' purification method we have better results with respect to the typical recirculation method and also we have an accelaration of the biodegradation processes in the landfill.

RIVER MAINTENANCE BASED UPON TECHNICAL AND ECOLOGICAL RESEARCH – A CASE STUDY

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ΤΕΧΝΙΚΗ ΚΑΙ ΟΙΚΟΛΟΓΙΚΗ ΕΡΕΥΝΑ ΓΙΑ ΤΗΝ ΠΡΟΣΤΑΣΙΑ ΠΟΤΑΜΩΝ – ΠΑΡΑΔΕΙΓΜΑ ΕΦΑΡΜΟΓΗΣ

Particularly in Europe a wide range of different claims on rivers led to the recent situation showing rivers not worth being entitled as such. Measures due to flood protection, hydropower exploitation, agriculture and forestry, settlement, fishery and recreation and all the consequences in chemical and physical parameters displaced structures features playing a key-role for ecological function.

The scientific knowledge as well as the public opinion opposites further impacts without a clear and sustainable concept to balance all the claims, to limit impacts, to repair failures of the past and to restore the rivers as a focus of environmental interest and starting point of ecological rehabilitation.

Within the last about ten years a couple of so-called „river-studies" has been worked out with continuously increasing quality according to scientific standards. In addition local governmental bodies have participated in this evolution process by regional studies and development concepts often initialised by recent troubles with a river. Typical fields of motivation has been floods, environmental aims, waste water management or the exploitation of hydropower.

The case study being subject of the contribution deals with a 70 km long river south of Vienna, Austria, called Piesting. The investigations concentrated on both interests in utilization and interests in protection.

The following interests of **human utilization and claims** has been identified:

on the river itself	*within the surroundings*
flood control	building up
small hydropower exploitation	agriculture
fisheries	forestry
recreation	special claims (for example military use)

Opposing the following public interests of **river protection** has been identified:

vegetation	limnology	water quality
bed load transport	morphology	ornithology

All the investigations aim at the definition of a guiding principle of the further development, serving threefold:

- to indicate aims of preservation and development
- to evaluate the recent situation and its distance to the target
- to render effective activities

The river course with a total length of 75 km was divided up into 10 main sections and 27 sub-sections according to similarities in basic features. The individual length varied between some hundred meters and about 7 km.

The working group was formed up of eight experts, each of them responsible for limited topics but with close connection to each other exchanging the results of data collection, methodological experiences and strategic proceeding. The representative of each subject has to define completely independent sectional principles of further development.

The following working step was to gain consentaneous principles on a very detailed level using two scenarios, characterising either the more technical or the more ecological way.

The visualising showed rather impressing dependencies and sensibilities unexpected. In a final state of work a lot of possible synergetic effects appeared between measures of flood control, hydropower exploitation and environmental rehabilitation, offering an acceptable basis to finance even under restrictive conditions. The following example will illustrate this final step.

Operational aims:	stress on protection		stress on claims	
Section: C1+2 km: 65,3-63,2			L: 2100	
Description: Regulated section after mouth of Zellenbach, canyon and basin close to Gutenstein				
Hydropower	no exploitation	maintainance modernisation	enlargement revitalisation	new sites closing the canyon
Flood control	no measures of protection	passive flood protection	retention basins effecting downstream	measures of regulation
Settlement Recreation Agriculture Forestry	no utilization	extensivation	keeping on	intensivation
Aquatic Ecology	preservation	get rid of single load factors	improve structure/river continuu Q_{min} fish bypass	revitalisation regulated section
Vegetation	floodplain forest	complete river bank forest	residual river bank forest	shrub veg.on the slope

Summing up, the group of total eight scientist working close together came to the conclusion, that the discussion and negotiation overlapping usual lines results in a significant increase of quality. The study has already been presented on a governmental level to inform the local politicians, the representatives of the government and the population interested in.

