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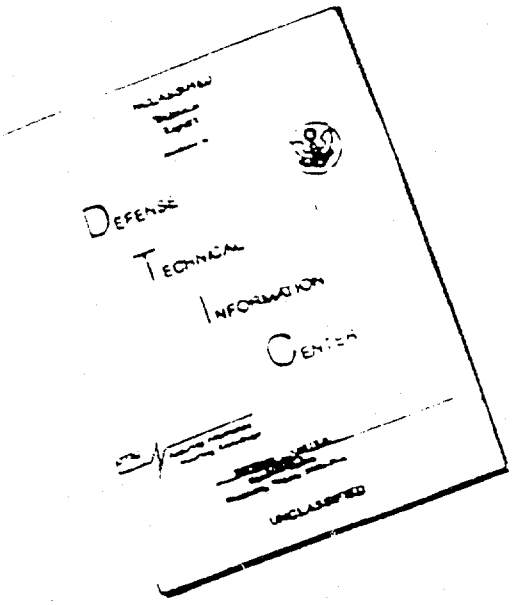
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Status of Knowledge

# of GROUND WATER CONTAMINANTS

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FEDERAL HOUSING ADMINISTRATION

Technical Studies Program.. March 1961

STATUS OF KNOWLEDGE

OF

GROUND WATER CONTAMINANTS

by

William E. Stanley and Rolf Eliassen

DEPARTMENT OF CIVIL AND SANITARY ENGINEERING

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CAMBRIDGE 39, MASS.

- - - - - - - - - - - - - - - - - - -

The Work Described in This Report Was Performed
For the Federal Housing Administration
Technical Studies Program

Under Contract No. HA(---) fh-757

December, 1960

FOREWORD

To meet the future water needs of our rocketing population and the rapid industrial growth and change, President Kennedy, in his message to Congress on Natural Resources said, "in many areas of the country we need new sources of supply--but in all areas we must protect the supplies we have."

Accordingly, FHA is pleased to present the following report as an example of the research the agency initiated to increase our basic knowledge about ground water contaminants, many of which produce diseases or illness or are potentially dangerous to the health of individuals living in residential developments.

In recent years ground water contamination has become more significant because the potable water supplies in many areas have approached or exceeded the safe yield; the population density and increased industrial wastes creates a heavier burden on our ground water resources; and the increased construction or residential projects which are beyond the mains of municipal water supplies and, therefore, are dependent upon ground water.

FHA believes the information contained in the Status of Knowledge of Ground Water Contaminants will have far reaching results and will materially aid all those involved in the development of methods to ensure the safety of ground water against contamination.

Federal Housing Administration

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CIVIL AND SANITARY ENGINEERING

CAMBRIDGE 39, MASS.

December 7, 1960

Mr. Neil A. Connor, Director
Architectural Standards Division
Federal Housing Administration
Washington 25, D.C.

Subject: Status of Knowledge of Ground Water Contaminants -
(Contract No. HA(---)fh-757.)

Dear Sir:

Herewith is transmitted our completed report entitled "Status of Knowledge of Ground Water Contaminants", in compliance with an agreement between Federal Housing Administration and Massachusetts Institute of Technology - Contract HA(---)fh-757.

The report includes the following major sections:

Summary, Conclusions, and Recommendations
Part I - An outline of the investigation
Part II - A summary of literature and suggested investigation
Part III - Supplemental information on selected contaminants.
(A series of appendices)

There is a bibliography at the end of Part II and a series of references at the end of many of the appendices.

Respectfully submitted,

Rolf Eliassen
Professor of Sanitary Engineering

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STATUS OF KNOWLEDGE

OF

GROUND WATER CONTAMINANTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Summary, Conclusions, and Recommendations

Ground water for water supplies in residential projects may be contaminated by physical, chemical, biological, or viral contaminants. The older concept of sanitarians which gave special attention to bacterial contamination, using coliform organisms as an indicator of bacterial contamination, must be widened to include not only biological and chemical pollution due to sewage, but also contamination by physical, chemical, biological, and viral contaminants.

An increasing number of contaminants and a higher frequency of ground water contamination are related to industrial development, particularly dispersal of industries in rural and semi-urban areas, including oil fields and petroleum marketing facilities. Also increasing dispersal of population densities in fringe areas and a substantially greater draft on ground water resources are important factors.

A classification of potential ground water contaminants is proposed and the status of present information on each contaminant is summarized by Table A - Status of Information on Ground Water Contaminants. This summary table indicates insufficient knowledge of many present and potential near future contaminants.

The objective of this investigation has been to search out literature bearing on various ground water contaminants; assemble and evaluate available information; and to determine the present state of knowledge relative to each contaminant. Particular attention has been paid to (1) permissible concentrations; (2) possibilities of forecasting contamination of ground water at specific locations; (3) additional information needed; (4) suggestions of methods for obtaining such additional needed information; and (5) recommended priorities for research to obtain such information. (Appendix J.).

Three important factors have increased greatly the importance of ground water contamination for residential projects within recent years:

(1) the potable water supply requirements in many areas are rapidly approaching, and at times exceeding, the safe yield of available water supplies, thus making necessary conservation of all ground water supplies in an uncontaminated state;

(2) concentrations of contaminants reaching ground waters have increased greatly due to greater population density, greater quantities of industrial waste waters, and greater demands placed on ground water resources;

(3) much larger numbers of population are living in rural areas or in the fringe areas of municipalities beyond the mains of municipal water supplies and thus are dependent upon ground water supplies, generally private wells and often shallow wells.

The numbers of physical and chemical contaminants which may reach ground waters are increasing rapidly with increases in the number, variety and dispersal into rural areas of industrial establishments. Also many more water borne biological and viral contaminants are being discovered, which may prove to be able to reach ground water and remain capable of causing disease or illness.

Table A is a summary showing the status of published information on important ground water contaminants and pertinent subdivisions of information relative to them. Much existing basic data is uncertain and will require further study and experience before firm conclusions may be reached and effective control measures instituted.

Some research is in progress on various phases of ground water contamination, particularly in the oil well areas and in certain sea coast areas. Some preliminary results have been published. Considerable unpublished experience data on cases of ground water contamination are available in the files of various public health agencies, salt water control agencies, and possibly other public agencies. Such data should be assembled, analyzed, and made available for the benefit of all agencies.

Additional research is needed to develop basic knowledge on the reactions which might occur as various contaminants in water pass through soil. Methods to ensure the safety of ground water against contamination should be developed from the results of such research programs.

The relative priority for research and study of the various ground water contaminants, or potential contaminants, will depend on several factors; (a) the probable comparable importance of the several contaminants with reference to potential health hazards; (b) the character of the presently available knowledge of the contaminants (i.e., some contaminants are well known to be dangerous even though complete information is not yet available); (c) the amount of complexity of preparatory research involved (example: Viral contaminants are increasing in importance. However, much medical and virological research is needed before most viral organisms can be identified); and (d) available qualified personnel facilities, and funds to develop research programs.

Suggested priorities are shown in the last (right hand) column of Table A. based largely on impressions from the literature and general knowledge. These are explained in Appendix J - REPORT ON PRIORITIES FOR RESEARCH PROJECTS.

Any plan for priority assignments must be subject to continual revision as knowledge acrues. Also many judgment factors are involved. The suggested priorities should provide an initial basis for general planning, with revisions to be anticipated in the light of additional knowledge and available facilities.

CONCLUSIONS

The survey of literature and a study of the present knowledge relative to ground water contamination may be summarized by a number of conclusions;

1. The need for uncontaminated ground water supplies is becoming increasingly important in the development of residential projects.

2. The rapid spread of population into fringe areas around urban centers; the increase in industrial waste waters; and the rapid dispersal of industries into rural and semi-urban areas have produced a rapid increase in numbers of ground water contaminants and frequency of contamination.

3. The present PHS Drinking Water Standards - 1946 have the primary purpose of protecting drinking water for interstate carriers and drinking water generally supplied to municipalities with reference to health hazards. There is a need for a water quality standard related to residential water supplies particularly, for those situations of water contamination where the public health is not a paramount problem.

4. Whereas many published discussions of professional standards (152) (421) suggest the desirability for lower allowances than given by the PHS Drinking Water Standards - 1946, there appears to be possibilities of permitting higher concentrations of certain types of ground water contaminants before condemning the only source of water for an individual residence or small group of residences, in residential projects, which do not endanger the public health.

5. To date health authorities and sanitarians have been so engrossed with contamination of surface waters that much experience data and information on ground water contamination problems have not been published. These data should be obtained, correlated and made available for the benefit of the public.

6. Much research is needed to ensure a proper knowledge of water contaminants and methods for controlling contamination of underground waters. The rate of increase in types and quantities of ground water contaminants is very rapid. Many preliminary suggestions for research are given in the report. A few specific recommendations are summarized in the following.

RECOMMENDATIONS

The following recommendations are respectfully submitted, based on the literature survey and a general study of information relative to ground water contaminants;

A. That the FHA develop water quality criteria to include realistic permissible limits for ground water contaminants related to the primary objective of protecting water supplies in residential projects. Two scales as to permissible concentration of contaminants might be considered, particularly for many contaminants which are objectionable due to esthetic considerations and are not directly health hazards. The development of such quality criteria might consider;

   a - A lower desirable concentration as a guide in the control of sources and potential sources of pollution.

   b - A higher concentration as the recommended upper limit for the use of a ground water source as a potable water supply.

B. That the present FHA manual "Minimum Property Standards for One and Two Living Units" be expanded to include water quality standards and recommendations as to concentrations of water contaminants for the guidance of inspectors, owners, and builders for those situations where public health considerations are not the major problem.

C. That the FHA promote researches to increase the knowledge of ground water contaminants and the control of ground water contamination, along the following general lines;

1. An investigation to compile and correlate extensive experience data, with reference to ground water contamination, presently available in the practical working files of the several state, county, and other public health agencies, salt water control agencies, and other public agencies, to make available such unpublished data for the general public benefit and to increase available knowledge of ground water contamination.

2. An investigation, including laboratory and pilot plant experimental investigations to develop adequate basic knowledge concerning objectionable characteristics of synthetic detergents, basic knowledge of the relationship between physical and chemical characteristics of soil, and the travel of detergents; and practical or feasible protective measures to reduce or prevent ground water contamination by synthetic detergents with particular reference to water supplies for residential projects.

3. An investigation of biological contaminants, including laboratory and pilot plant experimental studies to develop basic knowledge of the effect of travel through various soils on the numbers and probability of producing disease for various infective organisms, including viral, bacterial, amoebic and fungal organisms.

4. An investigation of contamination of ground water supplies by chlorides, including two major research programs;

   a. A review of results to date of work by several State salt water control agencies.

   b. An experimental research to determine (1) chlorides solution movements relative to soil characteristics; (2) rate of dilution by diffusion of chloride solutions with fresh water in soil; and (3) possible reduction of chlorides by any interaction with soil.

5. An investigation of nitrate-nitrogen contaminants in ground waters including;

   a. Methods of tests, measurements, and observations needed to determine probable travel of a surface nitrate pollution into soil and ground water for shallow and deep wells.

   b. The toxic concentration of nitrate-nitrogen and factors which control for infants and for adults.

   c. The effect of any possible ion exchange of nitrates and various soils plus the characteristics of soil nitrification.

6. A review of available unpublished information on toxic chemicals used for insecticides, larvacides, pesticides, and herbicides, to determine the magnitude of the public health hazard. Then possibly an experimental study to determine the effect of soil and ground water characteristics on the strength and travel aspects of these toxic chemicals.

7. An investigation of ground water contamination by petroleum oil products and waste waters relative to frequency; travel through soil or through soil and ground water; inter-relationship of waste waters and soil characteristics.

8. An investigation of radiological contaminants along two lines of study:

   a. A study of possibilities of promulgating an instructional manual - or supplement to the existing Minimum Standards - for the benefit of water users unversed in atomic energy or nuclear sciences.

   b. Laboratory and pilot plant experimental work to determine travel and dispersal characteristics of radioactive particles relative to soil characteristics.

9. A study of chemicals listed in the PHS Drinking Water Standards - 1946, with particular reference to the extreme concentrations before an only ground water supply must be abandoned. Also the relationship of soil characteristics and the travel and dispersal or dilution of the chemical contaminant.

10. An investigation of viral contaminants in two stages -

    Stage 1. An exploratory study to determine how current bio-assay procedures may be modified for more beneficial use by water chemists and biologists.

    Stage 2. A program of experimental studies of (1) assay efficiencies; (2) effect on viruses of salts and other components of soil or ground water; (3) virus concentrations; (4) travel through soil; and (5) other interrelation of viruses in the soil and in ground water - to determine the distances of travel of virile virus. Radio-tracer studies would be used throughout.

11. Investigation of potential inorganic chemical contaminants, possibly in two stages;

    Stage 1. An exploratory study to evaluate the most recent evidence, either published or unpublished, as to toxicity of the several chemicals with particular reference to maximum permissible concentrations.

    Stage 2. Experimental studies - comparable to studies proposed for chlorides, nitrates, and other inorganic chemicals - to determine chemical and hydro-mechanical relationship between chemicals and soil characteristics.

12. A study of metal finishing wastes - Investigational programs similar to item 11.

13. to 20. Inclusive (see Table A and Appendix J), similar research programs to that suggested for item 11.

Much of the effort in the foregoing recommended investigations would be in the nature of exploratory research to be followed by more specific researches, as may develop from initial projects. The increasing importance of and need for ground water as sources for potable water, particularly for residential projects, justify the suggested researches.

ACKNOWLEDGMENTS

The project reported upon herewith has been under the general supervision of Dr. Rolf Eliassen, Professor of Sanitary Engineering, with the technical direction and preparation of text handled by Professor William E. Stanley.

In the detailed work of the library survey, Professor Stanley was assisted in part by Research Assistants Messrs. Richard E. Speece and Larry M. Ogden and graduate students Messrs. K. V. Mariwala, M. A. Marbech, and Misses Elizabeth C. Maclean, Zohreh Sarmad, and Beth Walden. Miss Maclean made a specially commendable contribution on viral contaminants.

Much information was contributed by personnel of the U. S. Public Health Service and several State Health Departments.

TABLE "A" - STATUS OF INFORMATION ON GROUND WATER CONTAMINANTS

Legend: → S = Present knowledge is satisfactory → Blank space = Present knowledge insufficient; additional knowledge needed

Contaminant	Source of Contaminant	Effect on Water Quality	Permissible Concentration	Experience Data	Nature of Movement: Aerial Ground Water	Nature of Movement: In and O.C. G.W.	General Attn Soil: Aerial Ground Water	General Attn Soil: In and O.C. G.W.	Prediction of Movement: Present Art	Prediction of Movement: Improved Methods	Water Quality Control Measures	Reference Priority #	Footnote
I. PHYSICAL													
a. Turbidity	S	S	S	S	S	S	S	S					
b. Tastes	S	S		S									
c. Odor	S	S		S									
d. Color	S	S	S	S									
e. Temperature	S	S	S	S									
II. CHEMICAL													
1. Inorganic													
1a. Chlorides	S	S										#4	
1b. Chromates	S											#9	
1c. Nitrates		S										#5	
1d. Disinfectants													
Bromine	S	S	S	S								#19	
Chlorine	S												
Hydrogen Peroxide	S												
Iodine	S			S									
1e. Metal Finish. Wastes												#12	
1f. Chemicals - Covered by PHS Drinking Water Std's - 1962													
→ S - With Maximum Concentrations Specified by PHS (5 items)													
Lead	S	S		S									
Fluoride	S	S	S	S	S	S	S	S	S	S	S		
Arsenic	S	S											
Selenium	S	S											
Chromium (see 1b. above)													
→ S - With Recommended Concentrations - by PHS (8 items)													
Copper	S			S								#9	
Iron and Mn	S	S		S									
Magnesium	S	S											
Zinc	S												
Chlorides (see 1a. above)													
Sulfates	S												
Phenol													
Total Solids	S	S											
1g. Inorganic Chemicals - Potential Contaminants													
Aluminum												#11	
Barium													
Boron (Boric Acid)													
Cadmium													
Lithium													
Mercury													
Molybdenum													
Nickel													
Phosphorus													
Potassium													
Silica													
Silver													
Sodium													
Thallium													
Thorium													
Tin													
Titanium													
Vanadium													

NOTE: #1 priority — An investigation of unpublished experience data from files of public agencies.

TABLE "A" - STATUS OF INFORMATION ON GROUND WATER CONTAMINANTS (Continued)

Legend: → S = Present knowledge is satisfactory → Blank Space = (Present knowledge insufficient) (Additional knowledge needed)

Contaminant	Source of Contaminant	Effect on Water Quality	Permissible Concentration	Experience Data	Nature of Movement: Above Ground Water	Nature of Movement: In and With G.W.	Removal With Well: Above Ground Water	Removal With Well: In and With G.W.	Evaluation of Contamination: Present Info	Evaluation of Contamination: Information Needed	Water Quality Criteria Needed	Research Priority
II. CHEMICAL (Cont'd)												
A. Organic												
2a. Syn. Detergents	S	S		S								#2
2b. Domestic Sewage	S	S		S								
2c. Animal and Vegetable Process Wastes												
Packing Plants	S	S										#13
Slaughter-houses	S	S										
Rendering Plants	S	S										
Refine - Veg. Oils	S	S										
Cotton Seed	S	S										
Corn (Maize)	S	S										
Soya Bean	S	S										
Textile Wastes	S	S										
Milk Process.	S	S										
Distilleries	S	S										
Sugar Plants	S	S										
Paper & Pulp	S	S										
Wool Scouring	S	S										
2d. Petroleum Oil Wastes												
Oil Fields	S	S										#7
Refinery - Pet. Oils	S	S										
Marketing and Storage	S	S										
Gasolene	S	S										
2e. Coal Tar Products Wastes												
Acridine		S										#15
Cresylic Acid		S										
Cresols		S										
Naphthalene		S										
Phenanthrene		S										
Phenols		S										
Pyridine		S										
Quinoline		S										
Thiophene		S										
Xylene		S										
2f. Coke Gas Plant Wastes												
Ammoniacal Liquors	S	S										#14
Cyanides		S										
Organic Acids		S										
2g. Dye Wastes												
Aniline	S	S										#16
Nigrosine	S	S										
Picoline	S	S										

TABLE "A" - STATUS OF INFORMATION ON GROUND WATER CONTAMINANTS (Continued)

Legend: → S = Present knowledge is satisfactory → Blank Space = (Present knowledge insufficient (Additional knowledge needed

Contaminant	Sources of Contaminant	Effect on Water Quality	Permissible Concentration	Temperature Data	Nature of Movement: Above Ground Water	Nature of Movement: In and With G.W.	Removal thru Soil: Above Ground Water	Removal thru Soil: In and With G.W.	Evaluation of Contamination: Present Area	Evaluation of Contamination: Information Needed	Priority of Problem Needed	Monitoring Priority
VI-f. Organic Chemical (Cont'd)												
m. Explosives												
Ammonium Picrate	S	S										
Dinitrophenol		S										
Mononitrotoluene		S										
Nitro Benzene		S										
Orthodichlore Benzene		S										* 17
Picric Acid		S										
Tetryl		S										
TNT (Trinitro-toluene)	S	S										
n. Pesticides (Insecticides, Herbicides)												
Aldrin		S										
Benzene hexachloride		S										
Benzene hexachloro-cyclohexane		S										
Chlordane		S										
Dieldrin		S										
DDT or TDE		S										* 6
Malathion		S										
Mercuro-Organic		S										
Parathion		S										
Pyrethrum		S										
Rotenone		S										
Toxaphene		S										
o. Petrochemical Industries												
Basic Raw Material		S										
End Products		S										* 18
Intermediates		S										
VII. RADIOLOGICAL												
Radioactive Wastes	S	S	S	S							S	
a. Atomic Industry	S	S	S	S							S	* 8
b. Radioisotopes	S	S	S	S							S	
c. Atomic Weapons	S	S	S	S							S	
IV. BIOLOGICAL												
a. Amoebiasis	S	S	S	S								
b. Bacillary dys.	S	S	S	S								
c. Cholera	S	S	S	S								
d. Leptospirosis	S	S	S	S								* 3
e. Tularemia	S	S	S	S								
f. Typhoids	S	S	S	S								
g. Brucellosis	S	S	S	S								
V. VIRAL												
a. Hepatitis	S	S		S								
b. Poliomyelitis												
c. Coxsackie												
d. Echo Virus												* 10
e. Adenovirus												
f. Other Virus												

GROUND WATER CONTAMINATION

RESIDENTIAL PROJECTS

PART I - INTRODUCTION

A library survey has been made to seek out and evaluate available published knowledge on ground water contamination by various types of contaminants, with particular regard to potable water supplies for residential projects. Limited information has been obtained by correspondence. The scope, investigational procedures and definitions for a library survey are outlined in this introduction.

A summary of comparable information for the several substances which may contaminate ground waters is included in Part II - Summary Report. Some supplemental background information for several contaminants has been assembled in some detail as Part III - comprising a series of supplemental memoranda or appendices. Also Table A comprises a graphical summary of the present status of information

Scope and Conduct of Survey

The survey included library searches for published information on those materials which have caused or potentially might cause significant contamination of ground water, sufficient to be considered hazardous to potable water supplies.