REHABILITATION OF DEGRADED FOREST ECOSYSTEMS IN GREECE

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The history of forest in Greece is a history of forest fragmentation, degradation and sometimes eventually deforestation. The destruction and degradation of natural ecosystems in the Mediterranean area began in the ancient times, with the emergence of the first civilizations in the area. In Greece the majority of forest and natural ecosystems exhibit a degree of degradation. Human activities are always responsible for the degradation of the ecosystems. Basic reasons are overharvesting, intensive felling, clearance methods, wildfires and overgrazing. In recent times, air pollution, contamination of water and soil, and climatic changes might have an additive effect on ecosystem degradation. Furthermore, the increasing population density in the coastal and hilly areas has a negative effect on natural ecosystems of the Mediterranean vegetation zone by increasing the pressure for land-use change and the number of wildfires. Degradation implies a reduction in the biological productivity of the ecosystems while rehabilitation is a reversal of the process. The necessity of rehabilitation and restoration of the degraded ecosystems in the Mediterranean basin is generally recognized although it is not an easy to achieve goal. The target of rehabilitation and the degree of degradation must be clearly defined before any method is applied. The available tools and the existing financial sources must be taken in account. The methods for rehabilitation are two, the natural and artificial method. According to the natural method possible causes of degradation are restricted and ecosystems are left to recover. The significant advantage of the natural rehabilitation is that it can be applied in huge areas with no cost and with the most secure way, which is the natural evolution. The disadvantageous is that it comes along with slow rates and is not always according to our proposition. It is remarkable and encouraging that these ecosystems are well adapted to the extreme ecological conditions and it is unbelievable that those ecosystems replace the vegetation, increase of leaf area index and establish the balance of the ecosystems. The artificial methods request significant spends of energy and high financial support. Particular care must be given for the right choice of the species. Examples of natural rehabilitation after wildfires in Mediterranean pine forest in Greece are presented. The ecosystems of the Mediterranean conifers (*Pinus brutia Pinus halepensis*) are exceptionally flammable since the climate is characterized by a long dry period accompanied by high temperatures, high solar radiation, low air humidities as well as because almost all the species of these ecosystems are especially flammable. Moreover it is well established that almost all plant species dominating these ecosystems have evolved numerous adaptation mechanisms

particular concerning post-fire. Vegetation recovery following fire involves endogenous processes of local plant species that progressively return the burned system to a stage very similar to that which prevailed before the fire.

An example of natural rehabilitation of P*inus brutia* forest exists in Thassos after the fire in 1984. Thirteen years after the fire in 1996, the overall seedling density is 0.314 seedlings per m^2, adequately for natural reforestation. In Rodos island a wildfire happen in 1988. Ten years after in 1998 the post fire regeneration and size of pine seedlings showed that the overall density was 0.335 seedlings per m2 although the area was not well protected from grazing . The major conclusion reached was that pine seedling emergence, establishment and survival were significant and adequate for complete natural reforestation. Therefore in ecosystems of *P. halepensis* and *P. brutia* the best thing to do after the fire is absolutely nothing, beyond harvest of the dead standing material and the - protection from grazing.

MAPPING OF FOREST ECOSYSTEMS VULNERABILITY TO UV-B RADIATION IN GREECE, USING GEOGRAPHIC INFORMATION SYSTEMS

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ΧΑΡΤΟΓΡΑΦΗΣΗ ΤΗΣ ΕΥΑΙΣΘΗΣΙΑΣ ΤΩΝ ΕΛΛΗΝΙΚΩΝ ΔΑΣΙΚΩΝ ΟΙΚΟΣΥΣΤΗΜΑΤΩΝ ΣΤΗΝ ΥΠΕΡΙΩΔΗ ΑΚΤΙΝΟΒΟΛΙΑ ΜΕ ΤΗ ΧΡΗΣΗ ΓΕΩΓΡΑΦΙΚΩΝ ΣΥΣΤΗΜΑΤΩΝ ΠΛΗΡΟΦΟΡΙΩΝ

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1. INTRODUCTION

Man-made chemicals (CFCs, halons etc) liberated in the stratosphere the last 20 years, have significantly decreased the total ozone that forms a natural screen which absorbs most of the damaging UV radiation present in sunlight. This depletion caused the increase of UV-B, known as the biologically important part of solar ultraviolet radiation that reaches earth's surface and may cause damaging effects to plant ecosystems, such as reduction in growth yield, changes in levels and effects of plant hormones and alteration of periods of dormancy, flowering etc. Especially for forest species, reductions in photosynthetic rate and capacity have been described for a number of tree species (eg. conifer spp), showing that the potential for worldwide woodland and forest damage is clear.

2. OBJECTIVES

The main objectives of the study were:

a. To create a digital map of vulnerability of forest ecosystems to UV-B radiation in Greece, using Geographic Information Systems and evaluate these results.

In order to achieve this, it was necessary to:

a. To create and analyse a digital map of forest ecosystems in Greece and

b. To create and analyse a UV-B radiation distribution map of Greece.

3. MATERIALS and METHODS

To materialize this study GRASS 4.1 (Geographic Resource Analysis Support System) was used. GRASS is an integrated set of many programs designed to provide digitizing, modeling, image processing and map production.

The first step was to convert in a digital form, the four analogue forest maps of Greece. In addition, in order to produce a UV-B distribution map of the study area, many formulas were used to calculate the relative effective dose based on the direct and diffuse solar radiation, depended by altitude, sun

angle, latitude, longitude etc. Then a computer program was developed in GW-Basic, for computing the solar dose according to these equations, at given locations. Thus the digital UV-B radiation map was prepared, based on 8 UV-B radiation categories.

The combination of the two map layers through a model, created a composite dataset, that is a new layer that would be the final vulnerability map. The model used expresses a relation between the forest species and the UV-B dose, in order to derive the vulnerability of each area. Overall, the forest ecosystems categorization in respect to their sensitivity or resistance to UV-B radiation exposure was, grass, deciduous broadleaved trees, evergreen broadleaved trees, and conifers. Thus the initial forest map was reclassified into these 4 broad categories. The model used was,

$Y=x_1.x_2$, where Y=vulnerab. index, x_1=species categ (1-4), x_2=UV-B categ (1-8)

Based on the calculated vulnerability classes, the final map was produced.

4. RESULTS and DISCUSSION

Because the UV-B dose over Greece does not exhibit any extremely high or low values, the significant factor the could affect the final product of the mathematical expression is the forest species categories. The vulnerability values were also divided into 8 categories (from very slight to extreme). According to the results (Table 1) and the map the most dominant class is the 'slight' category, that spreads all over Greece. The reason of that is related to the fact that more than 30% of the total examined area is covered by grass, which is 'resistant' vegetation type to UV-B radiation exposure.

Also the sum of the last three classes 'severe', 'very severe' and 'extreme' was 15% and located in the mountainous zone of continental Greece and in a small portion in Crete. These areas are covered by conifer species, which are the most 'sensitive' species. In addition theses are high altitude areas of high UV-B exposures. Although overall, these areas are small in extent, UV-B radiation can be rather effective in altering photosynthetic activity, growth, productivity etc.

TABLE 1: Percentage acreage values of the vulnerability classes

Vulnerab. classes	Very slight	Slight	Medium	Moderate	High	Severe	Very severe	Extreme
Area (%)	13.66	39.40	9.33	17.09	6.04	10.53	2.95	1.00

5. SUMMARY

Continued depletions of the earth's stratospheric ozone layer is of major concern, because this is the primary attenuator of solar ultraviolet-B radiation (UV-B region, 280-320nm). UV-B can cause deleterious effects on tree growth and physiology of specific species, while others may be unaffected, being more resistant. In order to assess the risky areas in Greece, GIS technology was used. According to the final vulnerability map produced, although such areas were relatively small in extent, it gives a significant indication of the problem present.

RESTORATION OF WETLAND FUNCTIONS IN MEDITERRANEAN: THE KARLA CASE

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ΑΠΟΚΑΤΑΣΤΑΣΗ ΥΓΡΟΤΟΠΙΚΩΝ ΛΕΙΤΟΥΡΓΙΩΝ ΣΤΗ ΜΕΣΟΓΕΙΟ: Η ΠΕΡΙΠΤΩΣΗ ΤΗΣ ΤΕΩΣ ΛΙΜΝΗΣ ΚΑΡΛΑΣ

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Environmental restoration represents a model of positive interaction between man and the natural world. Instead of seeking to wall off the environment to protect it from human interaction, it recognises that humans are an integral component of the natural world. For this reason one of the most exciting and challenging aspects of management in the Mediterranean at present, is wetland restoration.