The initial step in the survey included a preliminary review of the abstracts of technical literature prepared by upwards of eighty abstracting agencies of which five agencies provide sufficient numbers of ground water references to warrant a more complete study and listing of reference items. Available writings were studied and excerpts of information assembled for various contaminants or group types of contaminants.

Data by Correspondence

Some data were obtained by correspondence with Federal and State agencies, particularly State Departments of Health - these are outlined as Appendix B of Part III - Supplemental Information.

These correspondence data plus a visit to the offices of a typical State Department of Health (Indiana) indicate that there may be a reservoir of experience data in the files of the several state sanitary engineering offices of sufficient value to justify an investigation, cooperative with the States, being made to summarize and record the instances of contamination by various substances, and possibly to obtain some indication of practical measures needed to abate such contamination.

Analysis of Literature

Assembled material from the literature was arranged for investigation for each contaminant under eleven information sub-divisions as follows:

Introduction

1. Sources
2. Effect on Water Quality
3. Reported Permissible Concentration
4. Experience to date

Passage Through Soil

5. Nature of Movement
   a. Above Ground Water
   b. In and With Ground Water
6. Removal of Contaminant
   a. Through Soil Above Ground Water
   b. In and With Ground Water

Determinations from Survey

7. Predicting Contamination
   a. Present Art
   b. Additional Information Needed
8. Water Quality Criteria Required
9. Suggestions for Obtaining Additional Information

10. Summary
11. References to Literature.

References to writings were initially found from abstracts of literature. Additional reference items were obtained from lists of references at the end of most published articles.

A number of memoranda of supplemental information were prepared (Part III) in which much of the information for sub-divisions 1 to 6, of the foregoing outline, was abstracted in the form of condensed excerpts from the several writings. The pertinent references have been listed under the sub-division 11. References to Literature as part of each supplemental memorandum.

These supplemental information summaries, plus consideration of the conclusions reported by authoritative writers, and our general knowledge from various sources, have provided a basis for a summary discussion of the several phases of each contaminant material, as indicated by the foregoing outline sub-division 7 to 10, inclusive. These summary discussions are given as Part II - Summary Report.

Water Quality Standards

The standard of water quality, considered to be of interest in the literature survey covered by this report, has been water quality with reference to domestic use, essentially a drinking water standard. Any satisfactory quality of ground water should be such as to be safe for drinking and culinary use, preferably without artifical treatment.

The Public Health Drinking Water Standards - 1946[108], originally promulgated in 1914, revised in 1925 (which edition became known world-wide as the "U.S. Treasury Standards"), revised again in 1942, and reissued in 1946, for control of water supplies on common carriers, are presently quite generally used as standards for safe drinking water.

However, the Public Health Drinking Water Standards - 1946 - cover a very limited number of contaminants. They do not cover a number of presently important chemical contaminants, such as synthetic detergents, nitrates, and others; also viral, some biological and other contaminants are not covered. There is no adequate general water quality standard presently available for residential ground water supplies.

Accordingly, there is a need in case of many contaminants, for better and more complete water quality standards with reference to ground water supplies; more specifically related to some of the contaminants which have become bettern known and others which have been produced extensively in recent years.

There is a real need for additional knowledge of many contaminant items, as briefly summarized in Part II - Summary Report.

Definition of Contamination

In this report, the word "Contamination" is considered to include the premise that something is introduced into or added to ground water and also to include situations where ground water naturally has in it substances hazardous to health or offensive to the senses, such as iron, manganese, nitrates, fluorides, or other substances, in concentrations above a permissible maximum.

So a definition of "contamination" has been used, based on a modification of the definition in the A.P.H.A. "Glossary-Water and Sewage Control Engineering", which revised definition may be stated as follows:

> Contamination - A general term signifying the introduction of substances into ground water; or ground water with a natural objectionable content of microorganisms, minerals, chemicals, or other substances which render the water unfit for a domestic water supply.

It has not been feasible or necessary to adjust all excerpts from literature to comply with this proposed definition.

Classification of Contaminants

Contaminants have been classified, for the reported study, as I - physical; II - chemical; III - radiological; IV - biological; and V - viral. To permit an orderly review within a reasonable length of text and time, contaminants have been grouped together by similar substances for which there have been experiences with ground water contamination. The chemical contaminants have been further sub-divided into two major sub-divisions; 1) inorganic, and 2) organic compounds.

This classification outline is shown by Table A, which includes a list of the several classifications of contaminants together with a symbol, for the various aspects of knowledge of each contaminant, to indicate the present status of published information, whether satisfactory or insufficient. Table A provides a quick reference basis for finding the areas where further research is needed.

Part II - Summary Report

An effort has been made to discuss briefly, in Part II, each contaminant, or group of contaminants, under the foregoing eleven sub-divisions. On the basis of the summarized information for sub-divisions 1 to 6; together with supplemental memoranda (Part III); conclusions reported by authoritative writers; and our own general knowledge from various sources, a brief statement has been prepared for each contaminant under the designation "Determinations from Survey" in the foregoing outline (sub-divisions 7 to 10 inclusive).

Part III - Supplemental Information

Brief summaries of background information on a number of ground water contaminants are recorded in Part III, of this report, which comprises several appendices. Certain appendices were written more comprehensively than others depending in part on the importance of the subject and in part on the interest and special knowledge of the researcher. Also, in each appendix, of Part III, there is a summary of the subject and suggestions for further research.

Research Needed

There are unknown aspects of practically all contaminants and research on various questions should be considered in order to provide the knowledge needed to ensure safe residential ground water supplies. Some suggestions are included in Part II, together with an opinion as to relative priority of practical researches.

GROUND WATER CONTAMINATION

RESIDENTIAL PROJECTS

PART II - SUMMARY REPORT

General Statement - Several general aspects of ground water contamination are briefly discussed in the following initial paragraphs. A summary report on information for each contaminant is then presented under ten divisions, as outlined in Part I - Introduction. A graphic summary of the status of present information is given by Table A.

1. Sources - General

Generally, ground water pollution may be due to waste waters from domestic, commercial, or industrial activities, which are deposited on or near the ground surface and which seep through the soil, along rock crevices, or through defective well casings, and may reach ground water used, or potentially useful, for domestic water supplies.

Under sources of contaminants are included domestic sewage, detergents, liquid process wastes from commercial and industrial activities, and some substances, generally chemicals, found naturally in ground waters in certain localities.

In some cases, sources of ground water contamination may be removed or abated by improvements of waste water disposal methods or by relocation of the waste water disposal facilities. Sometimes, changes in manufacturing processes may remove or reduce the objectionable waste materials.

Some ground water contaminants from underground sources of natural materials, which cause substantial problems of ground water contamination, may require extensive measures for improvement of water quality. Thus, salt water and oil from oil wells in many areas; salt water from salt deposits or perched salt water solutions; sea water intrusion along heavily pumped underground aquifiers; nitrates; iron; fluorides; and other natural minerals; have provided natural sources of ground water contamination.

2. Effect on Water Quality - General

In general, the effect of contamination on ground water quality, considered pertinent to this investigation and library survey, relates to domestic use of water. Adverse effect on water quality might include (1) any health hazards; (2) any possibility as to a potential health hazard; (3) any objectionable impairment of the esthetic character of water; and (4) any excessive increase in total solids or hardness of water - i.e., mineralization.

Each of the four general quality parameters have wide variations as to acceptable concentrations. In all cases of uncertainty the questionable substance has been included in this report as a potential contaminant and placed under the designation - Additional Water Quality Criteria Needed. The opinions of various qualified water quality experts may differ as to the inclusion or exclusion of some of such uncertain substances.

3. Reported Permissible Concentration

In general, the officially expressed, or tentative conclusions as to permissible concentrations, by any health authorities have been given more weight than the opinion of individual writers. However, in cases of many substances, health authorities have been slow to record tentative conclusions. Such authorities in general are slow to establish criteria and equally slow in modifying criteria once established - possibly correctly so.

However, until sufficient information is available to be convincing to a considerable number of well qualified water experts, any questionable substance should be placed in the category of - "Additional Water Quality Criteria Needed."

4. Experience to Date

In general, discussion herein on the experience phase of ground water contaminants has been recorded only sufficiently to show that some difficulties, or uncertainties have been reported. In the case of many new chemicals; and for some viral organisms, consideration of these as potential water contaminants may be justified on inferential information, such as the toxic effect of chemicals on fishes, the spread of viral infections in a characteristic water borne disease pattern, instead of waiting for positive evidence that the substances or organism is a water borne contaminant. Again this increases numbers of contaminants in the category of - "Additional Water Quality Criteria Needed."

PASSAGE THROUGH SOIL - GENERAL

5. Nature of Movement
6. Removal of Contaminant

In general, published information is meager and incomplete on both the movement of a contaminant through the soil and the removal of the contaminant as it passes through the soil - either above the ground water table or along with the ground water.

In some areas, such as the investigation of oil field wastes, the investigation of underground disposal of radioactive wastes, or investigation of the use of sewage effluents for ground water replacement, much exploratory type research has been done.

These investigations generally have produced only indicative rather than conclusive results. In most cases limitations as to the control of the many variables have reduced the value of the results. There is need for more basic research.

DETERMINATIONS FROM SURVEY - GENERAL

7. Predicting Contamination
8. Water Quality Criteria Required
9. Suggestions for Obtaining Additional Information
10. Summary

In general, the discussions of these phases of this investigation represent the considered opinions of the authors based on impressions from the survey and general professional experience, backed up by a limited number of references to published opinions of others, rather than any detailed review of all published conclusions, recommendations, or opinions of a vast array of writers. Time has been too short for such assembly of published ideas, many of which would be based on a very limited perspective, or limited experience background.

I. PHYSICAL CONTAMINANTS

Ground water quality as indicated by the five physical characteristics (a) turbidity; (b) tastes; (c) odors; (d) color; and (e) temperature (105)(really indices of water quality) are so commonly included whenever contamination of water is discussed, the five items have been included in the current search, together as a group of contaminants. This contaminant classification seems to be pertinent in the investigation of ground water contamination.

Excerpts of many writings are given as background or supplemental information in Part III - Appendix C. The following paragraphs record a summary of information from the literature. The present status of knowledge is indicated by Table A.

(a) Turbidity

The term turbidity is used to describe the presence of substances in water which interfere with its clarity (105). Other similar definitions are found in published writings (116) (101) (107) (112) (102).

1. Source. "The turbidity of water is caused by the presence of suspended matter, such as clay, silt, finely divided organic matter, plankton and other microscopic organisms." (116)

The sources of these items may be (1) surface water or industrial waste waters reaching the ground water by seepage through the soil or by passage through rock crevices or through defects in well casings; (2) some disturbance of the underground soil such as poorly developed wells; (3) dissolved minerals such as iron, which may be precipitated by aeration; or (4) some biological growth such as algae.

2. Effect on Water Quality - Turbidity may indicate pollution from a surface water source, and the ground water might be seriously contaminated; or the turbidity may be due to oxidized iron or manganese; or it may be due to an incompletely developed well or a poorly selected well screen.

There are differences in published viewpoints on the meaning, or effect of turbidity. Examples:

> Ehlers and Steel(119) wrote - "In wells and springs, --- a sudden increase in turbidity after a rain indicates a very dangerous condition, particularly in a limestone region."
>
> Babbit and Doland(113) were more general - "Sediment producing visible turbidity is ordinarly composed of fine particles of sand and clay and, as such, it is not particularly detrimental to the potability of the water --- A turbidity indicating surface runoff would suggest possible pollution and might cause condemnation of the water source."

Turbidity - Continued

3. Reported Permissible Concentration - A ground water with variable turbidity may be more objectionable than a uniform turbidity, particularly if the turbidity appears during or following rains.

Public Health Service Standards(108) sets a limit of 10 ppm (silica scale) for filtered water, but does not include any specific limitation for unfiltered waters. Goudey(114) and Salvato(111) are more specific. They suggest a turbidity of less than 10 ppm as "good" and a turbidity greater than 15 or 25 ppm as "limited" (Goudey) or "Would justify treatment of the water" (Salvato).

4. Experience to Date - The occurrence of turbidity is common - many published articles have made reference to turbidity as a factor of water quality - often in connection with a discussion of some specific experience of contamination by some substance.

Turbidity - Passage Through Soil

5. Nature of Movement (through soil) - Turbidity may be carried long distances along rock crevices either above or in and with ground water. Porous sand and gravel may permit turbidity to travel for considerable distances - 200 to 500 feet but, in general, sandy soils may hold up the passage of turbidity.

6. Removal of Turbidity may be by soil filtration, by chemical ion exchange, or by colloidal adsorption depending on character of the substance causing turbidity and the soil chemistry. Finer grained soils filter out turbidity in short distances by mechanical and colloidal reaction - sometimes in 10 or less feet. Direct channels such as rock crevices may remove very little turbidity either above or below the ground water surface.

Determinations from Survey - Turbidity

The summary of this phase of the current report is closely the same for all physical contaminants so will be discussed after consideration of the fifth item: Temperature.

(b) Tastes and (c) Odors

These items - tastes and odors - are so closely related in the literature (116), (103), (106), (107), that they will be discussed together. In most cases the objectionable "taste" is really an odor. The term "flavor" is widely used in the beverage industries, but it is not commonly used in water supply discussions.

1. Source - Tastes and odors in ground waters may be due to natural minerals - such as salt, iron, or sulphites, but also may be due to chemicals from industrial wastes; or from biological growths; or from decomposing organic matter, such as peat bogs.

There have been many discussions of tastes and odors (111), (113) (107) (103) (116) (101), but they are generally related to the cause or origin of the taste or odor, such as natural underground contaminating substances or waste waters which may have percolated through the soil or through a defective well casing.

Many industrial waste waters contain taste or odor producing elements. Some substances must be in heavy concentrations, other substances, such as chloro phenol may produce objectionable tastes or odors in very small concentrations.

2. Effects - The presence of substances causing tastes and odors are undesirable aesthetically and are generally indicative of pollution (116) (112) (107).

3. Reported Permissible Concentrations - The Public Health Service Standards (108) merely state "The water shall have no objectionable taste or odor". This may not be sufficient in many cases of residential supplies. McKee(107) has published a list of threshold numbers for 23 chemicals taken from the literature, but the reported values, in general, are without the support of any influential agency or organization.

Accordingly, further research would be necessary to establish specific permissible concentrations for most taste and odor contaminants.

4. Experience to Date - The references to tastes and odors in the literature are too numerous to summarize. In most instances the reference to tastes or odors is incidental to the discussion of some chemical or biological contamination.

Taste and Odors - Passage Through Soils

5. Nature of Movement - Tastes and odors, being generally caused by a substance in solution, may pass through the upper soil into the ground waters, excepting that many odor-producing organic materials, if subject to oxidation, may be reduced in concentration by being oxidized to a non-odorous substance, while passing through the aerated soil. Other organic compounds, such as phenols, petroleum products, and others, are less likely to be affected by the soil and may enter the ground water without reduction of their taste or odor characteristics.

6. Removal of Tastes and Odors - It appears likely and there has been some evidence that certain tastes and odors might be removed or reduced in concentration by oxidation, as explained above, other substances may be absorbed by some soils, or filtered out by adsorbtion. However, there appears to be very little specific evidence as to the relationship of soil characteristics and the rate of taste and odor removal.

Determinations from Survey - (See a following section)

(d) Color

Color has been discussed as "apparent" or "true" color. McKee(107) suggests that in water-works practice color of water is considered to be only that attributable to substances in solution, after suspensoids have been removed by centrifuging.

Generally, uncontaminated ground water should not be colored. However, some wells in close proximity to peat bogs, swamps, or deposits of decomposing organic materials may have a brownish or reddish color. Ground water with dissolved iron or manganese content may become reddish or blackish on exposure to air.

1. Source. Salvato(111) stated - "Water which has drained through peat bogs, swamps, forests or decomposing organic matter, may contain a stain due to tannates and organic acids dissolved from leaves, bark, and plants".

However, color may be of mineral or metallic origin(107) such as manganese and iron; also process wastes percolating through the soil may produce color, particularly dye wastes.

2. Effect on Water Quality - Babbitt(112) stated that color is undesirable aesthetically with no sanitary significance other than indicating source of the water. McKee(107) was more definite by stating "In domestic water, color is undesirable from esthetic considerations and also because it may dull clothes, or stain food and fixtures ---"

3. Reported Permissible Concentration - The P.H.S. Drinking Water Standards(108) limit color of filtered water to 20 ppm, but state "---Color limits for unfiltered waters ---- should be based on reasonable judgment and discretion ---".

Salvato(111) stated "Color should be less than 5 to 10 ppm ---" Coudey(114) proposed ground water classes as follows:

"Class AA - Excellent	Color less than 10
"Class A - Good	" " " 20"

Generally ground waters do not contain objectionable color concentrations.

4. Experience to Date - Like other physical contaminants - there have been many references to colored surface water, but not so many to ground waters excepting where aeration had oxidized and partially precipitated some mineral, generally iron, or where some industrial waste water such as dye solution had seeped into the ground water supply.

Color - Passage Through Soil

5. Nature of Movement - Color, due to a colloidal substance, may be reduced rapidly by passage through soil. Some dyes may persist for long distances. Gotaas et al(117) reported on a dye added to sewage which travelled 300 feet in 24 hours.

Although color in ground water is unusual, in unpolluted wells or springs, certain chemicals such as iron or manganese when exposed to air may precipitate and cause objectionable color formation, thus may obscure the color reducing effect of soil.

The oxidizing effect is less after the color producing substance enters ground water so the reduction of color becomes due more to adsorption or filtering action on the color producing colloids.

6. Removal of Color - The foregoing discussion indicates the basic factors which effect color removal. Little attention appears to have been given to quantitative measurements of color removal relative to the physical characteristics of soils, possibly because color has not been considered a good index of pollution.

Determinations from Survey (See a following section)

(e) Temperature

Generally any increase in the temperature of ground water would be objectionable and if in shallow wells the water should be suspect, as coming from some surface source of pollution. A few cases of high temperatures have occurred due to contamination by hot waste waters, but generally these contain chemical wastes of more importance relative to ground water contamination than the temperature effect. Also the temperature is rapidly reduced due to the cooling effect of the soil above the ground water and the fringe or capillary strata just above the ground water.

High temperatures are unusual, but occurring in deep wells may be due to escaping temperature from deep in the earth. Such waters may be used for hot bathes, but would not be used normally for drinking water without some treatment, at least cooling.

Determinations from Survey - Physical Contaminants

A number of writings include discussions of the foregoing five physical characteristics on the basis of parameters of contamination or degradation of water quality. It is somewhat more difficult to consider them as primary contaminants as will be done in the following paragraphs.

7. Predicting Physical Contamination - presently the possibilities of contamination by turbidity, color, and to a less frequent degree tastes and odors can be predicted reasonably well (a) in coarse gravel and boulders with little or no covering of fine grained soil; and (b) in rocky areas where the rock formations have many crevices or dissolved passage ways. In both of these cases turbidity and color in the ground water would be expected if any surface water were permitted to drain down hill in the open areas. Tastes and odors might be expected if the seepage waters contained the proper types of chemicals.

Prediction of temperature in ground water would relate to the infrequent occurrence of hot springs, or possibly to the entrance of hot water process wastes into the underground water, through porous areas or through openings.

The possibility of contamination through fine grained soils has not been fully developed. Additional information is needed to determine the effectiveness of barriers of fine grained soils, or the distances of travel for the different physical contaminants through soils of different degrees of fineness and different chemical composition. These questions involve physical, chemical, and biochemical reactions between the physical contaminant in the water and the soil characteristics, both physical and chemical.

8. Water Quality Criteria Required - Techniques are well established for determining turbidity, color, and temperature of water, but measurements of tastes and odors are not so well developed. McKee(107) observed that Standard Methods(116) for the examination of water and sewage does not prescribe a procedure for taste determination.

There is a need for more specific designation of the proper limits for the five physical quality items for ground waters.

9. Methods for Obtaining Additional Information - Possibly, the presently desirable, at times necessary information, on the physical contamination of ground water may best be obtained by a series of researches along these lines;

a) A study of the effect of turbidity, tastes, odors, colors, and possibly temperature on the usefulness of ground water for domestic water supplies.

b) A basic study of flow through porous media - the relationship of various soil characteristics and the travel of the several physical contaminants through the soil.

c) It may be necessary to set up a closely coordinated study of the chemical or biological agents which cause the objectional physical contamination.

d) Available data on measurement techniques for each physical contaminants in ground water should be reviewed and a standardized measurement procedure established for each.

10. Summary - Physical Contaminants - The physical characteristics of turbidity, tastes, odors, color, and temperature, represent contamination of ground waters. These items have been considered herein as contaminants, they may also be considered as evidence of contamination by soil, chemicals, biological agents, or other objectionable substances.

Greater attention should be given to these five characteristics in ground water analyses and standard procedures or techniques should be established for the determination and recording of concentration of each physical contaminant.

Water quality standards should be established as to the permissible concentrations of the several physical characteristics, together with procedures for measuring and recording each physical characteristic. Some research will be required.

11. References - See Bibliography - reference items Nos. 101 to 119, inclusive - for significant information on Physical Contaminants.