A wetland may perform, to a various degree, several of the following functions: nutrient removal/transformation, sediment and toxicant retention, floodwater storage, groundwater recharge, microclimate modification, shoreline stabilisation, food web support. Alteration of one or several of these functions leads to partial or total loss of many of the nearly 20 possible values which depend on the function. When society becomes aware of the human impacts on wetland functions and the relationship between functions and values, a positive force may arise for wetland restoration. The preexisting functions that have been lost from human impacts are the ones that most promptly need to be restored.

Wetland hydrology is the key factor controlling the structure and functioning of any wetland and therefore is a vital consideration for successful wetland restoration.

It has been long established that each wetland is a unique ecosystem requiring specific conservation, management, and rehabilitation approaches. However, the several common physical, biological, cultural, social, and economic features of the Mediterranean wetlands suggest that there may be benefits from developing some common approaches. For example, rehabilitation to ensure resilience and sustainability requires the integrated management not only of the restored wetland itself but of the hydrological basin as well. The planning and implementation of an effective and low-cost monitoring system is a *sine qua non* tool in checking the success of the restoration actions and measures and to prevent the threats of future human unwise interventions. In addition, reestablishment of wetland functions can provide society with economic benefits, can help control the pollution and increase biodiversity.

Lake Karla is one of the examples in the Mediterranean basin where favourable conditions for restoration exist. The Greek government has launched a 100 million ECU (partially from EU funds) project to restore the wetland. The project is based on a conventional technical and environmental impact assessment study, as well as on a restoration study.

The objective of the restoration study was to select the most appropriate restoration proposal and to assess each function to be restored. An approach was followed to evaluate restoration proposals based on the degree to which they restore preexisting wetland functions. We used a Geographical Information System to create the Digital Elevation Model of the wetland ideotype and two representative proposals for the restoration of Karla. The GIS also helped describe the characteristics that determine the wetland functions. The evaluation of proposals is subject to current socio-economic and environmental constraints. In evaluating future proposals, a feedback procedure was introdused to find the optimum proposal. The assessment of several function of the selected proposal was based on Adamus method (Wetland Evaluation Technique) in order to identify (wherever appropriate) additional interventions needed to restore the wetland functions in a more efficient way.

A SPATIAL DISTRIBUTION METHOD TO REHABILITATE THE RECHARGE-DISCHARGE FUNCTION OF ANTHEMOUNTAS WATERSHED

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ΜΕΘΟΔΟΣ ΒΑΣΙΣΜΕΝΗ ΣΤΗ ΧΩΡΙΚΗ ΚΑΤΑΝΟΜΗ ΔΕΔΟΜΕΝΩΝ ΓΙΑ ΤΗΝ ΑΝΟΡΘΩΣΗ ΤΗΣ ΛΕΙΤΟΥΡΓΙΑΣ ΕΠΑΝΑΠΛΗΡΩΣΗΣ-ΕΚΦΟΡΤΙΣΗΣ ΥΔΡΟΦΟΡΕΩΝ ΣΤΗ ΛΕΚΑΝΗ ΑΠΟΡΡΟΗΣ ΤΟΥ ΑΝΘΕΜΟΥΝΤΑ

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Throughout the Mediterranean region, human activities related to agriculture, housing, tourism, and industry put increasing pressures on the renewable groundwater resources of coastal watersheds, because these activities are developed with little consideration to the groundwater recharge/discharge function. The direct result of this problem is degradation of aquifers from salt water intrusion and of soil when irrigated with water pumped from these aquifers. The Anthemountas watershed in northern Greece typifies this problem since the disregard of the groundwater recharge/discharge function is causing gradual saltation of aquifers from the coastal zone to the hills of the watershed and an impact on soil resources. The objective of this study was to find out a procedure to rehabilitate this function based on the sustainable development of the watershed's agroecosystems. It was postulated that these agroecosystems are the main users of groundwater.