II. CHEMICAL CONTAMINANTS

The types of chemicals, the possibilities of quantities of chemical waste waters reaching ground water supplies, are increasing at an astronomical rate(120). Many chemicals, and chemical compounds have been proven toxic to fish, some to animals, others to lower types of life, and are or might be toxic to man, if ingested in sufficient quantities.

Accordingly, consideration has been given, in the literature survey, to a considerable number of chemicals and groups of chemical compounds, as listed in Table A, by groupings of chemicals or industrial waste waters. Some individual chemicals or chemical compounds may be found in two or more groupings, but will be discussed only once - in the grouping in which each chemical item seems to be found most commonly.

The several chemicals or groups of chemical waste waters have been arranged in two major classifications; 1. Inorganic and 2. Organic; as listed in Table A.

1. Inorganic Chemicals

The listed inorganic chemicals include 39 chemical items under seven main groupings. Each chemical item, such as chlorides, represent a number of chemical compounds, rather than the chloride ion.

1a. Chlorides

Chlorides become objectionable ground water contamination under two general conditions:

(1) When an individual ground water source has a higher salt content than can be expected from the salt content of the water from adjacent or nearby wells - which might indicate possible sewage pollution;

(2) When the chloride concentration becomes excessively high - higher than the maximum permissible salt concentration (not yet firmly established but probably in the order of 500 to 1000 ppm) for a satisfactory domestic water supply.

1. Sources of chlorides may be (a) brines from oil wells or from industrial processes; (b) intrusion of saline or sea water due to lowering of ground water by overpumping; and (c) other sources.

Numerous articles have been published relative to salt brines in the oil fields (124) (125) (126) (127) (128) (129), particularly in Texas, Kansas, and other mid western States, also to sea water intrusion along the coasts of Florida and California (121) (122) (130) (133) (134) (135) (136) (137). State control agencies have been set up and preliminary reports are available.

Brown(121) stated "Chlorides in natural waters may also be derived from sea water contamination of underground supplies, agricultural salts spread on fields, from -- sewage, and from ---- industrial effluents". McKee(122), Winslow and Kister(123), Todd(141) and other writers have discussed sources.

2. Effect on Water Quality - Chlorides in underground waters principally affect the palatability of the water. Brown(121) stated that chlorides "---affect the palatability of water, have soap destroying power, accelerate the corrosion of metals, and adversely affect industrial operations and products".

3. Reported Permissible Concentrations - the PHS Drinking Water Standard - 1946 (108) include the statement "Chlorides (cl) should not exceed 250 ppm".

Culp(140) of Kansas State Board of Health in discussing the question of chloride concentrations stated; "In --- public water supplies we use 250 ppm as the 'desirable maximum' and class --- 550 ppm of chlorides as 'useable waters'. I agree --- 1200 to 1400 ppm --- level which begins to produce discernable physiological effects".

McKee(122) discussing the PHS Drinking Water Standards, stated: "In other agencies or other countries, the criteria for chlorides have been given at values from 10 ppm to 500 ppm.".

4. Experience to Date - There have been many instances of chloride contamination of wells, especially in the oil fields and along the Florida and Southern California sea coasts. Several States have set up special laws and commissions to enforce them. A great deal of investigational work has been done.

The major effort of these agencies have been to develop regulations as to disposal of brines. In California some investigations have been made to determine the encroachment of sea water into underground aquifiers and possibilities of providing fresh water barriers.

Chloride - Passage Through Soil

5. Nature of Movement - In general, the literature indicates a premise that salt water percolates directly downward into the ground water. The published data is meager and uncertain. Shamburger(128), reporting on investigations in Texas, concluded that brine dumped into earthern pits in alluvial materials --- "either percolates downward to shallow water tables or it infiltrates porous zones --- and may seep into surface drainage ---".

Some investigations in Texas and in California give a few clues to movement of salt contaminants in ground water. Shamburger(128) proposed a theory of movement:

> "---the movement of brine in fresh water is not known ---. Seemingly it will settle to the base of fresh water due to higher specific gravity and move down gradient in well defined courses coincident with lower most avenues of permeability. Therefore, it may move in 'slugs' or 'tongues' ---It is possible for brine --- to encounter some wells and to miss others ---".

6. Removal of Chlorides Through Soil - Removal of chlorides from contaminated water by movement through the soil is unlikely - so most writers indicate. Reduction in concentration appears to be generally accomplished by dilution with water of low chloride content. Normal chloride content of ground water is low and the permissible chloride concentration relatively high (up to 500 to 1000 ppm). So improvement of chloride contamination would be expected with movement and time, excepting diffusion in fresh water by high chloride water is slow.

The Fifth European Seminar(149) on ground water pollution reached one general conclusion:

> "Some polluting substances are not removed in the ground --- salts such as chlorides have given the most trouble".

Chloride - Determinations from Survey

Extensive literature is available on chloride contamination of ground water, which covers many problems encountered in (1) disposal of salt brine from oil wells; (2) more recently, sea water intrusion into aquifiers where ground water has been heavily drawn upon, especially in Florida and Southern California areas; and (3) in the disposal of some industrial waste waters with a high chloride content. Suggestive determinations are given in the following paragraphs.

7. Predicting Chloride Contamination - The present art is largely empirical and surmise based on investigations of numerous boreholes and analyses of water samples taken from them, under five situations as to source of contamination;

a. Efforts to dispose of oil wells brines, and other salty process waste waters, by lagooning. Experience has shown that lagoons permit salt water to escape into the underground water bearing strata.

b. Abandonded oil wells have permitted salt brines to rise up and escape into higher strata of fresh water. Several States have laws requiring old oil wells to be sealed and the well filled in to guard against salt water leakage.

c. Old abandonded lagoons used for salt brines or salty industrial waste waters storage may require several years until fresh water dilution eventually reduces the chloride concentration below permissible limits. Frequent water quality tests are necessary to determine when the ground water is potable.

d. Some areas in Florida, and possibly other places, the construction of canals, waterways and drainage ditches has permitted sea water to flow inland and seep into fresh water strata.

e. Sea water intrusion due to over pumping of ground water sources has developed in recent years, especially in Southern California and Southern Florida. Two control measures have been tried: (1) reduction in pumpage on the underground aquifier and (2) establishment of a fresh water barrier by pumping fresh water into the water bearing strata.

Thus, forecasting of possible chloride contamination would involve a study of previous experiences in existing nearby wells, or an expensive underground survey with many borings and laboratory analyses of water samples.

Additional information which should be determined might include: (1) records of available data on ground water chloride content; (2) development of some quick method to determine the relative volumes of fresh water and saline water and underground flow rates; the directions of flows, the rates of spreading of the chloride contaminated water or the fresh water dilution rate, the relative inflow quantities of fresh and saline waters into small underground reservoirs, and other similar items. In short, some method to distinguish salt solutions from fresh water and to determine underground water flow rates.

8. Water Quality Criteria Needed - The present maximum concentration of 250 ppm, without regard to other factors, is too simple. A more realistic criteria for maximum concentrations is needed, related to the different tolerances of people, the effects of different combination of minerals or possibly organic compounds which modify the taste tolerances for chlorides. Also the physiological effects of sodium may be involved.

9. Suggestions for Obtaining Additional Information - a number of

a. A review of the results to date and the work presently in progress by several State salt water control agencies, to determine how their present and proposed activities may determine information of interest to ground water contamination related to residential projects.

b. A study of chloride solution movements relative to soil characteristics - this might be initially a laboratory study.

c. A study of dilution rates by diffusion of adjacent streams of chloride solutions and fresh water.

d. A study to determine if chlorides may be reduced by absorption, adsorption, or other action of any soil types.

These several investigations might be initiated by two procedures (1) a collection, largely by correspondence, of information from existing salt water control agencies and an analysis of the data, and

(2) a pilot plant scale experimental study using a series of lysimeters with different soil characteristics to determine hydraulic and geochemical reactions.

10. Summary - Usually some chlorides are found in ground water, generally in low concentrations. They may become objectional as indices of possible sewage pollution for individual wells where the concentrations are above the chloride concentration of adjacent ground water. Secondly, they may become objectional, due to effect on palatability of the water, when concentrations become excessive through entrance of brines from oil wells, industrial waste waters or salt water intrusion from the sea, or other sources, when aquifiers are pumped at a rate sufficient to lower the water table below the adjacent water having a high chloride concentration.

Many factors affect the concentration of chloride which may be objectionable in a domestic water supply. A study of these factors and possibilities of adjusting them would be a worthwhile research project.

The basic correction for chloride contamination is dilution with fresh water, so some pilot plant experimental research would be desirable to establish the relationship of soil characteristics and their hydraulic or geochemical effect on chloride concentrations.

11. References - See Bibliography - reference items Nos. 121 to 149 inclusive.

1b - Chromates

Trivalent chromium salts are not considered harmful, but the hexavalent chromium salts are limited to 0.05 ppm, on the basis of possible health menace, in PHS Drinking Water Standards - 1946(108). Toxicity tests on fish appear to raise a question as to whether the hexavalent chromate compounds are actually more toxic than the trivalent. There is uncertainty as to the proper value for the permissible concentrations for both tri-and hexavalent chromates. There are data which indicate higher concentrations might be used than specified by the PHS Drinking Water Standards.

However, any pollution by industrial waste waters might change rapidly and without warning from a low to a high concentration.

1. Sources - In general, sources of hexavalent chromates are industrial process wastes, usually from metal pickling and plating operations. Also chromous compounds are used in anodizing aluminum, the manufacturing of dyes, ceramics, paints, explosives, and some paper products. They include soluble hexavalent chromate salts of sodium, potassium, and ammonium(122).

Trivalent chromic salts include chlorides, nitrates, and sulfates which are quite soluble. These are employed as mordants in dyeing, in ceramic and glass industries and in photography(122) (150).

Thus, either hexavalent or trivalent chromates might reach ground waters by leaching of industrial waste waters or by percolation through soils along rock crevices or through defects in well casings.

2. Effect on Water Quality - Hexavalent forms of chromium are considered to be toxic and irritants, because of corrosive action on the skin and the intestinal tract. Salts of trivalent chromium are not considered physiologically significant or harmful(152).

However, there has developed some recent experiences which cause questions as to the exact effect on water quality.

3. Reported Permissible Concentrations - The PHS Drinking Water Standards(108) state "---hexavalent chromimum in excess of 0.05 ppm, shall constitute grounds for rejection of the supply". Graham(153) reported the hexavalent about 100 times more toxic than the trivalent form, and that 0.1 ppm of hexavalent chromium in drinking water may be quite harmful.

Part II - Chemical -
1b - Chromates

McKee(122) stated "Recent observations tend to discount the fears of the U.S.P.H.S.---" Pomeroy(154) reported using water with 10 ppm of potassium dichromate as his drinking water for 15 days. A family on Long Island was reported(150) to have used a well for over three years with hexavalent chromium wastes with a concentration ranging from an initial 1.0 ppm up to 25 ppm with no apparent ill effects.

Welsh and Thomas(152) after reviewing the record of standards and experience stated; "Recent observations indicate that the physiologic effect of hexavalent chromium may not be as serious as originally suspected." Also "The present limit of 0.05 ppm for hexavalent chromium appears to provide an adequate factor of safety for water users, especially in view of the fact that analyses have shown chromium concentrations in milk as high as 0.5 ppm(155)".

4. Experience to Date - The foregoing references to the experiences of Pomeroy and the Long Island family have been considered Welsh and Thomas(152) "---do not justify an immediate change in the maximum permissible limit whe concluded --- they do indicate the need for more information".

Reports by the Ohio River Commission(156) and Gross and Holler(157) indicate 500 ppm hexavalent salts may be non-toxic to rats and rabbits. McKee(122) records results of many toxicity tests on aquatic life(160) which indicate a possibility that trivalent chromium might also have a toxic threshold limit over a longer time period, which should not be overlooked in a ground water quality standard where isolated waste waters might seep into wells.

Chromates - Passage Through Soil

5. Nature of Movement - Above ground water the soluble chromium compounds in waste waters would seep through the soil or along rock crevices or through well casings. There appears to be no information as to the effect of the soil on the chromates, though one might expect that some part of the hexavalent might be reduced into the tri-valent form.

Also in and with ground water soluble chromate waste waters would probably flow with the ground water. A limited number of data are available.

In Michigan(158) a report showed chromate wastewater had travelled through sand to pollute wells in three years at a distance of about 1000 feet. Davids and Lieber(150) reported underground water strata contaminated with 40 ppm chromium from leaching pits.

6. Removal of Chromates - There appears to be no good evidence as to the rates of removal of chromates either above or in and with the ground water. Since hexavalent chromates may be oxidized it may be possible that some reduction could be found, but special researches may be necessary. Like chlorides the concentrations of chromates in ground water would gradually be reduced by dilution with fresh water.

A brief effort made by the California State Water Pollution Control Board to use a soluble chromate as a tracer(159) lead to the conclusion - --- "evidently the ion was absorbed because the near sampling wells yielded only weak concentrations, and the test was abandoned".

Chromates - Determinations from Survey

7. Predicting Contamination - The present art would suggest contamination of nearby ground waters whenever waste waters from certain type industrial processes would be discharged into storage lagoons or leaching pits in porous earth with disposal mainly by seepage into the soil.

Presently, it would be uncertain how far the contamination may travel or in what concentration it might reach any specific water source.

Further, present information would not be sufficient to determine what concentrations of either chromous or chromic compounds would be actually toxic to man. The concentration limit of 0.05 for hexavalent chromium specified by PHS Drinking Water Standards - 1946 may be entirely too low to be sustained if occasion should arise to challenge it.

Additional information is needed along these lines;

a. Relative toxicity of hexavalent and trivalent chromates - and the factors which affect toxicity to man.

b. What reactions take place when chromates pass through soils: For example, do hexavalent change to trivalent by reduction? do chromate concentrations reduce by adsorption or absorption, possibly by ion exchange? Other reactions?

c. Rate and distance of travel in different types of soil?

d. Rate of reduction of concentration by diffusion into fresh water in different soils?

e. Stability of hexavalent chromates in underground water and along rock passageways?

8. Water Quality Criteria Required - The present criteria in the PHS Drinking Water Standards is inadequate. There is good evidence that 0.05 ppm of hexavalent chromate may be too low. There is some evidence that trivalent chromate may be toxic.

Accordingly, more realistic criteria would be desirable for both the hexavalent and the trivalent chromium compounds. Certainly the possibilities of contamination by chromium compounds are sufficient to warrant consideration in any ground water quality standards.

9. Suggestions for Obtaining Additional Information - The following steps or phases of research are suggested:

a. Collect together available experience on locations, numbers, and waste water disposal methods for industries which produce chromate wastes; i.e., determine the magnitude of the problem and the rate of increase in numbers of industries which produce process waste waters containing chromates.

b. Assemble all available information on underground travel and distribution of chromium wastes.

c. Set up experimental units to determine the effects of soil characteristics or factors on chromium compounds, physical, hydraulic, and chemical. These might be laboratory jar tests initially, but late the use of lysimeter type soil columns would be desirable.

10. Summary - Many chromium compounds are soluble. Hexavalent chromates are considered dangerous and a limit of permissible maximum concentration of 0.05 ppm is contained in the current PHS Drinking Water Standards. Trivalent chromates have been considered unharmful and no maximum concentration has been set up.

However, there is evidence that a higher maximum concentration greater than 0.05 ppm for hexavalent may not be harmful and other information on toxicity appears to indicate the possibility that trivalent chromates may be toxic also. More realistic water quality standards should be determined than presently available.

The continued rapid industrial development in rural and outlying urban areas will likely add to the problems of contamination by chromates. Specific studies of this chemical contaminant would be desirable.

11. References - Bibliography - reference items 150 to 160 contain information of interest on chromate contaminants.

1c. Nitrates

Nitrate contamination of ground water has been a serious problem, particularly in certain mid-western areas. Nitrates have caused methemoglobinemia in infants less than 2 months old (blue babies) and has had a poisoning effect on cattle. Many well waters contain high concentrations of nitrate. Considerable background information is reported in Part III - Topic II-1c. Nitrate Contaminants.

1. Sources - The exact sources of nitrates are not determined. Many hypotheses have been given in the literature (165) (169) (173) (174) (163).

Some mineralized waters from deep wells contain a high nitrate content, indicative of some natural underground sources. Leaching of cesspools; excessive application of fertilizers; plant life, such as clover and legumes; surface water from privies, barns, barnyards, pigpens, poultry yards, and corrals; are reported to be chief sources of excessive nitrates in the shallow ground water.

2. Effect on Water Quality - The main effect is a toxicity which causes occasional cases of methemoglobinemia in very young infants. There seems to have been no serious effects on adults, but there has been some suggestion that we may not yet know the full effect of nitrates. In some cases very high nitrate concentrations (up to 638 and 974 ppm) have been reported with no cases of methoglobinemia reported. Other writers have indicated that methoglobinemia may be cured or prevented by simply putting lactic acid in the baby formula.

The full effect of nitrates as a ground water contaminant is still subject to uncertainty (165) (180) (182) (177).

3. Reported Permissible Concentration - There is no reference to nitrates in the PHS Drinking Water Standards - 1946(108). Permissible concentrations have been set-up or recommended by a few state public health agencies(161), but the record of the incidence of methemoglobinemia has not been definitely related to any specific concentration of nitrates(177). Any permissible or recommended concentration limits are presently merely arbitrary guesses. A few foreign countries have recommended maximum permissible concentrations which vary from 0.5 ppm to 228 ppm.(165) (178)

Cox et al(177) concluded from a widely distributed questionnaire (1951);
"---it is impossible at this time to select any precise concentration of nitrate in waters fed infants, which definitely --- are safe or unsafe for this purpose."

Concentrations between 10 and 20 ppm of nitrate-nitrogen have been recommended by numbers of writers as the upper limit of nitrate-nitrogen in water which should be used for infant feeding. (166) (171) (173) (179) (180) (181). However, these are merely individual opinions, with no professional group or official agency support.

4. Experience to Date - Many reported cases of methemoglobinemia were discussed by public health and water supply authorities from about 1948 to the late 1950's. The greater numbers of cases occurred in the central plains states and in central Canada.

Large numbers of cases of infant methemoglobinemia were reported in Minnesota (Resenfield and Huston(189); in Manitoba, Ellis et al(200) and Kay et al(161); in Kansas (Metzler and Stoltenberg(169); in Ohio (Waring(173); in New Mexico(197); in Illinois(161); in Texas (George and Hastings(174); in Michigan (McGuire(205); and in Nebraska(216) (217).

A number of experiences have been reported from England(180), from Virginia(211) Cox et al(177) from a general questionnaire found high nitrates in 47 states.

McKee(165) reported (from Caballero(178) standards for drinking water with limits for nitrates in Venezuela, Brazil, Dominican Republic, Mexico, and Uruguay (range from 0.5-10 ppm up to 228 ppm in Uruguay).

Thus, experience with the problem of nitrate contamination appears to be quite wide spread.

Nitrate - Passage Through Soil

Nitrates are the end products of aerobic stabilization of organic nitrogen(165). They are not abundant in natural surface waters as they serve as essential fertilizers for plant life. Underground waters are not affected, in general, by photosynthetic action so nitrates are not reduced to nitrites or organic nitrogen.

5. Nature of Movement - The present knowledge would indicate that nitrates, being soluble, are carried with the water. Also nitrates do not generally combine with other compounds so there should be little or no variation in the travel of the chemical from the travel of water, either above the water table or in and with ground water. However, this hypothesis has not been confirmed by research or performance experience.

There is evidence(207) that chemicals, including nitrates, travel farther and faster than do bacterial pollutants. One report(197) considers that nitrates are little affected by soil characteristics so travel farther than other chemicals. Another writer(174) would expect some reduction in nitrates due to iron and nitrate-reducing bacteria found in the soil.

6. Removal of Nitrates - There is considerable evidence that nitrates are produced by soil nitrification, i.e., biochemical action of the soil when ammonium nitrogen is supplied to it from barnyard and other sources of pollution. Several writers have explained the mechanics of soil nitrification (162) (199) (169) (207) (197).

Other writers(174) consider that both nitrate-reducing bacteria and ion exchange may be possibilities of reducing nitrates, in the soil above the ground water.

The several reported premises for nitrate reduction seem to be little more than surmises. It is known that nitrate reducing bacteria do exist, so probably there may be situations where the reduction activity may be greater than the soil nitrification activity.

There are no reported measurements of changes in nitrate content, but in and with the ground water dilution with fresh water would come into action, so where nitrate contaminant originates over a small area the concentration likely would be reduced by dilution with fresh water as the contaminant travels down grade. No evidence was found in the literature as to the rate of dilution.

Nitrates - Determinations from Survey

The literature includes many articles by public health experts, medical experts, geologists, and others who have reported much fragmentary information, but no summarized or conclusive evidence has been found.

7. Predicting Nitrate Contamination - Present Art would be able to predict reasonably the possibility of contamination of a shallow well located within the proximity of organic polluted surface soil with surface water percolating down through the polluted soil into the shallow aquifier. So down dip from a cesspool, a barnyard, a pigpen or other sources of contamination, a shallow well could be expected to be contaminated by nitrates.

Many deep wells contain water with high mineral content. This can be determined by mineral analyses. Since this situation usually extends over a relatively wide area the possibility of nitrate contamination of a particular deep well could be anticipated by water samples from adjacent deep wells.