First, a 19 years (1978-96) time series spatially distributed crop pattern, climatic, and groundwater data was analysed. It was shown that the irrigated agroecosystems of the watershed were primarily responsible for the degradation of this function. Therefore, the efforts towards sustainability of groundwater resources must focus on the extent and spatial distribution of those agroecosystems which can operate without exceeding a target quantity of crop water demand.

The criteria used to identify the appropriate agroecosystem types, extent, and spatial distribution were: a) relief, b) hydrology network, c) fluctuation of groundwater table, d) soil productivity, e) land cover, f) road network, g) existing pumping wells.

These criteria were digitised as different layers using Arc/Info and a procedure based on a Spatial Decision Support Tool (SDST) was followed to determine the types, extent and spatial distribution of agroecosystems which would operate under the sustainable target quantity of crop water demand. The SDST enables the decision maker to understand the spatial components of the environmental problem, to create alternative crop pattern scenarios to estimate the consequences of these scenarios on water use, and finally to select the most appropriate scenario, which will meet the pre-set target quantity sustainability index of water use.

ENGINEERING CRITERIA FOR THE DESIGN OF MULTI-COMPARTMENT *IN VITRO* ANIMAL MODELS FOR TOXICOLOGICAL STUDIES

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ΚΡΙΤΗΡΙΑ ΣΧΕΔΙΑΣΜΟΥ *IN VITRO* ΖΩΙΚΩΝ ΜΟΝΤΕΛΩΝ ΠΟΛΛΑΠΛΩΝ ΔΙΑΜΕΡΙΣΜΑΤΩΝ ΓΙΑ ΤΟΞΙΚΟΛΟΓΙΚΕΣ ΜΕΛΕΤΕΣ

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1. STATE-OF-THE-ART & THE INTEGRATED CELL CULTURE SYSTEM

The first step in *risk assessment* is to determine whether exposure of the population to the chemical under investigation is likely to have adverse health effects. A toxic substance can enter the human or animal body by ingestion, inhalation or contact with the skin (dermal) and once it is inside the body, the blood can distribute it to various organs. The toxic substance is subsequently either stored (e.g., in the fat) or eliminated by excretion or by transformation to metabolites that can be more easily removed from the body. There are several organs that are particularly affected by toxins. Hepatotoxins are all chemical agents that cause liver damage as they pass through and get metabolized to substances that are more easily excreted from the body. Typical hepatotoxins include organic compounds (e.g., tetrachloride, chloroform, trichloroethylene), pesticides (e.g., DDT, paraquat), heavy metals (arsenic, iron, maganese) and anabolic steroids. Nephrotoxins on the other hand damage the kidneys where the blood is filtered to remove wastes as urine. Chlorinated hydrocarbons and heavy metals (e.g., cadmium, mercury and lead) are typical nephtotoxins. Excessive kidney damage results initially in reduced removal of toxins as urine, followed by death due to poisoning. Besides the liver and the kidney, the lungs are also an important compartment since chemical toxic pollutants can severely impair their function. One way to quantify the toxicity of a chemical is by the minimum amount required to kill the organism. In particular, the dose that will kill 50% of the exposed population (LD_{50}) is a key indicator and it is often used as the sole toxicity indicator of a substance. Toxicological studies of that nature involve experiments with hundreds of animals that need to be sacrificed.

As an alternative to animal studies, one could employ in vitro cell culture models. In particular a system of interconnected bioreactors can resemble satisfactorily the various organ of the animal and the metabolic processes that take place in each organ. This **Integrated Cell Culture System** (ICCS) can actually be made a physical replica of the structure of a physiologically based pharmacokinetic model. Shuler et al. [1] have clearly indicated the advantages of such an approach. The ICCS has the following characteristics (see Fig. 1): (a) It is comprised of several compartments. Each cell culture compartment has a different cell type and represents a particular organ or tissue. (b) Recirculating culture medium connects the various cell culture compartments and acts as blood. As a result, within the ICCS, metabolites can be exchanged between the different cell types in each bioreactor (representing a different organ). (c) Serum and proteins can be added to the medium to obtain the same metabolic properties of blood (with respect to the toxic compound) and (d) Flexibility in

design to satisfy various scaling factors.

There are several reasons behind the motivation for the development of an ICCS, namely (i) realistic dose exposure scenarios and measurement of responses (periodic sampling), (ii) dosage can be added on a "mg-toxin/(kg-equivalent-body-weight)" basis, and (iii) the cell culture system can be used in conjunction with a pharmacokinetic model to test and refine mechanistic hypotheses.

2. DESIGN CRITERIA

The similarity criteria that must be satisfied are: recirculation flow rates, residence times, mass of the different organs, and liquid hold up in each organ. The most important parameter is the ratio between the mass of the cells in a compartment (bioreactor) to the mass of the organ (or tissue) it represents. More precisely, one would like to maintain the desirable ratio of the cell surface area in the organ to the total cell surface area in the cell culture compartment since the cells act as a catalyst. Next, the recirculation rate through each organ should be scaled down by the same ratio so that the blood flow rate per cell surface area is the same in the ICCS. If we now wish to maintain the same residence times between each compartment of the ICCS and the corresponding organ, the liquid hold up in each compartment has to be scaled down by the same factor.

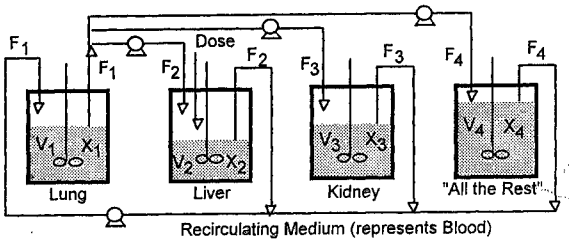


Fig.1: Schematic diagram of an Integrated Cell Culture System emulating the whole animal. Each bioreactor represents a particular organ and its liquid volume, cell type, cell concentration and medium (blood) recirculation rate have been scaled down from the whole animal. A one time dose or periodic addition of a toxin is injected into the system and its concentration (together with the products of biodegradation) can be monitored in every compartment. Cell death is monitored by LDH (lactate dehydrogenase) release into the medium.

The number of compartments (bioreactors) and type of cells that must be included in the cell culture system depend on the nature of the toxic substance under investigation. Typically besides the liver other compartments where the toxic compound is expected to have a major effect (biotransformation or acute cell death) should be included. The remaining organs and tissues are often lumped into one compartment and its size if often taken much smaller than that dictated by the scale down calculations.

3. BIOREACTOR DESIGN

Let us consider a ICCS similar to the cell culture system of Shuler et al. [1] used for studying naphthalene toxicity. Assume that the ICCS represents one half of a rat weighing 220 g. It has been shown that reactive metabolites (naphthalene oxide, dihydrodiol) are formed in the liver and are then circulated to other tissues. Epithelial cells of the mouse lung are the target of napthalene toxicity. As a result, a minimal compartmental model could be a liver compartment with hepatocytes (H4IIE cells) [2], a lung compartment with L2 lung cells and an "other tissues"-compartment with fibroblasts. Let us concentrate on the design of the liver compartment. The liver characteristics of the rat are: liquid volume (hold up) 7.4 mL, blood flow rate 18.3 ml/min and primary cell surface area 21100 cm^2. Let us consider a microcarrier-culture perfused-bioreactor for the liver compartment. From the requirement of a total cell surface area of 21100 x 0.50 cm^2, and knowing the number of cells per microcarrier bead (Cytodex 3), the required amount of dry-weight beads is found to be 2.29 g. If we wish to maintain the same residence time (24.3 s) and at the same time have the correct medium flow rate (0.5 x 18.3 mL/min) through the bioreactor, the liquid hold up must be 3.70 mL. Having the swell factor for Cytodex 3, we compute a required bead loading of 64 g/L corresponding to a liquid void fraction of 10%! However, the minimum void fraction that we can have with Cytodex 3 is that of a packed bed and it is about 37%. In conclusion, it is impossible to satisfy all

design criteria with microcarrier cultures.