Additional information would be necessary to determine several aspects of the problem of nitrate-nitrogen contamination;

a. Methods are needed by which the probable distance and direction of travel of nitrates from a surface pollution could be determined. What measurements are needed? What tests?

b. Something similar would be desirable for deep wells.

c. Presently, the actual permissible limit of concentration is not established, nor the factors which control the toxic effect. Studies of these factors would be desirable.

d. Further review of the experience records in various health agencies might indicate the likelihood of adverse effects on adults or possibly the remedial measures to be taken.

e. A study of the ion exchange value with nitrates for various types of soil chemicals might be justified.

f. Similarly a study of the soil nitrification characteristics would be justified.

8. Water Quality Criteria Required - The PHS Drinking Water Standards (108) or (209) include no reference to nitrates. There is definitely a need for some authoritative criteria. Presently, there is insufficient information on which to base a criteria.

Additional research may be needed to determine basic cause factors. This may involve both physical and clinitical studies. Possibly water quality criteria may require advice as to methods to offset or guard against the toxic effects of high nitrate water in places where no other water is available.

9. Suggestions for Obtaining Additional Information - The published data is old (1951). Much new information must now be available.

Accordingly, a number of possible studies are suggested;

a. As an initial step - initiate an extended inquiry to public health, medical, and water supply agencies to uncover a probable large number of unpublished data and experiences. Something more extensive than a mere questionnaire to overloaded public health officials should be done.

b. A summary of present known medical methods to overcome the physiological effects of high nitrate-nitrogen content of drinking water, for the purpose of establishing the importance of the nitrate contaminant question.

c. An experimental study of household water treatment units to determine a practical household method for reducing the nitrate content of residential water supplies.

10. Summary - The literature shows many rural wells are contaminated by nitrates, especially in the Central States. A record has been made of a large number of cases of cyanosis which have occurred in bottle fed babies.

Chemical contamination of rural wells by nitrates is likely to increase with an increase in soil pollution without proper sewerage.

Some health agencies have set up advisory instructions, but as yet there is no general water quality criteria for nitrates in drinking water. There are so many factors affecting the toxic effects of nitrates that a simple water quality standard may not be satisfactory.

Research is justifiable to develop methods for predicting nitrate contamination; for determining water quality standards; for setting up methods to offset or remedy the affects of nitrate contaminants.

11. References - See BIBLIOGRAPHY - Topic II 1c. Nitrates Items Nos. 161 to 219, inclusive.

1d. Disinfectants

The following four chemicals which have germicidal power have been included as a group under the designation Disinfectants:

Bromine
Chlorine
Hydrogen Peroxide
Iodine

Of these, chlorine dissolves readily in water (258) and has been widely used for disinfection of water supplies and waste waters. All of the chemicals are toxic to bacteria, lower aquatic life and to fishes in concentrations as low as 20 ppm and up to 400 ppm (221). Hence they must be considered as potential toxic contaminants in ground waters, should the past rapid development continue in the use of them by industries.

The halogens, bromine, chlorine, and iodine, have similar germicidal power, but different physiological effects when used in drinking water. Chlorine has been used freely and generally to disinfect drinking water. Bromine has been used to a limited extent to disinfect swimming pools. Iodine, in elemental form, is only slightly soluble in water so its germicidal or disinfecting power comes from tri-iodides (222).

Bromine has been reported to be toxic to lower forms of aquatic life in concentrations as low as 10 ppm (223) and fishes have been affected in concentrations as low as 20 ppm (223).

Chlorine gas is used widely as a disinfectant and as a bleaching agent. The technical literature on chlorine is extensive - well beyond the scope of this study to summarize.

There have been suggestions that chlorine in drinking water may cause physiological disturbances, such as colitis, asthma, and eczema (224). However, the physiological limiting concentrations are not yet known (225) (226) (227), but are probably well above the 1.0 or 2.0 ppm which often become objectionable due to tastes and odors.

Some concern has been directed at the extensive use of chlorine in municipal water supplies due to the possibility of corrosion of zinc or the solution of lead, but these questions seem to have been proven unfounded (228) (229).

Hydrogen peroxide has been used commercially as a medical disinfectant. More recently it, together with hydrazine has been used in rocket fuels. Thus any extensive testing or rocket motors may make these chemicals potential ground water contaminants.

Iodine is not used widely and is less likely to become a ground water contaminant in the near future.

1. Sources - The major sources of disinfectants, as potential ground water contaminants may be the discharge of the chemicals with process waste waters from industries, especially where the industry may be located in a rural area and the waste waters are discharged into pits or lagoons.

2. Effect on Water Quality - Objectionable tastes and odors caused by these disinfectants probably would make water containing them unacceptable for drinking and culinary use at concentrations well below the toxic concentrations (225) (226) (224). However, definite toxic characteristics of these chemicals has been shown by many tests on fishes for which McKee (122) has assembled references (222) (221) (230) (231) (232) (233) (234) (235) (237) (238) (239).

3. Reported Permissible Concentrations - Many writers have discussed permissible concentrations of chlorine in water supplies. In relatively pure waters free of chemicals which form objectional compounds with chlorine, such as phenol, free residual chlorine concentrations up to 2.0 ppm (236) has been acceptable, but generally 0.1 to 0.2 ppm residual free chlorine is not objectionable (225).

However, the threshold concentration causing objectionable tastes and odors depends upon the chemical content of the water. For example, phenols produce objectionable esthetic conditions at very low concentrations (226).

Since wasted chlorine solutions most likely would reach underground water through some process waste waters and after passing through various types of soil materials there would be uncertainty as to the chloro-compounds which actually reached the underground water.

Similarly, bromides resulting from the chemical reactions of bromide solutions might have long term adverse physiological effects which are as yet unknown (240).

4. Experience to Date - There have been many experiences of waste waters from industrial operations containing chlorine, such as bleaching waste waters in textile mills and paper mills (241) (242). Many factories and power plants use chlorine or bromine for control of organisms in cooling water (231) (236) (226) (251). Many water supplies for industrial processes are chlorinated to control slimes (253) (254) (255) (256).

Reported experiences with hydrogen peroxide and iodine have not been found in the literature survey, excepting one instance of hydrogen peroxide and hydrazine wastes from a rocket (257). These chemical items are potential future problems.

PASSAGE THROUGH SOIL

5. Nature of Movement - Present knowledge of the movement of disinfectant chemicals through soils is meager if not non-existent. These chemicals are quite active and combine with many substances, particularly chlorine - the most common disinfectant. They probably would not go far through the soil without combining with soil organic matter to become complex forms of chlorides, bromides and possibly iodides.

So ground water contamination probably would be by chloral compounds, some of which would produce objectionable tastes and odors, excepting in cases of fissured rock or defective well casings where the waste waters may reach ground water directly.

To date no information has been found on the distance of travel of disinfectant chemicals in and with the ground water.

Removal of Contaminants - No specific information was found on removals of disinfectant chemicals in passing through soil. The two possibilities relative to movement given above may be related to potential removals. In the case of fissured rock or openings in well casings some portion of the disinfectant waste water might reach the ground water directly, in individual wells. In other cases, the contaminants might be changed to chlorous compounds, bromides, or iodides which, in certain cases, such as chloro-phenols, could conceivably increase the objectionably characteristics until dilution reduced the chemical concentration below the permissibly threshold odor value.

DETERMINATIONS FROM SURVEY

The available knowledge on disinfectant chemicals, aside from their value as disinfectants, is so meager that definite determinations cannot be made.

Predicting Contamination - The present art of predicting contamination from disinfectants involves the general consideration which should be given to any industrial process waste water likely to reach ground water. If the waste water is discharged on to permeable soil or into fissured rock there would be danger of contamination of the ground water in any nearby well or spring.

The information needed for definite knowledge involes three phases:

1. More complete information on the sources and frequency of discharged waste waters containing quantities of disinfectants.

2. Information on the physical or chemical reactions which take place between the disinfectant chemicals and the chemical or organic content of the soil.

3. The effect of travel through soil or in and with the ground water and the rate of dilution with fresh water.

Water Quality Criteria Required. Presently no water quality criteria for drinking water exist with reference to concentrations of bromine, chlorine, hydrogen peroxide, or iodine (or iodides). There are some criteria for industrial water uses.

Accordingly, criteria should be developed. However, considerable new knowledge would be required on the physiological effects of various concentrations of chemical disinfectants and on the changes which occur as the disinfectants enter the ground water.

Suggestions for Obtaining Information - The following steps should develop useful information as a basis for setting up water quality criteria:

1. A study of the numbers of industrial operations which produce waste waters containing disinfectant chemicals.

2. A study of the occurrences of waste water discharges into areas which affect ground waters.

3. If and when the potential occurrence of ground water contamination warrants, a laboratory study should be made to obtain information on the physio-chemical reactions which take place when these disinfectants pass through soils of various characteristics.

Summary - The listed four chemical disinfectants are potential ground water contaminants. Chlorine is widely used and is found in many industrial process waste waters. The other three chemicals are not generally used, but are potentialities with the modern rapid increase in industries which produce process waste waters, containing large quantities and varieties of chemicals.

The literature specifically related or indirectly related to ground water contamination is quite meager. To date no water quality criteria for drinking water have been found in the literature, but some criteria have been found for industrial waters (241) (242) (243), for food-processing (248) (249) and for irrigation (260).

The literature does not indicate any great demand for water criteria relative to disinfectant chemicals. However, there is sufficient evidence to show an increase in the occurrence of industrial waste water containing at least chlorine to justify consideration of a field survey to determine the potentialities of this group of disinfectant - chemicals as ground water contaminants, probably in connection with a survey of other chemical contaminants.

References - See Bibliography reference items Nos. 221 to 260 inclusive.

1e - Metal Finishing Wastes

Eldridge[261] in an early (1942) treatise, divided waste waters from metal industries into three groups:

(a) Acid and alkaline pickling or cleaning liquors;
(b) Metallic-cyanide solutions and washings from plating processes;
(c) Waste cyanide from heat treating.

Gurnham[262] more recently (1955) stated;

> "The principal iron and steel industry waste is spent pickle liquor from cleaning and descaling of steel sheets and similar products. Sulfuric and other acids are used--- The liquor must then be disposed of. ---by discharge underground, to lagoons or porous soils---There are serious objections---since gradual oxidation of iron salts will produce colors---"
>
> "---contamination by the non ferrous metallurgical industries---from pickling operations in the copper and brass industries. Spent pickle liquors contain free sulfuric or other acid, copper and zinc ions --- chromium and iron."

Gurnham[262] also listed (page 6) the following types of waste waters from metal-finishing and electroplating shops:

a - Oily and greasy
b - Colored
c - Toxic
d - Acid
e - High temperatures.

1. Sources - The sources of metal finishing or plating wastes as ground water contaminants would, in general, be metal finishing or plating shops in semi-urban or rural areas where the waste waters are disposed of by putting them into pits or lagoons and allowing them to seep away into porous soil.

Sometimes such waste waters when discharged into streams have entered porous strata and moved into the ground water[267]. However, this is probably not a general situation, as more frequently the ground water table is above the stream water level and generally ground water feeds the stream.

The rapid and continuing movement, in recent years, of metal working plants into outlying and rural areas has materially increased the sources of potential ground water contamination from metal finishing plating waste waters.

2. Effect on Water Quality - Quite generally these metal waste waters would contaminate the ground water by their acidity which might result in the ground water picking up hardness from the soil and being corrosive to pipes and water works.

Also metal ions enter the ground water such as iron, copper, chromium and others, depending on what metals are being treated or used in the finishing or plating operations.

The plating of copper produces sodium cyanide(263) and copper ions. Chromium plating results in chromium ions in the waste waters(263) as well as copper, nickel, iron, and other items.

So ground waters may be contaminated with toxic metals and taste producing metals, such as iron, when plating wastes or metal cleaning wastes are allowed to be disposed of by leaching into soil and then into ground water.

3. Reported Permissible Concentrations - No reports were found as to permissible concentrations of metal finishing or plating wastes, as such. The permissible concentrations probably must be related to the various ions of toxic or deleterious materials; cyanide, chlorium, copper, iron, acids, and the like. These are discussed in other sections.

4. Experience to Date - There have been numerous reports of plating wastes or of pickling liquors being discharged into pits or lagoons from which objectional contamination elements reached the ground water.

Two experiences(150) (158) with chromium wastes have been referred to under Topic II-1b - Chromates.

An experience was encountered during 1959 (private communication) in Western Wisconsin where a metal stamp company disposes of its metal cleaning and plating waste waters into an open pit thence by leaching into the ground water. Complaints have been made of tastes and acidity in water from a well several hundred feet distance. This industrial operation, recently developed in a rural area, may become an objectionable source of ground water contamination.

A similar experience at Anderson, Indiana, was reported in 1950 to the Indiana State Board of Health of contamination entering a private well from a lagoon into which waste waters were discharged from plating processes.

Billings et al[264] reported (1952) "plating wastes continued for the third year to soak into the sandy soil a few hundred feet from the municipal well in another village."

Billings et al[264] also reported on a problem of plating wastes at Bronson, Mich., where one point strongly emphasized in a circuit court case was the absence of any official toxicity standards for plating wastes.

Billings et al[265] reported - "Pollution is reported to have resulted from ----- pickling liquors --- is generally a local effect. The localities --- tend to be urban and semi-urban in character,---"

Miller et al[266] for the AWWA Task Group 2450R Report (1957) included reference to the long time effects of acidic wastes dumped into a nearby estuarine swamp in Maryland. The Task Group cited a second example, of wastes from local aircraft plants being emptied into leaching pits and water samples from nearby wells which showed traces of cadmium and chromium.

PASSAGE THROUGH SOIL

5. Nature of Movement - Butler et al[207] concluded from then (1954) available information that chemicals did not change much in passing through soil above the ground water. However, Greenberg[268] found boron failed to penetrate more than 2 feet. So there is uncertainty about the nature of movement of plating or metal finishing wastes above ground water. Kaufman and Orlob[269] concluded (1956) the fundamental physio-chemical nature of chemicals passing through porous media is not well understood.

The movement of plating or metal finishing wastes in and with ground water is subject to many uncertainties. The acid component is likely to be reduced by combining with alkaline constituents in the soil. Butler et al[207] found European data showing pickling liquors traveling considerable distances. German reports[270] [271] found picric acid wastes traveling as much as 3 miles in 4 to 6 years.

There is evidence that plating or metal finishing waste waters do contaminate ground waters, but more complete data will be needed on the physio-chemical relationship of acids and chemicals in these wastes and the reactions which take place when the liquid wastes pass through soils of different physical and mineral characters.

6. Removal of Plating Wastes Contaminants - The information presently available includes instances where the acidity and toxic materials in plating wastes have been extended over long distances. In other cases much of the material has been removed in short distances.

Obviously, fissured rocks and coarse gravel might carry these wastes long distances. Also the dilution of the waste waters with fresh water would reduce the concentration of objectionable elements.

Much remains to be done before the effect can be determined of various soil chemical components on the toxic or acidic components of plating or metal finishing wastes.

DETERMINATIONS FROM SURVEY

The disposal of metal finishing and plating wastes into ground waters has been a minor sanitary problem until the relative recent dispersal of metal finishing plants into semi-urban and rural areas. The information on metal finishing and plating waste contamination of ground water is quite meager.

7. Predicting Contamination - The present art of predicting is quite inadequate. There is sufficient evidence to indicate possible contamination of ground water down slope of any site where metal finishing waste waters may be disposed of by seepage into the ground water.

There is not sufficient information to determine (1) the distance down slope of waste waters may eventually extend; (2) the rate of movement laterally is unknown; and (3) the effects of various soil components in neutralizing the toxic elements of waste waters are unknown.

8. Water Quality Criteria Required - A water quality criteria relative to plating, or metal finishing waste waters should include two aspects; (1) the permissible type and concentration of acidity and (2) the concentration of various chemicals which may be found in such wastes.

The question of acidity may be especially related to plating or metal finishing wastes. The question of the several chemicals would probably be better included under the consideration of each individual chemical, such as, cyanides; chromium; copper, nickel; iron; and the like.

9. Suggestions for Obtaining Additional Information - A number of steps might be undertaken to obtain useful information as a basis for setting up criteria for water quality and methods for anticipating possibilities of ground water contamination for any specific plating or metal finishing waste disposal project. The following general items are suggested:

(1) A study of the present and probable future numbers of industries which may discharge metal finishing wastes into ground water.

(2) An analytical study to determine the concentrations, and types of toxic and objectionable constituents in plating or metal finishing waste waters.

(3) The methods available and results to be expected by waste water treatment processes.

(4) The length of time required to remove objectionable elements from the soil and ground water after underground disposal is discontinued or reduced by appropriate treatment.

(5) Probably experimental lysimeter type studies may be desirable, but probably these would be related to the various toxic chemicals in the wastes.

10. Summary - Metal finishing, more especially metal plating operations are being moved into semi-urban and rural areas, where the waste waters are frequently disposed of by seepage into the ground water. Generally, the waste water quantities are placed in pits or lagoons extending down to ground water so the problem becomes that of what happens to the contaminants in traveling in and with the ground water.

Such waste waters contain acids, and various metal ions which may be toxic or at least would be objectionable in drinking water.

Presently, the information is inadequate on numbers of factories and characteristics of the waste waters. There is evidence that chemicals and acidity of these waste waters may travel considerable distances through water bearing strata and also may remain in aquifiers for long periods of time.

However, the evidence is limited and contradictory as to what happens to the waste materials in passing through soil in and with ground water.

11. References - See Bibliography items Nos. 261 to 271, inclusive.

1f. Chemicals - Covered by PHS Drinking Water Standards

Thirteen chemicals have been considered in two groupings namely because they are included in the current (1946) PHS Drinking Water Standards and under two groupings therein.

A. Chemicals With Maximum Concentration Specified - (5 items)

The PHS Drinking Water Standards - 1946(108) include five chemicals for which maximum permissible concentrations are specified:

Chemical	Specified Maximum Concentration ppm
Lead (Pb)	0.1
Fluoride	1.5
Arsenic	0.05
Selenium	0.05
Chromium-hexavalent	0.05

These specified maximum permissible concentrations will be discussed in following paragraphs:

1. Sources - The source of any toxic chemical is important in considering the maximum permissible limit. Probable sources(152) are as follows:

Lead - may be found naturally in some waters, it may be introduced by industrial waste waters, or it may be dissolved from lead pipes in plumbing handling corrosive water. However, modern plumbing is made generally without use of lead. So contamination by waste waters may be the likely source of lead contamination of ground waters. In addition to the metallic lead ion several soluble lead salts are toxic, such as lead acetate, lead arsenate, lead chloride, lead nitrate, and lead sulfite. The carbonate and hydroxide salts are not so soluble(122).

Fluoride - occurs naturally in some ground waters, or may be the result of direct contamination from insecticides or industrial waste waters. Elemental fluorine is very reactive and is never found free in nature. Fluoride is added to many municipal water supplies.

Arsenic - may occur naturally or may result from contamination by insecticides, weed killers, or industrial waste waters.

Selenium - occurs in many soils and in some natural waters, or may be a constituent of an industrial waste water. Some natural soils contain 1-6 ppm of selenium(153).

Chromium - may be introduced in ground water from industrial waste waters, such as plating wastes. (See Topic II-1b Chromates)

The five toxic chemicals may originate from industrial waste waters. With the rapid trend toward constructing new industries in rural areas and disposal of wastes into the ground, there are possibilities of considerable increase in the importance of these, and other, toxic materials in ground waters.

2. Effect on Water Quality - All five chemicals are considered toxic so the main effect on water quality would be potential toxicity to water consumers. Generally the quantities per unit volume of water are so small that no other effects have been reported.

Lead - McKee(122) gives a good summary on the toxicity of lead - stating that lead poisoning of human beings is reported for concentrations as follows:

(a) "0.042 to 0.18 ppm (277) (281) (105) (282)
(b) "0.2 to 0.3 " (283) (277) (284) (285) (286)
(c) "0.4 to 0.72 " (287) (278) (288) (279) (289) (290) (491) (277)
(d) "1.0 or more (up to 25 ppm) (277) (292) (293) (289) (280) (294) (194) (283) (295)

McKee also expressed the opinion:

"Certain lead salts, such as the acetate and chloride, are readily soluble, but owing to the fact that the carbonate and hydroxide are insoluble and the sulfate is only sparingly soluble, lead will not remain long in natural waters".

Fluoride - possibly more study has been given to the effects of fluorides on human beings than to any other chemical. A considerable number of long terms (up to 10 years) routine studies have been made of the toxic effects of fluoride, with particular reference to the mottling of teeth. Many items in the literature show the advantages of 0.8 to 1.5 ppm of fluoride in drinking water to reduce dental decay. The presence of about 1.0 ppm of fluoride may be more beneficial than detrimental(122).

Many hundreds of municipal water supplies are being treated by adding sufficient fluoride to maintain about 1.0 ppm fluoride. A great many people oppose the addition of fluoride to municipal drinking water - claiming many reasons, but primarily objecting to the "medication" of the water supply.

Arsenic - Toxicity appears to be the effect of arsenic. The effect on water consumers may be slow requiring 2 to 6 years continued use to produce arsenosis(122).

Selenium - again toxicity is possibly the only effect of selenium, excepting possibly soils containing selenium might be the cause of turbidity, but this would be rare for ground waters and would not be due to the selenium. Several writers have proposed that selenium is highly toxic to man (276) (296) (280) (156). However, McKee(122) concluded that "---proof of human injury by selenium is scanty,---"; which is still a fair statement of the situation.

Probably selenium contamination of ground waters will be infrequent as long as surface wash of soil is prevented by properly constructed wells. The numbers of industrial waste waters containing seleniferous salts are few, particularly in rural areas.

So, compared to possibilities in foods, selenium poisoning from ground waters appears fairly remote.

Chromium - (See Topic II-1b Chromates)

3. Reported Permissible Concentrations - As already indicated the PHS Drinking Water Standards - 1946(108) specify very low concentrations for the five chemicals - lead, fluoride, arsenic, selenium, and chromium-hexavalent.

Welsh and Thomas(152) have reported that the permissible concentrations for lead has remained the same since the 1925 Treasury Standards(272). The other four chemicals were added in 1942 to the PHS Drinking Water Standards(273). Fluoride was put in at 1.0 ppm in the 1942 standards then increased to 1.5 ppm in the 1946 Standards(108). Arsenic and Selenium were kept at 0.05 in both 1942 and 1946 Standards, while hexavalent chromium was increased from 0.0 ppm in the 1942 Standards to 0.05 ppm in the 1946 Standards.

Some evidence has been published (152) (274) (275) (276) that the present specified concentrations in PHS Standards(108) - any excess of which, "----, shall constitute grounds for rejection of the supply". (108 p. 12) - might be too restrictive for some of the chemicals, particularly for residential supplies where a well or other ground water may be the only feasible source.

Welsh and Thomas(152) reported higher tolerances by the U.S.Food and Drug Administration and other agencies as to maximum concentrations as follows:

a) Lead - "A tolerance of 7 ppm of lead in food" (274)
b) Fluoride - "---concentrations less than 5 ppm are almost completely excreted."
"---exceeds 5-6 ppm with its prolonged use give rise to detectable changes, and then only in the most susceptible people."
c) Arsenic - "The Food and Drug Adm. permits 1.43 ppm of arsenic in food."
d) Selenium - "Studies --- have shown that the hazard due to ---selenium in water is of secondary importance compared to the hazard from its occurrence in food." (275, 276)
e) Chromium - "Recent observations indicate that the physiologic effect of hexavalent chromium may not be as serious as originally suspected."
(See also Topic II-1b - Chromates)

However, after reviewing a portion of the literature on these foregoing five chemicals Welsh and Thomas(152) cautiously concluded:

"The present limit appears to provide an adequate factor of safety for water users."

It would seem that a more scientific basis should be available for setting such low permissible concentrations than merely "--- <u>appears</u> to provide an adequate factor of safety---".

Information with particular reference to each chemical, relative to permissible concentrations, are indicated in the following:

<u>Lead</u> - McKee(122) reported that the Soviet Union(297), German(298), and Argentina(299) all used the 0.1 ppm concentration limit as established in the 1925 Treasury Standards and still used by the USPHS. A limit as low as 0.025 ppm has been recommended (300); according to McKee.

<u>Fluoride</u> - The PHS Drinking Water Standard of 1.5 ppm was arrived at after a great deal of investigation. The 1942 Standard (273) of 1.0 was raised to 1.5 ppm for the 1946 Standard (108). Considering the extremely controversorial discussions on the use of fluoride in municipal water supplies and the several long term (10 years) studies of the effects of fluoridation - it would appear that the 1.5 ppm limitation is well supported. However, evidence indicates that natural waters with 5-6 ppm fluoride concentration may be safely used (152) (304).

Arsenic - The PHS Drinking Water Standards(108) specifying a maximum limit of 0.05 ppm was originally set up in the 1942 Standards(273). McKee(122) listed concentrations reported to be safe in drinking water ranging from 0.05 to 1.0 ppm (301) (236) (156) (277) (302) (303) (299) (297) (280) (240).

Selenium - The maximum permissible limit of 0.05 ppm of selenium was also initially specified by the PHS Standards of 1942(273) and continued in the 1946 Standards(108). This appears to have been included largely on the basis of the considerable experience with selenium poisoning of animals.

Chromium - (See Topic II 1b - Chromates)

4. Experience to Date - A great volume of literature recording much experience data, is available for lead and fluoride contaminants. Lead poisoning has been known for hundreds of years (152). Extensive epidemiologic data have been reported by various State health departments and by the U.S. Public Health Service. Less experience data is available for arsenic and selenium. Chromium was discussed hereintofore (under Topic II 1b - Chromates) and need not be repeated.

Arsenic compounds, included in insecticides and weed killers and in many industrial liquid wastes, have become more important in recent years as potential ground water contaminants.

Clark(305) reported poisoning of humans by arsenic from cattle-dipping tanks where the poisonous chemical got into wells in concentrations up to 12 ppm, resulting in two deaths. Fairhall(280) reported experiences of 0.21-1.4 ppm being poisonous to humans. Goudey(306) reported that some part of the population of Los Angeles consumed water containing arsenic concentrations up to 1.0 ppm for several months (1943) without ill effects (236). Brown(307) reported experiences showing the effect on humans and on vegetation of arsenic trioxide used for insect control. Wyllie(308) reported an early (1936) investigation of arsenic in a well water.

Selenium - As late as 1950 competent appraisal (236) of the toxic effects of selenium stated;

"---the toxic effects of selenium are primarily associated with --- foods --- rather than drinking waters. ---the very possibility that potable waters may sometimes contain toxic doses lead to the inclusion of a mandatory selenium limits of 0.05 ppm---".

Welsh and Thomas[152] referred back to 1944 (155) with reference to toxicity of selenium to animals and back to 1937 (275) to show that selenium in food was more important than selenium in water. They also referred to a survey reported in 1936 by Smith et al (276(which covered the possibilities of selenium poisoning of rural populations.

McKee[122] concluded; "as compared to food, water appears to be a relatively unimportant source of selenium poisoning---". Also "proof of human injury by selenium is scanty --- but it is widely believed that selenium is highly toxic to man (276) (296) (280) (156)".

Thus, it appears that experience with ground water contamination by selenium has been limited and the literature meager.

PASSAGE THROUGH SOIL

5. Nature of Movement ----)
6. Removal of Contaminants) - Little information has been found on the passage through soil of lead, fluoride, arsenic, or selenium. Data on chromium is given hereintofore (See Topic II - 1b).

Since all four chemicals occur as staple compounds in solution, it would appear that should the source of contamination be an industrial waste water, it is probable that the contaminant would pass through the soil into the ground water and along with ground water to the well with little or no change, excepting that due to dilution by fresh water.

Fluoride is found naturally to a major extent, in ground waters, while selenium is related to the soil in many areas.

DETERMINATIONS FROM SURVEY

The five toxic chemicals, included in the PHS Drinking Water Standards with quite low mandatory limits, appear to be of actual lesser value than possibly other recently developed contaminants.

7. Predicting Contamination - The present art is fairly well known. Lead has been a problem for hundres of years, due to lead pipes in plumbing systems. Modern plumbing uses very little lead, so industrial waste waters are the present more likely sources of lead and any such waste waters could be checked for lead.

Arsenic is most likely to be from insecticides, weed killers, or industrial waste waters and thus may be anticipated if coarse porous soils overlay or are closely adjacent to the ground water source.

Fluoride and selenium are found naturally in ground waters, particularly fluorides, chemical analyses of nearby ground water supplies should show the presence and concentration of these chemicals.

However, very little appears to be known as to the distance and speed of travel. The question of reduction in concentration by dilution should be similar to many other staple inorganic chemical contaminants.

Chromium has been discussed hereintofore. (Topic II 1b - Chromates)

8. Water Quality Criteria - It is probable that the current specified maximum limits for lead and fluorides may be reasonable for municipal water supplies.

However, there seems to be ample evidence that fluoride concentrations up to 5 or 6 ppm would be safe for ground water supplies containing natural fluoride so some modification in criteria ought to be made to permit use of waters with a higher natural fluoride content before treatment need be considered, i.e., the official water criteria should distinguish between the maximum allowable amount of fluoride permitted to be artifically put into potable water, as compared to the maximum concentration permissible in residential water supplies before the expense of fluoride removal must be undertaken.

Similar conditions might exist relative to the permissible concentrations of arsenic and selenium. The present maximum concentration of 0.05 ppm appears to be too low for the present drastic statement" — grounds for rejection of the supply" (108 p. 12), when applied to residential ground water supplies.

The question of maximum concentrations should be reviewed and some relaxation allowed, in official standards, to permit the use of ground waters serving small residential installations, excepting if the contamination is due to seepage of industrial waste waters, where the specified concentration should be considered as the initial evidence of a contaminant concentration which might become much higher before the waste water already in the soil can be diluted by the natural underground water flow.

Thus, any concentration of 0.05 ppm should be sufficient to require discontinuance of the waste water disposal, but the water supply might be continued in use until some higher concentration of fluoride, arsenic, or selenium was reached.

9. Suggestions for Obtaining Additional Information - It would seem worthwhile to consider the four chemicals; lead, fluoride, arsenic, and selenium (see Topic II - 1b - Chromium) from three points of view:

1. What has been the extent of recent ground water contamination experience recorded by public health agencies - but not yet summarized or published?

2. What methods are available and how costly for the reduction of contaminant concentrations, which might be used before a ground water supply need be abandoned?

3. Could a double standard be enforced; i.e., one concentration as a maximum for artificial contamination, such as industrial waste waters, and a second which would be the maximum safe concentration before water treatment must be installed or the source of water abandoned?

10. Summary - The five chemical contaminants now given mandatory limits of concentration by the PHS Drinking Water Standards(108) include two chemicals for which a great volume of literature is available - lead and fluoride - two chemicals, arsenic and selenium, which are uncertain as to importance in ground water contamination, and a fifth chemical, hexavalent, chromium, which is becoming quite important (see Topic II-1b.)

These five chemicals have been included in the current Public Health Service Standards as mandatory maximum permissible concentration as though any higher concentration would be a serious health hazard. There is considerable evidence that higher concentrations would not endanger health.

Accordingly, it is suggested that consideration be given to the development of a more realistic standard including two limiting concentrations; which would represent the maximum concentration permissible before the source of the ground water contamination should be removed. A second - a higher concentration - would represent the maximum safe concentration before a residential water source would need be abandoned, or a water treatment process installed.

1f - Chemicals Covered by P.H.S.Drinking Water Standards

B. With Recommended Concentrations (8 items)

The PHS Drinking Water Standards - 1946 (108) include eight chemical substances with recommended concentrations under the statement:

> "---which---should preferably not occur in excess of the following concentrations where other more suitable supplies are available in the judgment of the certifying authority".

Chemical	Should not exceed	
(1) Copper (Cu)	3.0 ppm	
(2) Iron (Fe) and Manganese (Mn)	0.3 "	(combined)
(3) Magnesium (Mg)	125 "	
(4) Zinc (Zn)	15 "	
(5) Chloride (Cl)	250 "	(see Topic II-1a)
(6) Sulfate (SO_4)	250 "	
(7) Phenolic compounds	0.001 "	(of phenol)
(8) Total solids	(500 "	good chem.quality
	(1000 "	"may be permitted"

Also "For chemically treated waters,--- Three requirements should be met"

(1) Phenolphthalein alkalinity - not greater than 15 ppm plus 4/10 total alkalinity
(2) Normal carbonate alkalinity should not exceed 120 ppm
(3) "If excess alkalinity is produced --- total alkalinity should not exceed hardness of more than 35 ppm."

However, these three requirements relate to results of water treatment so should not be included as items of potential ground water contamination in residential projects.

Chlorides have been discussed hereintofore (Topic II-1a) and will not be further considered in this section.

1. Sources - The above eight chemical substances, with the exception of phenolic compounds, are found in natural waters, some only in small amounts. All eight of the listed chemicals may be contaminants reaching ground waters from industrial waste waters. It is this later potential source which is of principal interest in the development of residential projects. Corrosive ground waters might pick up copper, iron, and zinc from pipes in sufficient amounts to cause objectionable tastes or discolorations.

2. Effect on Water Quality - In general, the effect of these several chemical substances on water quality may be briefly stated as follows:

(1) Copper - The toxicity of copper is not yet clearly established (122) (152). Some authorities (183) (309) consider doses of copper over 100 m.g. are likely to be injurious. However, copper has esthetical objections. McKee(122) stated:

> "Concentrations of 15 ppm can give water a noticeable metallic taste, and as much as 5 ppm (309) (155) (326) (310) renders water unpalatable."

Presently it appears the main effect of copper is the objectionable metallic taste produced.

(2) Iron and Manganese - The objectionable effects of iron and manganese comprise three main problems which arise when ground waters contain an excessive content of iron or iron and manganese:

(a) Objectionable tastes
(b) Staining of laundry and porcelain fixtures
(c) Deterimental growths of iron (or manganese) bacteria. These can thrive where iron content is less than 0.1 p.p.m.

(3) Magnesium - Salts of this chemical occur in large quantities in natural waters. It is an essential mineral element for human beings (122) and is not a public-health hazard. Before toxic concentrations are reached the taste becomes quite unpleasant (240). Taste thresholds range from 200 to 800 ppm (311) whereas any evidence of toxicity effects occur with considerably higher concentrations (312) (313).

At higher concentrations, magnesium salts are sometimes laxative to water users who have not developed a tolerance to magnesium, particularly magnesium sulfate, i.e., "Epsom Salts". Magnesium comprises one part of the hardness of natural waters (122). So an important effect of magnesium would be the undesirable characteristic effect of hardness in washing and cleaning uses of water.

(4) Zinc - Soluble salts of zinc are objectionable due to esthetic reasons - they give a stringent unpleasant taste (314). Robson and Lewis(315) claim the taste threshold may be 25 ppm. Kehoe et al(155) stated 50 ppm gave a metallic taste while 30 ppm caused a milky appearance. Other writers have reported opalescent water and a greasy film on boiling water with as little as 5 ppm (316) (317).

Chloride - See Topic II-1a.

Sulfates - Objectionable effects of sulfates have not been well established. McKee(122) stated relative to the USPHS recommended 250 ppm:

> "This limit does not appear to be based on taste or physiological effects other than a laxative action toward new users".

Welsh and Thomas(152) considered the laxative effect to be significant, but set the cathartic concentration at 1000-2000 ppm. They also referred to taste thresholds 200 to 600 ppm reported by Moore(311).

Moore(311) has indicated that sulfates up to 1000 ppm are harmless, excepting there may be some slight tastes noticeable to a few people.

Sulfides cause more unpleasant tastes than sulphates. However, it seems unlikely that sulfates would be reduced to sulfides in natural ground waters under normal conditions.

Phenolic Compounds - These organic chemicals are included here merely because they are listed in PHS Drinking Water Standards along with the foregoing list of inorganic chemicals.

Phenols are toxic, but toxic concentrations are much higher than taste and odor concentration would permit (122) (152).

Thus, the limiting factor controlling the effect of phenols is the objectionable tastes and odors, particularly if ground water must be chlorinated.

Total Solids - Total solids represent the dry residue from water after evaporation, and would include suspended solids or turbidity together with dissolved matter. Turbidity has been considered under physical qualities (Topic Ia.) In general, total solids in ground water may be considered as a measure of the dissolved minerals in the water. The PHS Drinking Water Standards have included a recommended limit on total solids since the 1925 "Treasury Standards" (272).

Welsh and Thomas[152] referring to an older reference (115) stated:

> "Some authorities believe that the total solids limitation was based on the fact that people who are accustomed to drinking soft water may suffer some physical discomfort when they consume water with a high mineral content."

There appears to be little concern expressed in the literature as to the effect of total solids, except that some chemical compounds which are included in the total solids determinations may have objectionable esthetic or minor physiological effects, such as nitrates, sulfates or chlorides.

3. Reported Permissible Concentrations - The Public Health Service[108] have set up the foregoing indicated concentrations with the qualifying statement:

> "---should preferably not occur in excess of --- concentrations".

State Boards of Health, in general, follow the lead of the USPHS. Some other suggestive ideas are as follows:

Copper - The U.S. Treasury Standards (1925)[272] set maximum permissible limits of 0.2 ppm. In 1942 the PHS Drinking Water Standards[273] increased the concentration to 3.0 ppm and changed the chemical substance from the maximum permissible to the recommended chemical limits list. The same concentration was kept in the recommended limits list in the 1946 Standards[108].

In Holland the permissible copper content is 3.0 ppm for water after standing 16 hours in pipes and 2.0 ppm for normal flowing tap water (122) (318). While Argentina and Russia have set a maximum permissible concentration in water supplies of 0.2 ppm (122) (299) (297) - same as the 1925 Treasury Standard.

Some writers seem to suggest that consideration might be given to the question of whether or not copper should be changed to the maximum permissible concentration. Many ground waters are aggressive and may corrode copper piping in the house plumbing. However, there is little evidence in the literature that copper is a dangerous contaminant so the main problem would be the question of tastes. There appears to be some indication that noticeable tastes would occur with 1.5 ppm (122).

Iron and Manganese - A recommended combined concentration for iron and manganese of 0.3 ppm, included in the PHS Drinking Water Standards (see above) (108) was included in the 1942 Standards (273) (152) and in 1925 Treasury Standards, excepting the Treasury Standards referred to iron only (272).

Some writers (319) (320) have proposed a maximum concentration of not more than 0.1 ppm based upon esthetic and taste considerations. Trouble has been experienced with Crenothrix and other bacteria with concentrations of iron as low as 0.025 (122) (321). Thresh and Beale(277) reported many years ago (1925) that Crenothrix troubles were experienced normally when iron concentration exceeded 0.02 ppm.

The problem of the proper iron and manganese concentration is a question of esthetics and possibly economics, so the present Standards should be reviewed realistically if and when sufficient evidence of trouble develops to justify an investigation into methods of iron and manganese removal for individual residences.

Sometimes iron may be picked up from the plumbing if the water contains a high CO_2 content, which may complicate iron removal treatment. Small amounts of manganese also complicates the functioning of some iron removal processes.

Magnesium - The PHS Drinking Water Standards(108) recommended limit of 125 ppm is up from 100 ppm in the 1925 Treasury Standard(272). Welsh and Thomas justify this concentration "---on the basis of aesthetic considerations and minimization of possible physiologic effects".

Two water quality experts, Baylis(422) and Goudey(114) have proposed concentrations of magnesium ranging from 15 to 150 ppm, partly on the basis of industrial use of water. However, these proposed concentrations were for the purpose of classifying water, particularly ground water by Goudey, and did not propose condemnation of water with higher concentrations.

Since magnesium, together with calcium, constitutes hardness in natural waters the limitation of hardness, in some uses of ground water, would constitute a limitation on magnesium.

The present PHS Standards(108) recommended limit of 125 ppm of magnesium appears reasonable as an upper limit for consideration of water softening processes, but not for condemnation of the source of water. No ground water supply should be condemned as a source on such a low limit as 125 ppm of magnesium.

Zinc - The present recommended limit of 15 ppm (108) is a relaxation from the specified maximum permissible limit of 5.0 ppm in the 1925 Treasury Standards(272). Welsh and Thomas(152) concluded "---15 ppm for zinc is based primarily on aesthetic--- considerations".

McKee(122) reports that literature (323) (324) (325) shows waters containing 11.2 up to 50 ppm have been used for considerable periods without harmful effects.

Since zinc usually is found in natural ground waters only in trace amounts any concentration as high as 15 ppm in a ground water supply would indicate a possible contamination by industrial waste waters with the possibility of rapid increase in objectionable chemical contaminants as the industrial waste waters percolated through the soil.

Accordingly, a concentration of 15 ppm of zinc would be a reasonable upper limit indicating the need of a careful study to determine the source of the contamination - not necessarily a basis to abandon a ground water supply.

Chloride - (See Topic II-1a)

Sulfate - The Public Health Service Standards have recommended an upper limit of 250 ppm of sulfate since 1925(272) (273) (108).

Welsh and Thomas(152) stated; "The 250 ppm limit --- was based on factors other than physiologic effect---" They did not commit themselves to an opinion as to the desirability of the presently recommended limit of 250 ppm.

McKee(122) found "Public water supplies with sulfate contents above this limit (250 ppm) are commonly and constantly used without adverse effects" (326)

There appears to be no substantiated basis for keeping the limit for sulfates as low as 250 ppm. So consideration should be given to increasing the recommended limit up to 500 or 750 ppm and then to use it merely as a guide to relative qualities of two or more possible ground water supplies, and as an index of possible contamination by industrial waste water seeping into the ground water.

Phenolic Compounds - Recommended limits for phenol at 0.001 ppm have been established only since 1942 (152). The recommended concentration probably was established on the basis of tastes resulting from chlorination of waters (122).

Since phenols in ground waters generally result from contamination due to industrial waste waters, the permissible concentration should probably be related to the potential results from industrial waste waters seepage into a ground water supply.

Consideration should be given to using a permissible concentration closer to the concentration which would be noticed without chlorination possibly 0.01-0.02 ppm (327) (328).