If instead, we consider a flat surface bioreactor (T-flask type), the required size is about 1 m^2 with a liquid height of 3.5 μm which again is impossible to attain. The required liquid depth can be increased by an order of magnitude and the size of the unit can also be reduced by the same amount if we consider highly corrugated surfaces constructed with standard microfabrication techniques employed by the semiconductor industry. However, the required liquid level is still significantly lower than practical limits. The only bioreactor design that can accommodate all design criteria is that of hollow fiber. However, in this case we loose the flexibility to sample the compartment during the operation and follow intracellular and extracellular metabolites.

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ACTIVE FAULTING STUDIES IN GREECE: THEIR ENGINEERING AND ENVIRONMENTAL IMPLICATIONS

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ΜΕΛΕΤΗ ΤΩΝ ΕΝΕΡΓΩΝ ΡΗΓΜΑΤΩΝ ΣΤΗΝ ΕΛΛΑΔΑ: ΤΕΧΝΙΚΟΓΕΩΛΟΓΙΚΕΣ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΙΚΕΣ ΕΦΑΡΜΟΓΕΣ

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The notion of Fault Activity is important for Seismic Hazard Assessment. An Active (or Capable) Fault is a geological structure that has an established record of activity once at least in the 10,000 or 35,000 years or repeated activity during late Quaternary (half a million) years, and the capability of generating earthquakes. Mapping of active fault zones, with all geological, morphotectonic, geophysical, geochemical and geodetic methods, will allow to record and to understand the crustal processes associated with the seismic cycle of a fault network and to check the ability of instrumentation and analysis of data in precursors studies. However, there are wide variations in the criteria for fault activity.

Devastating earthquakes have occurred in seismic active zones of Greek territory. A simple morphoneotectonic map of Aegean broader area (Greece and surrounding region) has been made in scale 1:1,000,000, as a first approach of the geologic-seismic activity of the region. The map shows active or possible active fault. Some of these faults seem to have been activated during Miocene, Pliocene or Quaternary, and only few of them are associated with known historical or instrumentally recorded earthquakes. Although Greece has one of the longest and densest records of historic seismisity in the word, only few of these events have shown positively associated to a specific and well-identified seismogenic fault (see Table).

Seismic Hazard Maps, based both in geological and seismological data, are the basic input for a comprehensive strategy of seismic risk studies, including the adoption of national seismic zoning and of safe building construction codes. Active faults have not been taken into consideration in the drafting of the Seismic Building Code of the country. On the other hand the experience of geological input in such maps is extremely limited in Greece, but the necessity and the interest for technical works and environmental designs is rapidly increasing. Some examples of Seismic Hazard Analysis based mainly on Geological data are given, namely: 1) the role of Kammena Vourla — Agios Konstantinos new highway (tunnel, bridges, cut and covers); 2) the identification of faults surrounding Almopaeos (S. Almopia-W. Macedonia) dam; 3) Larissa basin (Thessaly) active faults (Seismic potential and creeping). They try to: a) Define the earth source's geometry and earthquake potential. That is, neotectonic mapping and fault segmentation. Geomorphic and geometric irregularities permit long faults to be divided into segments. Segments based on Geology may correspond to earthquake rupture zones, permitting a forecast of the magnitude of a possible future seismic event (s). b) Estimation of the maximum expected Magnitude (the earthquake that is expected to produce the strongest level of shaking). 3) Assessment of Mean and Maximum surface displacement (horizontal and vertical) which is of crucial importance for constructions.

Empirical relationships between earthquake Magnitude and fault length, rupture area, maximum displacement, based on statistical analyses of word-wide historical earthquakes (e.g. *Wells &*

Coppersmith 1994) have been tested and applied for some Greek earthquakes and associated faults. Results (recalculation) are shown in the following empirical relationships:

a) Moment Magnitude — Surface Rupture Length Mw=5.37+1.12logL
b) Moment Magnitude — Maximum Displacement Mw=6.72+0.22logMD
c) Moment Magnitude — Average Displacement Mw=6.79+0.20logAD
d) Moment Magnitude — Rupture Area Mw=2.84+1.45logRA

They fit well enough for the surface rupture length, rupture area in relation to Moment- Surface Magnitudes, but they do not for Maximum displacement, which has been estimated smaller empirically, following the most reliable data for Greek seismic events and palaeseismological results.