By the time the phenol reaches the noticeable concentration, the water supply might need to be chlorinated because of possible bacterial contamination, in that case the chloro-phenol taste and odor would be quite noticeably.

Total Solids - The PHS Standards(108) set 500 ppm of total solids "---for a water of good chemical quality." Also the Standards state "--if such water is not available, a total solids content of 1000 ppm may be permitted." Thus, the recommended limit would be 1000 ppm if applied to a residential project with an individual water supply.

Welsh and Thomas(152) concluded, "---the limitation appears to provide adequate protection". However, no supporting evidence was presented by them.

Total solids may be dissolved or suspended, depending on size of the particle. In general, suspended solids would affect turbidity which has been discussed under I - Physical Contaminants.

Many chemicals constitute dissolved solids(122). The physiological or esthetic effect of dissolved solids would depend upon the particular chemical involved. So limitations of objectionable chemicals may affect the desirable maximum concentration of total solids in some cases.

McKee(122) reports that highly mineralized waters with 2000 to 4000 ppm total solids are used in many communities where no better water is available (329) (311) (277) (330). He also stated; "---more than 4000 ppm are considered unfit for human use---".

Schoeller(331) has described higher concentrations, particularly of salt, being used in some desert regions. Many water supplies in North Africa(336) have total solids greater than 4000 ppm and are used by native populations who, over several generations, have become accustomed to the high mineral content. Generally, Europeans and Americans found a salt content of 1200-1500 and total solids of possibly 2000 the upper limit.

4. Experience to Date - Numerous articles relating to various experiences have been written about each of the eight chemicals included in this section. Chlorides have been discussed at length in Topic II-1a, hereintofore.

Since none of the chemicals are considered a significant public health hazard, the principal objection in residential projects would be a matter of esthetic consideration. This results in a wide divergence of opinions as to what is objectionable, depending on the sensitivity of the individual consumer.

Only a very brief review of past experiences seems necessary.

Copper - Many articles on the use of copper salts - particularly copper sulfate - in treatment of water supplies for the control of organisms (155) (332) (333) (334) (335). Other writers have been concerned with the effect of corrosive waters and the resulting staining of plumbing fixtures or the pickup of copper by water standing in pipes (318). There are many reports on metallic taste due to copper (309) (155) (183) (556) and discoloration of water (337). McKee(122) has referred to reports of people in copper industries picking up enough copper to affect the coloration of their skin and hair (309) (194) (183).

Iron and Manganese - A great deal of experience data is available. The knowledge of these two is so well known it appears unnecessary to attempt any reference to specific experiences.

Magnesium - This is a most common element and occurs in practically all water supplies, particularly ground waters. There seems to be no good reason to list experience records additional to those already referred to hereintofore.

Zinc - Experiences with zonc in ground waters for residential projects are probably related to industries in isolated areas discharging waste waters into pits or lagoons or to corrosive well waters picking up zinc oxide from galvanized piping (323) (317).

Sulfates, Phenols, Total Solids - There appears to be no references worth consideration additional to those already referred to. Recent unpublished experiences with waste waters from isolated industries might be available in the files of public health agencies.

PASSAGE THROUGH SOIL

5. Nature of Movement -------)
6. Removal of Contaminants --) - The salts of the several metals are highly soluble, excepting the oxides, so passage through soils in sufficient flows of water probably would not affect the concentrations. However, exposure to air in the soil above the ground water would oxidize many of the metallic salts with resultant precipation of some portion of the oxides. The precipitates would then be partially removed in the soil.

Articles in the literature have not been found which give sufficient data on the effectiveness of passage contaminated waste waters through soils. Chlorides have been discussed under Topic II-1a.

Sulfates may be relatively insoluble or highly soluble(122). The less soluble sulfates would be removed to some degree particularly above the ground water. Since sulfates are stable chemicals little change in chemical composition would be expected unless organic matter and sulfate splitting bacteria were present. No information was located on studies of distances to which sulfate contamination would travel.

Phenolic compounds may be rapidly reduced in the soil.- Investigations in California (926) showed that initially the phenols in waste waters were rapidly reduced, when leached through soil columns, but the ability of soil to reduce the phenol was rapidly reduced probably by the using up of oxygen. Lagooning(338) caused a reduction in phenol. Sayre and Stringfield(339) reported that phenols in the highly polluted Ohio River at Parkersburg, West Virginia did not affect wells 150 feet from the river. More complete information is needed.

Total Solids - In general, total solids in solution within the range of 1000 to 2000 ppm would not be affected by passage through soil. However, some industrial waste waters may contain colloidal material or suspended particles which might be removed in the soil.

DETERMINATIONS FROM SURVEY

The eight chemicals for which PHS Drinking Water Standards include recommended concentrations appear to be quite important, but the exact significance has not been determined. In some cases, such as copper, iron, zinc, and possibly manganese, the other chemicals in the water, particularly free carbondioxide, may have greater effect on the concentration of the contaminant in the water as used than the concentration in the natural underground water.

7. Predicting Contamination - Often some intimation of the natural content of the listed chemicals in ground water may be found from analyses of adjacent wells. However, the present art is inadequate for predicting the contamination by these eight chemicals. In some cases the natural content of some of the chemicals may be determined from analyses of nearby wells. In other cases - for example iron - it is not feasible to anticipate reliably the natural iron content in the ground water even after a well is installed, test pumped, and tested. Sometimes excessive iron appears after a considerable period of heavy use.

The geology of the site of a proposed well may indicate the potential contamination by one or more of the eight chemicals should industrial waste waters be leached into the soil at some nearby point.

8. Water Quality Criteria - The recommended concentrations, set up by PHS Drinking Water Standards, may be reasonably approximate guides for common carrier water supplies where "-- the judgment of the certifying authority" can be exercised as between two or more sources on behalf of a considerable number of people.

However, for residential supplies, where the available sources may be limited to one or two possibilities and the contamination problem would be more esthetic rather than physiological and would affect fewer people, some modification in quality criteria might be considered. At least this deserves further consideration.

9. Suggestions for Obtaining Additional Information - It would seem desirable that more definite standards be stated. A mere "recommended concentration", which leaves the implication that higher concentrations are dangerous, seems hardly satisfactory for a home owner or owners of a group of residences.

Possibly the same three questions suggested for the chemicals with specified concentration limits (page 45) should also apply to these eight chemicals with recommended limits.

10. Summary - The eight chemicals now given recommended limits of concentration by the PHS Drinking Water Standards(108) appear to become objectionable esthetically in water at much lower concentrations than concentrations which would have any physiological effects, excepting perhaps magnesium which sometimes has a laxative effect on new users.

There is evidence that concentrations much higher than the concentrations recommended by the PHS Standards could be permitted for residential projects. There is evidence that no ill physiological effects would result from use of drinking considerable water over long periods of time with concentrations of the eight chemicals much higher than would produce very objectionable tastes, so higher concentrations might be set up on the basis of esthetic acceptance rather than health menace considerations.

Further study should be made of modifications in the permissible or recommended concentrations with reference to ground water supplies for residential projects.

11. References to Literature - Bibliography items 272 to 339, inclusive.

1g - Potential Inorganic Chemical Contaminants

Many inorganic chemicals, additional to the five items discussed under sections II-1a to II-1e, inclusive, and the thirteen chemicals covered by PHS Drinking Water Standards(108) have toxic qualities and might be a menace to health or possibly to the esthetic character of ground water supplies. The literature examined provides insufficient evidence as to the degree of toxicity, and as to experiences with contamination of ground waters.

On the basis of the library survey and with particular attention to the summary of literature relative to toxicity reported by McKee(165), a list of eighteen additional chemicals have been selected for consideration as potential ground water contaminants.

The selected eighteen potential basic chemicals (or minerals), listed alphabetically, are as follows:

Aluminum	Potassium
Barium	Silica
Boron (Boric Acid)	Silver
Cadmium	Sodium
Litium	Thallium
Mercury	Thorium
Molybdenum	Tin
Nickel	Titanium
Phosphorus	Vanadium

Some of these chemicals or their salts are as yet not well known in connection with ground water contamination, but the rapid development of all manners of new products and the dispersal of new factories into rural areas adjacent to residential developments make desirable some consideration of these several items.

1. Sources - The salts of some chemical items, such as boron, cadmium, silica, and sodium may be found naturally in ground water in sufficient concentrations to be considered potentially objectionable. Also, most of the 18 listed chemical items may come from industrial waste waters.

Aluminum - Many salts of aluminum are soluble and may be found in various industrial effluents (122) such as dye works, cloth-printing, tanning and finishing leather, refining operations, disinfection, and other processes. Certain aluminum salts are also used in water treatment processes.

Barium - Soluble barium salts are used in dyeing fabrics, in tanning operations, manufacture of dyes, explosives, and other industrial processes and may be discharged in some industrial waste waters.

Boron - Boron is found in some underground waters and in citrus fruit plant waste waters. Sodium borate is used in cleaning compounds, for control of weeds (340), and paper mill slimes (341). Boric acid is used in certain industrial processes, in insecticides, in dyeing, and in printing (156) (280) (342) (343) (344) (345).

Cadmium - Cadmium, as an element is not readily soluble, but cadmium salts are soluble in water and may be found in waste waters from lead mines, textile finishing works, pigment factories, and many chemical industries. Cadmium plated containers and pipes have been considered possible sources of dissolved cadmium (151) (152) (122) (156) (346) (347) (348).

Litium - This metal is not commonly found in nature, but some litium salts are used for medicinal waters, in glass manufacture, and in storage batteries (122).

Mercury - Many mercuric and mercurous salts are soluble and have been found in waste waters from factories for disinfectants, leather tanning, some textile finishing, herbicides, lead mining, and many chemicals (223) (151). Also herbicides such as "Scutl" and disinfectants may be washed into areas where they may seep into ground water, or through defective well casing into wells.

Molybdenum - This metal or its salts are not considered significant in surface water pollution. However, in some rural areas soil from pastures may contain 20 to 100 ppm of molybdenum salts. Studies have been suggested and may warrant further consideration in rural and semi-urban areas which were formerly pasture land for cattle (349) (350) (351).

Nickel - Soluble nickel salts may be discharged from factory processes, such as plating wastes, ceramic coloring, and other manufacturing processes. In general, nickel salts are not found in natural ground waters although nickel compounds are found in ores and minerals in the earth structure (258) (352) (353).

Phosphorus - In the form of phosphates, this mineral is found in many soluble compounds. Phosphates may be found in ground waters as the result of degradation of ores or from seepage of agricultural drainage. Leaching from heavy applications of fertilizer or from cesspools may provide high concentrations of phosphates. Some waste cooling waters or seepage from cooling water lagoons may furnish phosphates to the ground water. Phosphoric acid is used in several industrial applications. Phosphates may reach ground water from cesspools, fertilizers, or industrial waste waters, (258) (354) (342).

Potassium - Potassium salts are so soluble it is difficult to remove them. They make up a large part of the earth structure and are useful in many industrial processes, particularly in fertilizers and some glass manufacture, oil well brines. Many industrial waste waters contain large quantities of potassium chlorides. Textile, electroplating, and other industrial processes produce waste waters containing potassium cyanide or a combination of potassium with iron and cyanide compounds (151) (355).

Potassium hydroxide is found in waste waters from dyeing and bleaching of cotton, soap manufacturing, detergents, and many small industries such as paint removers, electroplating, printing ink makers, wood industries, and others.

Silica - In general silica as sand or quarts or as silicates in various minerals are found as finely divided suspensions in underground waters and thus would in part make up turbidity. Compounds of silicon are found in many industrial waste waters (277) (151). Silicates are often used as coagulants or to inhibit corrosion of pipes (356) (357).

Silver - Silver ions are not expected to occur in significant concentrations in natural waters (165), but a concentration of 0.2 ppm was reported at Denver (183). Some silver compounds such as silver nitrate or silver sulfates are soluble. Silver compounds in small amounts may be found in waste waters from a considerable number of manufacturing processes, such as electroplating, photographic supplies, ink manufacture, porcelain marking, and others.

Sodium - Many compounds of sodium are soluble in water and constitute a large part of the earth surface material (258). Sodium salts are included in many industrial waste waters. So ground waters may receive substantial concentrations of sodium from natural underground deposits or from many types of industrial waste waters.

Thallium - Salts of thallium are used in rodent and ant poisons (151) which may enter or reach a well water or leach into ground water, if the poison is improperly handled. Waste waters from plants which manufacture rodent poisons or ant baits might find their way by seepage into the ground water.

Thorium - A relatively rare metal is used in electrical lamp mantles and filaments. Some experience has been reported for the chloride (358). Very little information has been found on the future contamination potentialities and possible sources of thorium compounds.

Tin - Stannous or stannic compounds - chlorides, chromate, oxide and sulfide - are used in dye houses, weighting of silk, varnishes and other processes. Many tin salts are insoluble or soluble in small amounts, but soluble tin salts may be contained in various process waste waters and by seepage through soil or entrance through defective well casings may reach ground water supplies (183).

Titanium - This metal is used as an alloy in steel fabrication. Some experiences have shown substantial amounts of titanium in water, but the origin was not determined (359).

Vanadium - Certain vanadium compounds are quite soluble and may be found in waste waters from dyeing and printing fabrics, glass manufacture, processing of photographic materials.

2. Effect on Water Quality - There is small evidence showing some of the 18 listed chemicals may have physiological effects on ground water supplies. These chemicals are potential contaminants, but published information is too meager to determine the probability of toxicity problems in ground waters which may be due to some of the many compounds of the 18 basic elements.

a - Aluminum Effects - Generally, the use of aluminum is not considered a public-health problem (165). Aluminum chloride, potassium sulfate, and ammonium sulfate, soluble chemicals found in industrial waste waters, have been found toxic to Dapnia magna (360) (361) and fish in greater concentrations (156). Much lower concentrations of aluminum nitrate have been toxic to stickleback. Aluminum sulfate is used extensively as coagulant in municipal water treatment.

b - Barium Effects - Some writers believe all soluble barium salts are toxic (156) (258). There are unknown aspects so more study would be desirable(240). The chloride and nitrate of barium have been tested for toxic effect on fish and smaller organisms (223) (361) (151). Consideration has been given to a limitation on the amount of barium dust in air pollution. More information is needed to provide any authentic basis for a limitation on barium salts in ground water.

c - Effect of Boron - In the forms of boric acid, sodium borate, or sodium perborate there are results of toxicity tests to indicate these compounds are probably toxic if a sufficient concentration should get into ground water (240) (156) (362).

d - Effect of Cadmium - Some health departments have forbidden the use of cadmium-plated food containers, because cadmium in considered toxic (165). Cadmium is expected to accumulate in the body tissues. One report indicated a boy was killed in a short time by about 9 grams of cadmium chloride (156). Rabbits and cats have been killed by cadmium chloride in their diet. Also cadmium nitrate has proven toxic for stickleback at less than 1/2 ppm. Other reports show evidence of cadmium toxicity (346) (347) (348).

There appears to be sufficient evidence to show that cadmium is toxic, but there is insufficient information to determine the toxicity threshold for people or whether there may be any accumulative effect (223) (361) (363).

e - Litium Effects - There is little information published on the effects of litium in ground water. One report (223) indicates that a relatively high concentration of litium chloride (3750 ppm) was lethal to goldfish. Another report (361) found less than 7.2 ppm would stop activity of Daphnia magna. Thus, some small evidence of toxicity has been found in the literature (365).

f - Mercury Effect - One writer (364) suggests that 10 ppm of mercury in water may be safe if no more than 1/3 gallons per day be consumed by an adult, but might be fatal if 2 gallons were consumed. Mercury chloride is reported to be 50 percent fatal if as much as one gram be taken in drinking water (151). Small fishes have been killed with concentrations of 5 to 40 ppm (366) (367) (223) (369). Much smaller concentrations (0.006 to 0.2 ppm) were lethal for Daphnia magna and a flat worm (361). When mercury chloride is combined with copper compounds the toxicity appears to increase (370). Other mercury compounds such as P. acetate ("Scutl") and P. lactate have been reported much more toxic than mercury chloride (372) (371).

There are many writings showing mercury compounds would be toxic if they reached ground water in sufficient concentrations.

g - Effect of Molybdenum - Salts of this element are not considered significant in surface water pollution (165). However, ground waters for rural residential projects might be contaminated from soil of pastures where cattle have scoured (350) (351). It was reported (349) that studies of the significance of molybdenum were being made in Australia. The possible toxic effects of this mineral element seems to be similar to selenium.

h - Nickel Effect on Ground Water - Nickel seems to have been toxic to plant growth and large dosages were reported lethal to dogs (156). Wastes from nickel plating have proven toxic to various small organisms (361) (348).

i - Phosphorus Effects - The phosphates in water treatment tend to encourage growths of organisms (183) (373). Hexamephosphates have been considered toxic to some degree (374). In the form of phosphine gas, phosphorus is quite toxic (258) (342). There appears to be some possibilities that leaching of phosphates from fertilizers, cesspools, and possibly certain industrial wastes might contaminate ground waters. It has been suggested that 0.2 ppm of phosphate in ground water might be considered an index of fecal contamination (375).

j - Potassium Effects - A dose of 1 to 2 grams of potassium is cathartic (165). Certain salts have a taste threshold of about 400 ppm (311). Early writers presented experimental data showing toxicity of potassium salts to fishes (376) (223) (377). Potassium salts are quite common and very active under certain circumstances (258). However, there appears to be no complete knowledge of the total effects of potassium.

k - Silica Effects - There is some evidence that the concentrations of silica or silicates normally found in natural waters have caused no ill physiological effects (194), but Raux (378) suggests some years ago that 50 ppm or more of silica causes turbidity problems. The major effects of silica has been to form encrustations on heating tubes in boilers and hot water heaters.

l - Silver Effects - There are older reports that silver in dosages of less than 0.01 ppm have sterilization action (379) (380). It was reported that these concentrations are not toxic to persons nor do they have esthetic effects (381). However, small dosages have been reported as toxic to smaller organisms (348) (361). So there may be toxic effects to persons in drinking waters if sufficient concentrations should reach ground waters by leaching of industrial waste waters.

m - Sodium Effects - Sodium has been found objectionable to persons with several different diseases and doctors routinely prescribe sodium free diets (292). Many sodium salts are freely soluble in water so excessively high concentrations of sodium may reach ground waters. Sodium carbonate and probably other sodium salts have taste threshold in the magnitude of 15 to 75 ppm (311). On the other hand much higher concentrations have been considered safe by earlier writers (277) (194). Since the carbonate is toxic to plants (258) there is uncertainty as to the actual effects of sodium in ground waters. More information is needed.

n - Thallium Effects - Toxicity is the principal potential effect of salts of thallium (258) (307) (382). More complete information is needed.

o - Thorium Effects - Potential toxicity appears to be the uncertain effect of thorium salts (358) (258), but little appears to be known about these chemicals.

p - Tin Effects - Tannous and tannic salts have been found toxic to fish, rats, and cats (361) (156) (358) (383). There is also information that considerable tin is contained in diets of people without adverse effect. More complete information is needed.

q - Titanium Effects - The effects in ground waters of this relatively uncommon chemical are not known.

r - Vanadium Effects - Toxicity effect of vanadium compounds appears probable from some discussions of effects on plants, algae, and rats (384) (385) (386) (151). There have been reports that intestinal upsets have been caused by vanadium in food.

3. Report Permissible Concentration - The 1946 PHS Drinking Water Standards (108) give no indication as to concentrations for the foregoing listed 18 chemicals. A few writers have suggested safe concentrations and in some cases foreign official standards have been set up. There have been suggestions as to permissible concentrations, of certain chemicals, for water to be used in industrial processes.

However, no permissible concentrations have been proposed for ground waters and in no cases have permissible concentrations been considered in terms of two ranges of permissible and safe concentrations for individual water supplies, as suggested hereintofore.

Briefly the suggestions as to permissible concentrations found in literature are as follows:

a - Aluminum)
b - Barium) None relative to residential water supplies.

c - Boron - Hoskin (387) recommended a boron limit of 20 ppm for drinking water. Goudey (344) reported that concentrations up to 30 ppm were not harmful.

d - Cadmium - The U.S.S.R. established a limit of 0.1 ppm for cadmium (297). Welsh and Thomas (152) have stated ". . .This value may be a satisfactory limit for use in the United States until further experience and knowledge provide a more feasible limit." Thus, it has been proposed to base PHS Drinking Water Standards on Russian standards.

e - Litium - An early (1934) suggestion by Hibbard (388) of 5 ppm for drinking and cooling purposes seems to be the only published information.

f - Mercury - A maximum permissible concentration of 0.005 ppm in the U.S.S.R. was reported by Kirkor (297).

g - Molybdenum - No information found on permissible concentration.

h - Nickel - Again Kirkor (297) reports a U.S.S.R. permissible limit of 1.0 ppm. There are other writers who indicate this concentration may be overly conservative (156).

i - Phosphorus - No literature on permissible concentrations of phosphorus compounds nor phosphates. Safe doses have been suggested (374) ranging from 90 to 450 grams, depending on the compound. Excessive phosphate concentration has been considered undesirable, but no suggestions as to definite limits have been found in the literature.

j - Potassium - Moore (311) has suggested a maximum permissible concentration of 1000 to 2000 ppm, but also considers 350 ppm as a taste threshold for the chloride salt. Early (1937) reports (223) indicate fish have been killed by lower concentrations.

k - Silica - No definite discussions of a permissible concentration for silica have been found. Concentrations of 4 to 8 ppm have been used in municipal water supplies for corrosion control without objections (277).

l - Silver - No standards for permissible concentration of silver nor any suggestions of proposed concentration, have been found.

m - Sodium - An early (1934) writer's suggestion (388) of 10 ppm as a desirable limit on sodium has not been given much attention. Another early (1939) report (331) suggested that a water supply might contain up to 115 ppm of sodium. Goudey's (114) proposed ground water classification for domestic use (Class AA) would limit sodium bicarbonate to 0 ppm. The taste of sodium is reported to be noticeable in concentrations of 15 to 75 ppm (311). However, discussing the "Treasury Standards" Hoskins (387) suggested that the permissible concentration for sodium carbonate could be raised. Concentrations of 360 to 500 ppm have been discussed (194).

Sodium chloride has been discussed under Topic II-1a. Chlorides.

Some sodium compounds such as sodium borate (341), sodium cyanide (156), and possible others, may have concentration limits because of toxic characteristics. In other cases, perhaps more generally limiting the concentrations of sodium ions, may be the need of a low sodium diet by considerable numbers of people suffering with various ailments.

No conclusive evidence as to the proper minimum concentration of sodium has been found in the literature.

n - Thallium)
o - Thorium)
p - Tin) The literature studied presents no definite data on limitations for safe concentrations of these five metals, nor their salts, which occur naturally in trace quantities, if at all, in ground waters.
q - Tilanium)
r - Vangdium)

4. Experience to Date - The 18 inorganic chemicals, listed in a preceeding paragraph (page 57), are largely metals and their salts which, quite generally, have been found in industrial waste waters. To date the experience with ground water contamination has been limited and only a few instances have been published. Dispersal of industries into outlying urban and rural areas has been rapidly increasing the potential ground water contamination.

a - Aluminum salts have been studied with reference to toxicity - Aluminum ions have been found non toxic by earlier writers (183) (240) (284); aluminum sulfate, nitrate and chloride have been found toxic to fish and smaller organisms (223) (361); the oxide has been the suspected cause of the death of cattle (389); the sulfate (filter alum) has been extensively used, but there has been some evidence that it may increase the solubility of lead (229) and may irritate mucous membranes.

b - Barium - The Industrial Hygienists have considered barium in air dangerous. The 1950 ORSANCO report (156) considered some barium salts quite toxic with effects on the blood and nerve systems. The contention of earlier (1938) writers (240) that the effects of barium are not understood seems still to hold.

c - Boron - Several writers (236) (280) (344) (345) (387) have discussed boron concentrations in the Los Angeles water supply. Other experiences have been reported from Italy.

d - Cadmium - The Ohio Commission has reported (156) cases of food poisoning by cadmium. Although health authorities have been concerned about cadmium, no literature on specific ground water contamination experiences has been found.

e - Litium - This metal, as a chloride, has been found in mineral spring waters and in artificial mineral waters, but no reports of ground water contamination have been found.

f - Mercury - Many reports have been found on the toxic effects of mercury compounds, but no report on a specific experience with ground water contamination.

g - Molybdenum - Reports (350) (351) on effects on cattle on one farm and similar experiences in Australia (390) seem to be the present record of potential ground water contamination by salts of molybdenum.

h - Nickel - No reported specific experiences of ground water contamination have been found.

i - Phosphorus - McKee (165) has assembled 18 references to discussions of the effects of phosphates, but no records of ground water contamination have been found.

j - Potassium - A report (391) on a large fish kill in New York by industrial waste waters containing potassium ferrocyanide and an earlier report (368) on fish kills by other salts illustrate potential possibilities of ground water contamination.

k - Silica - Many papers have been written on silica and silicates in water supplies, but no report of a specific experience with ground water contamination has been found.

l - Silver - Only small concentrations of silver have been reported in ground waters (183). No reports or experiences have been found for high concentrations in ground water from industrial waste waters.

m - Sodium - Many analyses have shown high sodium concentrations in ground waters.

n - Thallium)
o - Thorium)
p - Tin) No reports have been found of specific experiences
q - Titanium) with ground water contamination.
r - Vanadium)

PASSAGE THROUGH SOIL

5. Nature of Movement)
6. Removal of Contaminants) No literature has been found with specific information, on the nature of movement or the removal of these potential contaminants by passage through soil. McKee (165) has surmised that many salts of these several potential metallic contaminants might be changed to insoluble compounds.

DETERMINATIONS FROM SURVEY

7. Predicting Contamination - Presently there appears to be no method to predict ground water contamination by waste waters containing any of the foregoing list of eighteen potential chemical contaminants, excepting by general hypothesis based on reduction of concentration by ground water dilutions and possible chemical reactions which would change certain compounds to other salts less soluble. No literature has been found with specific information on either ground water movements or removals of these metallic compounds.

Information is needed as to the possibilities of chemical changes in and through the soil and also as diffusion of the chemical solutes into the ground water to obtain the effect of dilution. This is a common problem with all chemicals. Also more information is needed on the experiences of contamination of ground waters by these eighteen chemical items.

8. Water Quality Criteria Required - There appears to be sufficient information on the toxicity of some of the chemicals to justify a water quality criteria. For example Barium salts; Cadmium salts; Mercury compounds; Potassium compounds; and possible Sodium salts. However, more specific information is needed to determine the relative importance of these elements.

There is insufficient information on which to base a judgement as to the need for criteria for many of the chemicals or the permissible concentrations for all of the eighteen listed potential chemical contaminants.

9. Suggestions for Obtaining Additional Information - An initial investigation should include the collection of specific information on unpublished experiences with ground water contamination by any of the eighteen potential chemical contaminants. The same type of inquiry of various agencies already suggested several times hereintofore, should be the first step.

A second step should involve a summary of the present medical knowledge of the toxic effects of these several chemicals.

A third step, for such chemicals as are found toxic, should include investigations of the hydraulic; physical and chemical reactions between the chemicals and various types of soil.

10. Summary - The eighteen chemicals listed as "potential contaminants" have been discussed by a number of writers, with sufficient evidence of toxicity characteristics to warrant consideration as potential contaminants. In most cases the degree of toxicity is not well established or, in some cases, now even well understood.

The literature includes a number of discussions of possible toxic effects, but very little is reported of actual experiences with ground water contamination. Published experience data appear to be insufficient to clearly determine the relative importance of the several chemicals. Some proposals have been discussed recently relative to permissible concentrations for barium and cadmium.. Recent rapid dispersal of factories may have resulted in cases of unpublished experiences, some records of which may be available in files of various public agencies.

11. References to Literature - Bibliography items 340 to 391, inclusive.

II. CHEMICAL CONTAMINANTS (Continued)

2. Organic Chemical Contaminants

There are huge numbers of organic chemicals which may be contaminants of ground water, either due to objectional esthetic qualities or as toxic matter. Ettinger(392) recently reported:

> "More than 500,000 organic chemicals are known and have been synthesized and described. A few dozen of them are accepted by the Food and Drug Administration as being safe for addition to food and beverages."

The presently reported survey could not possibly attempt to review individually the huge numbers of organic chemicals, which numbers are increasing rapidly and constantly.

Certain chemical compounds have been known as ground water contaminants for several years - such as sewage chemicals, synthetic detergents, waste waters from factories which process many animal and vegetable products. McKee(165) has reported the characteristics of many organic chemicals, including numerous tests for toxicity.

In order to provide a reasonable coverage of organic chemicals and the potentiality of such chemicals becoming ground water contaminants, ten major groups have been selected relating largely to the sources of organic waste waters, as follows:

2a - Synthetic Detergents
2b - Domestic Sewage (Chemicals only)
2c - Animal and Vegetable Process Wastes
2d - Petroleum Oil Wastes
2e - Coal Tar Products Wastes

2f - Coke Gas Plant Wastes
2g - Dye Wastes
2h - Explosive Wastes
2i - Insecticides, Larvicides, Pesticides, Herbicides
2j - Petrochemicals

These ten groups permit a general survey of the status of present knowledge and to determine a general outline of additional information needed. As knowledge becomes more extensive other chemical items or types of process wastes may be added to the list or some of the initial 10 groups might be broken down into individual chemical compounds or other groups of items.

2a - Synthetic Detergent Contaminants

Many recent writings have appeared discussing reported experiences of ground water contamination by synthetic detergents. These are reviewed in some detail in Appendix E.

1. Sources - of ground water contamination by syndets have been: (a) sewage from household sewage disposal facilities (395) (399); (b) sewage lagoons; (c) laundry waste water disposal by seepage into soil; and (d) some industrial waste waters.

2. Water Quality Effects - have included (a) an off-taste of water (398); (b) frothing or foaming of the water; and (c) a discoloration of the water. There seems to be no toxicity problem, excepting that syndets may be considered evidence of sewage, hence potential pathogenic contamination.

3. Reported Permissible Concentrations - The reported evidence on several experiences indicate an ABS content of 1.0 ppm likely would cause objectionable tastes or possibly foaming and discoloration (407) (395). A number of reports indicate that the toxicity threshold is still unknown (401) (Norwell & Linquist). The AASGP Committee (Moss et al) (406) of the soap and glycerine producers concluded;

> "---ABS can be consumed at concentrations at least several times those presently found in drinking waters without producing any long-term physiological effects."

Presently, there appears to be no official water quality Standard giving a permissible concentration value. In a recent paper (Hopkins and Gullans) (408) proposed a limit of 0.5 ppm of ABS on the basis that undesirable foaming might occur and "---that at least 5% of the water is of sewage origin".

4. Experience to Date - During the past 10 years many experiences with syndets in surface waters have been reported. An early reported experience by Flynn et al (395) gave a great deal of information on contamination of ground water on Long Island extended back to 1957 in areas where no such evidence was found in a 1955 survey.

In 1956 a report was published (402) of an experimental study in Kearney, Nebraska. Letters of inquiry to State Sanitary Engineers in 1959 (Appendix B) brought out six states reporting appearance of syndets in wells (403). A quick reconnaissance survey by the U.S. Geological Survey (405) in 1959 resulted in finding six locations where water analyses showed ABS in well waters. Newell and Almquist reported (407) experiences in connection with contamination of well waters by synthetic detergents were noticed "about four years ago ---" (Prior to September 1959).

It is very likely that many more experienceswill be reported in the near future. To some measure the foaming or discoloration due to ABS is evidence, observable by the householders of sewage contamination of their wells, which sewage pollution may have existed for years. Accordingly, the serious problem may be that of sewage pollution.

PASSAGE OF SYNDETS THROUGH SOIL

5. Nature of Movement)
6. Removal of Syndet) Experience data from Kearney, Nebraska (402) and from Long Island (398) (395) indicate that syndets may move in "slugs" and may not be reduced, excepting by dilution with fresh water.

DETERMINATIONS FROM SURVEY - SYNDETS

7. Predicting Contamination - Flynn (395) concluded that with individual wells and sewage disposal systems on small lots syndets could be anticipated in the wells. However, there is no conclusive evidence relative to the prediction of contamination in various types of soils and types of wells.

Considerable information is needed to show the relationship of ABS concentration and soil characteristics. Chemical, hydro-mechanical, and biological soil reactions may - and quite likely do - affect the concentration and movement of ABS.

8. Water Quality Criteria Required - Some criteria as to ABS concentration should be established particularly applicable to well waters for residential projects. Also any criteria for ABS, i.e., synthetic detergents, ought also to include some consideration of sewage contamination.

9. Suggestions for Obtaining Information - Presently the literature seems to indicate that synthetic detergents will require extensive laboratory and field studies to determine a proper scientific basis for understanding and predicting the probable effects of synthetic detergents on ground water contamination. More detailed suggestions are given in Appendix E.

10. Summary - Synthetic detergents are being used in huge quantities and all individual sewage disposal systems have become major or potential sources for syndet (also sewage) contamination of water supplies wells for residential projects.

The situation is getting progressively worse, so rapidly that special attention should be given to these organic chemicals. An active research program should be initiated promptly to determine the effects of soil characteristics on the ABS constituent of synthetic detergents.

11. References - Bibliography items 393 to 408, inclusive.

2b.- Domestic Sewage Chemical Contaminants

Domestic sewage is the source of many organic chemical compounds, i.e., organic matter deposited in the soil when sewage is allowed to leach into the soil. For many years domestic sewage contamination has been quite generally related to potential biological contamination and more recently to potential viral contamination of ground water.

It is the function of this section to consider only the chemical constituents of sewage. Biological and viral contaminants are discussed in later sections (Section IV. Biological Contaminants and Section V. Viral Contaminants).

Sewage is not normally analyzed to show all of its chemical constituents (409) (410), but laboratory examinations have included limited determinations frequently designated "Sanitary Analyses" which have included some or all of the following items:

a) Ammonia - Free and Albuminoid
b) Total Nitrogen (also Nitrites, Nitrates sometimes)
c) Total Solids (suspended and dissolved)
d) Chlorides
e) Oxygen consumed)
f) B.O.D.) Considered to be a measure or organic matter.
g) Dissolved Oxygen
h) Oils, Fats, and Grease
i) Sulfates
j) Hydrogen Sulfides
k) pH Values

Prior to the advent of bacteriological knowledge efforts were made to measure concentration of water pollution by chemical analyses (not including B.O.D. a more recent analytical determination) (409) (411) (412).

1. Sources of Sewage Chemical Contaminants - Such sources include: (a) residential cesspools and septic tank leaching fields (413); (b) effluents from municipal sewage plants; (c) sewage or sludge lagoons (415); and (d) sometimes leaky sewers (414). In some areas serious consideration has been given to ground water replenishment by sewage reclamation (416) and numerous studies have been reported on the potential pollution effects on ground water.

2. Effect on Water Quality - Sewage may affect the physical, chemical or biological quality of water (417). After leaching through the soil the turbidity aspects of the physical qualities may be reduced, but color and possibly odor may remain if the sewage concentration is high.

Chemical effects may include salt content, ammonia nitrogen and hydrogen sulfide (417). Other writers (413) report ammonia, chlorides, and alkalinities in higher concentrations than in natural ground waters of the respective areas.

3. Reported Permissible Concentrations - In recent years examinations of water relative to sewage contamination have been so concerned with bacterial contamination that little or no attention has been given to setting any limitations on chemical concentrations. In many areas the chemical content of natural ground water may be higher than the concentration of the sewage, relative to certain chemicals.

Accordingly, no exact concentration limits may be considered objectionable until the natural concentrations of the chemicals in the ground water are known. Some earlier writers indicated concentrations of certain chemicals, such as ammonia, nitrites, nitrates, oxygen consumed, and other determinations designated as "sanitary chemical analyses".

These appear to be of very little value as compared to more modern determinations of syndets, bacterial analyses, and microscopic examinations, particularly examinations by electronic microscopes.

4. Experiences to Date - Many writers have discussed and reported upon sewage contamination of ground waters. An early (1927) experimental investigation reported by Stiles et al (419) showed uranin reaching wells at distances up to 450 feet from the point of injection, and remaining in the ground water for up to more than two years seven months.

A second early (1932) study reported by Dappert(414) furnished data on activated sludge plant effluent seepage into ground water and its travel to a spring about one quarter mile away.

Other experiences could be summarized, but the more recent experiences with synthetic detergents, discussed hereintofore appear to be much better indices of sewage contaminations.

PASSAGE THROUGH SOIL

5. Nature of Movement)
6. Removal of Contaminants) - Butler, et al(416) have reported that chemicals travel further and faster than bacterial contamination in ground water. Earlier writers(419) reported that chemicals from sewage appeared to float out in a blanket close to the ground water table and tend to filter out into the capillary fringe in the soil and travel of contamination was in the direction of ground water flow.

Salvato(420) pointed out (1958) that soil characteristics more variably and had great effect on underground sewage pollution travel. Extensive investigations are underway particularly in California in connection with efforts to replenish ground waters with reclamation of sewage. Conclusive results have not been determined.

The removal of chemicals by travel through the soil appears to be quite variable, depending on the chemical and on the soil physical and chemical characteristics. Some information is available (416) (419), but much more information will be required. The problem is complicated.

DETERMINATION FROM SURVEY

7. Predicting Contamination - Available literature does not clearly indicate any sure procedure to predict ground water contamination by sewage chemicals. More information must be obtained on several complicated relationships between characteristics of chemicals and of soils.

8. Water Quality Criteria Needed - There are no specific quality criteria for many chemical constituents of sewage. The Public Health Standards(108) indicate very low permissible concentrations for certain chemicals, but more applicable criteria are needed, as discussed hereintofore under inorganic chemicals and synthetic detergents.

9. Suggestions for Obtaining Information - Field investigations should be continued, which have been under way by various authorities(117) to determine possibilities of ground water replacement. In addition, laboratory scale and experimental pilot plants of the lysimeter type should be set up with various known soil constituents and solutions containing various chemicals passed through the soil columns to determine relationships of chemical ions and soil, as has been suggested hereintofore for other chemical contaminants.

However, any proposed research relative to sewage chemicals should be correlated with similar researches proposed hereintofore for various chemicals such as syndets and others.

10. Summary - Sewage chemicals may contaminate underground water by movement of sewage through soil into ground water supplies. The most frequent sources are cesspools, septic tank effluents, and other sources of sewage flows or sewage sludge.

Normally the small concentrations of chemicals in sewage may be insignificant compared to chemical concentrations from industrial waste waters. Certain sewage borne chemicals, such as synthetic detergents have become quite significant. These are discussed hereintofore.

Bacterial and viral contamination through the agency of sewage have been and still may be so much more important than sewage chemicals, that near future research projects might well concentrate on such biological contaminants, excepting experience has indicated that under some circumstances sewage chemicals may be easier to follow in movement through soil than biological organisms.

11. References - Bibliography Items 409 to 420, inclusive.

2c to 2h - Industrial Process Waste Waters

Process waste waters from many industrial processes contain organic chemicals which may be toxic or may produce objectionable esthetic effects in ground water supplies. These may become ground water contaminants in areas where discharge of process waste waters into surface water ways may not be feasible or would be too costly.

There are many instances where process waste waters are disposed of by lagooning, by leaching into water bearing strata, or by injection into the ground water through bore holes or wells. Such process waste water disposal to the ground water is probably increasing with the rapid dispersal of industries into suburban and rural areas (421) (422) (271).

Miller et al(422) have reported:

> "The disposal of liquid wastes through wells has received considerable attention from industry and government agencies. ---Most wastes --- were so objectionable that it was thought sound policy to get them out of the way by planting. ---the liquid bodies do not always stay where they are planted. Statutory regulations and public opinion dictate the need for rigid standards---"

It is the general purpose of this section to briefly review the six groups of industrial process waste waters, listed in Table "A", Topics 2c to 2h, inclusive, which have fairly common problems of ground water contamination, similar characteristics as to sources of contamination, effect on water quality, generally unknown permissible concentrations, and meager experience data, to date, on their effect as ground water contaminants.

The six groupings (from Table A) are as follows:

2c. Animal and Vegetable Process Waste Waters

Packing Plants
Slaughter Houses
Rendering Plants
Refineries - Vegetable Oils
  Cotton Seed
  Corn (Maize)
  Soya Beans
Textile Mill Wastes
Milk Processing
Distilleries
Sugar Plants
Paper and Pulp
Wool Scouring

2d. Petroleum Oil Processing Wastes

Oil Field Wastes
Refinery Wastes - Petroleum Oils
Marketing and Storage of Petroleum Oil Products
Gasolene - leaks and losses

2e. Coal Tar Products. Process Waste Waters

Acridine
Cresylic Acid
Creosols (Cresylic Acid)
Naphthalene
Phenanthrone
Phenols
Pyridine
Quinoline
Thiophene
Xylene

2f. Coke Gas Plant Waste Waters

Ammoniacal Liquors
Cyanides
Organic Acids

2g. Dye Waste Waters

Aniline
Nigrosine
Picoline
Others?

2h. Explosive Mfg. Wastes

Ammomium Picrate
Dinitrophenol
Mononitrotoluene
Nitro Benzene
Orthodichlorobenzene
Picric Acid
Tetryl
TNT (Trinitrololuene)

The foregoing six groupings of organic chemical wastes include two groups or types of industrial operations which produce complex organic chemical wastes, which are listed without attempting to specify the component chemicals. Several objectionable organic chemicals may be present in the process waste waters from two or more groups of industries.

In the other four groups of industrial operations the chemicals listed, and possibly others, are those most commonly reported as potentially toxic materials. These may be considered as illustrative or representative organic chemicals which may contaminate ground water. Again some of these listed chemicals might also be produced by industrial processes under other groupings of industrial process waters.

1. Sources - The sources of ground water contamination by the organic chemical process wastes in the six groupings most likely would be from industrial plants located in areas, generally suburban or rural, where discharge of process waste waters into surface waters may not be feasible or permissible and underground disposal is attempted either directly by discharge into bore holes or into wells or indirectly by discharge into leaching pools or lagoons. The latter appears to be most common.

The source of chemical contaminants generally is waste materials no longer useful to the manufacturing processes. Sometimes the waste products may be in the solid state placed in waste dumps and then reaching the ground water through solution by rain water or surface flows.