Morphoneotectonic map of the broader Aegean region, where the main Active (seismogenic faults) and possible (neotectonic) faults are shown.

TABLE Shallow earthquakes which are associated with surface fault traces from broader Aegean region

Year Date	Area Region	Magn.	Intens.	SRL (km)	MD (m)	AD (m)	RA (km^2)
1861 Dec 26	Valimitica (N. Peloponnesos)	6.7	X	13	1	0.5	-
1867 March 7	Lesbos (N. Aegean Isl.)	>6.5	X	(3)			
1894 April 27	Atalanti-Thermopylae (Central Greece)	7.0	X	25+	1.5	0.5	-
1893 Feb 9	Samothrace Isl. (N.Aegean)	6.8	IX	(5)			
1899 Sept. 20	Aidine (W Turkey)	7.0	IX	40	1		
1904 April 4	Krupnik (Bulgaria)	7.1	X	30	2	-	
1912 Aug. 9	Callipoles (Thrace-NW Turkey)	7.6	X	(50)	3		
1919 Nov. 18	Zeytindag-Pergama (NW Turkey)	7.0	IX				
1928 April 14	Chirpan-Plovdiv (Bulgaria)	6.6	IX				
1928 April 18	Popovitsa-Plovdiv (Bulgaria)	6.9	X	(40)	(3)		
1932 Sept. 26	W. Chalkidiki (N. Greece)	6.9	X	15+	1.6	0.4	-
1938 April 19	Kirsehir (Turkey)	6.8	X	15	0.6		
1941 March 1	Larissa-Thessaly (C. Greece)	6.3	VIII	?			
1944 June 25	Safane (W. Turkey)	6.1	VIII	20	0.30	0.10	
1944 Oct. 6	Aivasic (W. Turkey)	6.9	IX				
1953 March 18	Genise (NW Turkey)	7.4	IX+	58	2.8		
1954 April 30	Sophades (SW Thessaly-C. Greece)	7.0	IX+	30	0.9	0.3	-
1955 July 16	Buyuk Menderes Graben (W. Turkey)	6.9	VIII				
1957 March 8	Velestino-Magnesia (Thessaly-Greece)	6.8	IX+	(2)			
1964 Oct. 6	Manigias (W Turkey)	6.9	IX	40		0.1	
1967 Nov. 30	Dibra (Albania)	6.6	IX	10	0.5		
1968 Feb. 19	Agios Efstratios Isl (North Aegean)	7.1	IX	(3)	0.5		
1969 March 23	Demirsi -Simav fault (W. Turkey)	6.1	VIII				
1969 March 28	Alasehir (W. Turkey)	6.6	VIII	36	0.8		
1970 March 28	Gediz (W. Turkey)	7.1	V	45	2.8		
1971 May 12	Bourdour (SW Turkey)	6.2	VIII	1	0.14		
1978 June 20	Thessaloniki-Mygdonia (N. Greece)	6.5	VIII	12	0.25	0.08	390
1980 July 9	Magnesia (S. Thessaly-C. Greece)	6.4	VIII	9	0.2	0.2	330
1981 Feb 24	Alkionides-E. Corinthian Gulf (Greece)	6.7	IX	15+	1.5	0.7	440
1981 March 4	Kaparelli-Boeotia (Central Greece)	6.4	IX+	12	1.2	0.6	230
1983 March 16	Akarnania (Western Central Greece)	5.4	VII	?	0.2	0.15	160
1986 Sept 13	Kalamata (SW. Peloponnesos-Greece)	6.0	IX	15	0.12	0.6	
1988 Oct. 16	Kylline-Elia (NW Peloponnesos-Greece)	6.0	VIII	?			
1995 May 13	Kozani-Grevena (W Macedonia-Greece)	6.6	IX	15+	0.12	0.06	300
1995 June 15	Aegion (N. Peloponnesos-Greece)	6.2	VIII	7	0.02	0.02	-
1995 Oct. 1	Dinar (SW Turkey)	6.1	IX	10	0.25	0.12	



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