Under Topic 2d (Petroleum Oil Wastes) there should be considered also the sources of contaminants incident to the handling, storage, and marketing of petroleum oil products. Generally, the objectionable chemicals are in solution or partial solution in process waste waters and are carried to a point of disposal by water carriage.

2. Water Quality Effects - have included (1) an off-color or off-taste, thus reducing or spoiling the esthetic quality of the water, or (2) a sufficient toxicity to be dangerous to health if consumed in sufficient quantities. The effect on color, taste, or odor characteristics of ground water supplies may be the most common water quality effect.

3. Reported Permissible Concentrations - There appear to be no official standards which set permissible concentrations for most, if not all, of the organic chemicals in the six groups of process waste waters. In certain cases, such as phenols and cyanides, the PHS Drinking Water Standards - 1946 (108) include partial standards, as discussed hereintofore.

Even as late as March 1960 Welsh and Thomas(152), in a discussion of chemical limits in the PHS Drinking Water Standards, practically ignored the rapidly developing problems of organic chemical contaminants reaching ground waters.

In general, the literature on these various organic chemical process wastes relates to their effect on stream pollution. Insufficient attention seems to have been given to the contaminants and allowable concentrations in ground water supplies.

Some future possibilities as to permissible standards have been discussed by Hopkins and Cullans(408) who have stated:

> "Today the new challenge --- is the control and removal of the chemicals and isotopes which are being produced in a bewildering array of new compounds. ---very little is known about the extent of pollution --- by these new chemicals ---. In the current revision of the USPHS Drinking Water Standards, by far the greatest amount of effort has gone into the problem of setting limits for chemical contaminants. ---It has been recommended that drinking water contain not more than 200 ppb of CSCFF." (CSCFS=Chloroform-soluble carbon filter extract. (392)

There has been very little data to support any conclusion that the proper permissible concentration is 200 ppb as proposed for this carbon filter extract measurement, which is in effect a "catch-all" test on the premise that any concentration of chloroform-soluble carbon filter extract materials would be undesirable. It is recognized that the isolation for many of the CSCFF constituents would be a very difficult problem and that a compromise, such as a "catch-all" test is needed and does represent a forward step.

However, this does not indicate what organic chemicals are present, nor give any evidence as to the maximum concentration which can be permitted before an only residential water supply must be abandoned.

4. Experience to Date - Many articles in the literature report surface water pollution experiences. Relatively few discussions have been found of experiences specifically related to ground water contamination. This has been due largely because major numbers of industrial plants with process waste waters have been located along surface water ways or located in areas isolated from residences, where no ground water supplies were nearby.

A few illustrative experiences have been located which appear to indicate a trend toward greater frequency of ground water contamination. Ground water contamination troubles from some of these are just beginning to appear as the adjacent areas are developed and wells are installed for residential projects.

Miller et al(422) discussing underground disposal of waste waters reported:

> "Some serious problems have occurred in Wisconsin and Michigan because inadequate investigation failed to reveal sufficient data concerning soil and water table characteristics. Some shallow well waters developed undesirable taste, odor, and color."

Correspondence with State Health Agencies (Appendix B) brought out a number of instances of ground water pollution by organic chemicals. Examples: Illinois: pollution — due to break in gasolene supply line; Indiana: an instance of gasolene in a public water supply, (several other investigations were discussed verbally); Iowa: wells contaminated by oil products, industrial wastes, chemical wastes, and nitrate content; Kansas: wells contaminated by gasolene, oil field brines, and by detergents; Maryland: wells contaminated by industrial wastes, and wide spread contamination in housing developments; Massachusetts: many investigations of chemical waste contamination of ground water; Minnesota: well contamination by dye solution, gasolene tastes and odors in another case, pollution by chemicals from pole treating plants, and waste water from zeolite softening plant; Montana: report on petroleum products travel through soil;

Nevada: subsurface well chemically saturated from an industry; New Mexico: contamination from uranium mills, high nitrates, and waste disposal; New York: studies on gasolene and natural gas contamination of ground water, special study on detergent and laundry contamination of wells, and study of barium in public water supplies; Oklahoma: salt water pollution, oil refinery waste pollution, and oil field wastes contamination of ground waters; Pennsylvania: tests for detecting chemicals in contamination of underground waters; Texas: reports on brines and chemical contamination of ground water; West Virginia: wells grossly polluted by milky wastes, apple seeds, brines, acid and irony waters, industrial wastes, and infiltration of contaminated river water; Wyoming: oil field contamination, diesel oil, crude oil, and phenolic wastes.

Lang(270) reported some early (1932) experiences with contamination of ground water by wood tar, pickling liquors, and picric acid wastes. Later (1940) Lang and Burns(271) reported phenol tastes and fungus growths in wells from garbage dumps and a leaking sewer pipe.

Calvert(423) reported chemical contamination of ground water from impounded garbage, as early as 1932. More recently (1952) Muller(424) reported some German experience with gasolene contamination of wells located long distances from the source of the waste water.

Many illustrations of potential ground water contamination by chemicals have been reported from investigations of artificial recharge of ground water supplies in Ohio, Texas, New York, Kansas, California, and elsewhere (425) (426) (427) (428) (429) (430) (431) (432).

Many instances of contamination of rural wells by underground disposal of waste waters from smaller chemical plants located in rural areas probably have not become known publically because of private agreements between the industry and the owners of the affected wells. As land areas in the vicinity of these industries are built up the problem of ground water contamination becomes more difficult.

Many articles descriptive of chemical contamination experiences have appeared during the past number of years (435) (159) (434) (435) (436) (437) (438).

PASSAGE THROUGH SOIL

5. Nature of Movement)
6. Removal of Contaminants) - information is meager. Much of the discussion that has been written for inorganic chemicals and for organic chemicals, particularly for synthetic detergents (Sect. 2a) and domestic sewage chemicals (Sect. 2b), apply to the many organic chemicals in industrial process wastes.

Gotaas and associates(117) have reported:

> "---All investigators seem to agree, however, that pollution travels farthest in the direction of ground water flow, and that chemicals travel much farther than bacteria in a water bearing stratum."

They also presented a tabular summary of published data showing travel of chemicals with distances ranging from about 100 feet to distances up to 20 miles. Several instances were reported where chemicals traveled 2 to 5 miles.

There are various factors which cause some chemicals to be removed by passage through soil: (1) filtering action of the soil, (2) chemical reaction with the soil, and (3) other possible factors.

However, very little specific knowledge appears available relating to travel and removal of chemicals in which the character of the chemical is related to the physical-chemical characteristics of the soil, either above or below the water table. Some meager information is available (416) (419) (117), but quite insufficient.

DETERMINATIONS FROM SURVEY

7. Predicting Contamination - Where existing industries may be discharging liquid process wastes, or had done so in recent years, into lagoons or into underground disposal areas, sometime even into practically dry streams, the probable contamination of ground water can be anticipated, particularly down-dip of the point of waste water disposal. To determine the distance down-stream or distances to the sides or even up-dip that the chemical contaminant had travelled may require considerable underground investigation and analyses of water samples obtained from wells, bore holes, or by test well drilling.

To predict the possibilities of the continued extension of the underground contamination or the possibilities of contamination from proposed or future industrial installation would require more information than presently available on adjacent soils and on the interrelations of chemical characteristics and the physical and chemical characteristics of soils - together with the flow characteristics of the ground water.

8. Water Quality Criteria Needed - The many chemicals likely to be found in waste waters from industrial processes, may be toxic in varying degrees or may simply be objectionable because of odor, taste, color, or other esthetic reasons.

Several years ago (1945) Hart et al(439) discussed toxicity of industrial wastes on fishes. Many other writers have done so since. There have been considerable attention to the effect of industrial wastes on cattle (440), but surprisingly little attention has been reported as to the effect of industrial wastes on man.

Criteria are needed to indicate the concentrations, of various organic chemicals, beyond which residential water supplies must be abandoned - even though the only water supply. These should be in addition to the proposed CSCFF test, which would indicate a desirable limit for municipal water supplies.

Much research and development is needed to (a) determine the objectionable chemicals present in various process waste waters, (b) establish the undesirable characteristics of the many chemicals, and (c) to set up desirable permissible concentrations and extreme maximum concentration beyond which the affected ground water supply must be abandoned.

9. Suggestions for Obtaining Information - A number of research studies and investigations should be considered:

a) A nation wide survey to determine the present status of disposal of industrial process waste waters into places (lagoons, boreholes, wells, etc.) where the chemical waste waters are likely to contaminate ground water supplies.

b) A study of the trend in the numbers of such methods of waste water disposal.

c) A determination of the objectionable chemicals in various industrial process waste waters and the concentrations which may be toxic or may be objectionable for esthetic reasons.

d) A study of the hydro-physical, bio-chemical, or other soil characteristics with reference to the travel and the removal of the offensive chemicals.

These investigations would be complex and time consuming. Accordingly, the suggested initial research ((a) above) should determine the rapidity of the increase in underground disposal of chemicals in industrial process waste waters and the urgency for the other phases of investigation.

10. Summary - Many industrial process waste waters include organic chemicals, many of which would be contaminants if they reach ground water supplies in sufficient concentrations. The dispersal of industries into rural or suburban localities where waterways are not available may result in disposal of process waste waters into lagoons, old wells, leaching beds, bore holes, or other discharges into underground water bearing strata and thus constitute a pollution of underground water supplies.

Considerable numbers of experiences have been recorded. Many more actual or potential problems of ground water contamination are likely as rural and suburban areas become developed as residential projects depending on ground water for residential water supplies.

Information is inadequate on the numbers of industrial installations, the chemical character of their process waste waters, the seriousness of the chemicals as ground water contaminants, and what concentrations of the various chemicals can be tolerated.

11. References - Bibliography Items 421 to 440, inclusive.

Topic II-2i. Pesticides (Insecticides, Herbicides)

The use of organic pesticides has increased very rapidly and steadily (211). Many new toxic materials and new uses for older materials are being developed each year. Sales of all formulations now amount to billions of pounds yearly, with usage so great that many fishkills have resulted. Heukelekian and Associates(441) have concluded:

> "Synthetic organic pesticides now must be considered as water pollutants".

The word "Pesticides" has been used as a general term to include; insecticides, rodenticides, herbicides, and bactericides. Sometimes the term "larvacides" is found in discussions of chemicals used to kill the larva stage of insects.

Van Nostrand's Scientific Encyclopedia(442) (1958 Ed.) includes the definition:

> "A legal definition for a pesticide is that it is any substance or mixture of substances used in the production, storage, or transportation of food which is intended for preventing, destroying, repelling, or mitigating any insects, rodents, fungi, or weeds, and other forms of plant or animal life or viruses, except viruses on or in living man or other animals".

This definition must be enlarged, with reference to ground water contaminants to also include many substances used to control objectionable insects, weeds, and probably other undesirable life or organisms. (Example: Some types of fish in ponds or water reservoirs).

Many articles have appeared in the literature during recent years describing and discussing pollution of surface waters, particularly relative to fish kills due to pesticides being washed into streams. (Example: .Heukelekian et al(441) review 20 articles published in 1959). Comparatively few writers have discussed problems of ground water contamination.

Any complete list of chemicals used for pesticides would be beyond the scope of this report. A few illustrative items, by several larger groups may be justified. Many chemicals are used in two or more of the groupings.

Insecticides - ("Representative Insecticides" (442)) The following partial list is representative of many chemicals applied to the control of insects:

A - SYNTHETIC ORGANIC

Common Name (or Trade Name)	Chemical Name (or Chief Ingredient)
DDT	Dichlorodiphenyltrichloroethane
Methoxychlor	Dimethoxydiphenyltrichloroethane
TDE	Tetrachlorodiphenylethane
DCPM	Di(chlorophenoxy)methane
BHC	Hexachlorocyclohexane
"Lindane"	Hexachlorocyclohexane (gamma isomer only)
Chlordane	Octachlorohexahydromethanoindene
Aldrin (HHDN)	Hexachlorohexahydroendoexodimethanonaphthalene
TEPP	Tetraethyl pyrophosphate
"Schradan" (OMPA)	Octomethyl pyrophosphoramide
Parathion	Diethylnitrophenyl thiophosphate
Malathion	Dimethyl dithiophosphate of diethyl mercaptosuccinate phenothiazine
Rhodanates	General name for thiocyanates
"Arathone"	Dinitrocaprylphenyl crotanate
NATURAL ORGANIC INSECTICIDES	
	Nicotine
	Nicotine sulfate
	Nornicotine
	Pyrethrum
Allethrin	(Synthetic product allied to compound in pyrethrum)
	Rotenone and Rotenoids
	Sabadilla
	Hellebore
	Various Oils and Tars

B - INORGANIC INSECTICIDES

	Arsenates and Arsenites of Calcium, Copper (Paris Green), Magnesium, Sodium, and Lead
	Fluorides, Fluosilicates and other Fluorine Compounds
Tartar Emetic	Antimony Potassium Tartrate
	Compounds of Mercury, Thallium and Selenium
	Phosphides
	Cyanides
	Sulfur Compounds

Rodenticides - (Authority - VanNostrand's (442))

a) Before 1920 - (mainly inorganic)
- Arsenic compounds
- Barium carbonate
- Phosphorus
- Strychnine

b) Just prior to War II -
- Red squill (known to ancient Egyptians)
- Thallium sulfate
- Zinc phosphide
- Chloropicrin

c) During World War II - (mainly organic)
- ANTU
- 1080
- Warfarin
- Pival

Herbicides (Weedicides) - (Same authority (442))

a) Organic -
- 2,4-dichlorophenoxy-acetic acid (2,4-D)
- 2,4,5-trichlorophenosy-acetic acid (2,4,5-T)
- 4-chloro-2-methyl-phenoxyacetic acid
- Isopropyl-N-(3-chlorophenyl)-carbamate (chloro IPC)
- 4,6-dinitro-o-cresol (DNOC)
- Dinitro-o-sec-butylphenol (DNOSBP)
- Trichloroacetic acid (TCA or TCAA)
- 2,2-dichloropropionic acid (Dalapon)
- Pentachlorophenol (PCP)
- Maleic hydrazide (MH)
- N-1-naphthylphthalamic acid (NPA)
- Phenyl mercuric acetate
- Monochloroacetic acid
- Sodium naphthaleneacetate (SNA)

b) Inorganic -
- Sodium arsenite
- Calcium cyanamide
- Sulfamic acid
- Ammonium sulfamate
- Ammonium thiocyanate
- Solium chlorate
- Potassium cyanate (KCNO)
- Sodium methaarsenite

Other lists of pesticides, in earlier articles (443) (444) include names of several other chemicals. McKee(122) under "Insecticides and Larvicides" lists, Dieldrin, toxaphene. There may be other trade names. For example; Chlordane is also known as "Velsicol 1068", "CD-68" and "Octa-Klor" (151) (122).

The foregoing lists indicate a large numbers of chemicals, some inorganic; but more organic compounds are now being widely used as pesticides. Data is not complete as to the number that may be toxic to man, but most of them have been found to be toxic to fishes, ref. McKee (122) and 1959 WPCF Review (445) (447) (448) (449) (450) (451), so may be potentially toxic to man if they should reach ground water supplies in sufficient concentrations.

The VanNostrand's Encyclopedia (442) includes the statement:

> "The majority of chemical protective measures are designed for the actual destruction of the pests; hence the substances used may be classed as poisons."

Many chemical compounds have been formulated in chemical warfare researches. Some of them have found their way into commercial use; others may do so.

1. Sources of Pesticide Contamination - Possible contamination of ground water by pesticides generally would involve the leaching into the soil of surface water, or rainwater, which had become laden with some chemical which had been distributed for pest control, or the direct entrance into a well or a spring of water laden with toxic chemicals through openings or defects in the protective wells or structure for the well or spring.

Since pesticides are generally used sporatically it is unlikely that a continuous build-up of chemicals over a period of time would develop into a toxic concentration, but rather any contamination would be the result of a relatively large flow of rain water run-off shortly after the application of a pesticidal chemical.

2. Effect on Water Quality - Chemicals used for pesticides might effect water quality by causing turbidity and objectional flavor, or by producing toxic conditions if concentrations become sufficient. In some cases leaching of the chemical solution through the soil might remove turbidity and color, but still leave toxic chemicals in solution at sufficient concentration to produce tastes and/or also possibly to be toxic, in the case of certain chemicals.

3. Reported Permissible Concentration - In general, no specific permissible concentrations of pesticidal chemicals in water supplies have been reported. Some chemicals, such as arsenic, phenol, chromates, have been given a specified maximum concentration in the PHS Drinking Water Standards - 1946(108), as discussed hereintofore. A proposed CSCFF concentration of 200 ppb (392) probably would involve a good many of the synthetic organic pesticides.

However, the PHS Standards - 1946[108] and the proposed CSCFF test results (392) relate to a maximum desirable concentration for municipal water supplies and not necessarily to the maximum permissible concentration before the water becomes unusable for an individual residence. Also many chemical pesticides may not be toxic to persons in any concentration at all likely to reach any ground water supply.

4. Experiences to Date - Many articles describe experiences with contamination of surface waters and effects on fish. Very few articles have considered ground water contamination.

A great mass of technical articles have been published on DDT Bishopp[452] found 965 articles published between Jan. 1943 to June 1946. Most writers consider DDT a safe insecticide so far as danger to humans is concerned.

However, Brown[307] has set the lethal dose of DDT in kerosene for man at 150 mg. per kg. of body weight. Harry Jordan has urged caution in that little is known about accumulated effects of DDT. Bishopp[452] concluded that DDT may be stored in the body so sub-lethal doses may build up in the body and become fatal.

Certain benzene hexachloride compounds, such as Lindane, BHC, Gammexane, and others, are powerful insecticides with estimated doses fatal to humans much lower than DDT dosages (248). However, it has been also estimated that an objectional musty taste or odor would prevent the use of water for drinking with concentrations much below the estimated lethal concentration (151).

Other chemicals, for example Toxaphene with a strong turpene odor, would probably be objectionable for esthetic reasons long before the concentration reached lethal concentrations (307).

An early (1952 article by Carson[453] indicates "Parathion" to be toxic to man at less than 1 mg. per kilogram of body weight, but does not give any experience data.

McKee[122] reports several articles (454) (455) (456) (311) on experience in California (Alhambra) where a quantity of chemicals, used in the manufacture of the "2,4-D" weed killer, was dumped into a sewer, passed through a sewage treatment plant, traveled 3 to 5 miles overland, then seeped into the undergrown water bearing strata used as a municipal supply for Montebello and caused objectional tastes and odors with an estimated dilution of 1/10,000,000 for the original chemical.

There have been reports of chemicals used for termite control being found in an underground water supply.

Warrick(457) made an early (1951) report on a spectacular fishkill by insectidal chemicals washed into a river by a rainstorm shortly after insectides had been heavily spread over a large area to kill undesirable insects.

Two early (1947 and 1949) reports record arsenical poisoning of persons using well water (in South Africa and in Venezuela) which had become contaminated by an arsenic compound dip used for the control of ticks on cattle. The spent dipping solution had been disposed of by dumping on land and after a number of years had reached wells being used for drinking water supply. Two instances were reported in South Africa (458) with several deaths reported - in one case a concentration of 0.84 gr. of arsenic per gallon of water was reported. Similar experience was reported for Venezuela, excepting no deaths were reported (459).

Currie(460) in an early (1947) review of the action of arsenic referred to cases of cancer, reported from Silesia and from Argentina which were considered to be due to arsenic in water supplies.

Leeman et al(461) discussing the effect of "BHC", "DDT" and phosphoric acid esters on several types of foods, and on drinking water found objectionable flavors resulted from the use of insecticides and impaired quality of food stuffs.

Lyne and McLachan,(462) discussing water contamination by trichloroethylene, stated that wells near factories often are rendered unfit for drinking. Two cases were described - in one case a tank of liquid burst and the liquid reached the ground water. In the second case a well was contaminated 150-200 yards from a gravel pit into which waste trichloroethylene had been dumped for more than 4 years. Water contained 18 ppm of chemical, caused stomach disorder and dizziness.

PASSAGE THROUGH SOIL

5. Nature of Movement)
6. Removal of Contaminants) - Published information is meager. There have been some experiences to indicate that some insecticidal chemicals may travel long distances without reduction in their chemical characteristics which cause taste and orders in drinking water from ground water supplies (122). Also other evidence indicates the possibility of some chemicals - arsenic for example - building up in the soil over a period of many years, until dangerous concentration may be reached (458) (459).

It is likely that the several complex organic chemicals presently used as pesticides, may be affected differently in passing through soil. Much information is needed to determine both the nature of movement and the extent of removal of pesticidal chemicals as contaminants from ground waters.

DETERMINATIONS FROM SURVEY

7. Predicting Contamination - There is evidence on which to base predictions that certain liquid waste chemicals used for pest control - arsenic dips for example - could endanger ground water supplies (458) and (459). Also available evidence indicates other pest control chemicals could cause objectional tastes and odors in ground water supplies, if permitted to reach the ground water, even in small concentrations.

However, there is meager data from which to forecast the possibilites of ground water contamination of the ever increasing use of complex organic chemicals for insect or other pest control by dosing large areas by dust or liquid sprays. Numerous fish kills indicate potential hazards to ground water supplies under the proper conditions of a heavy spray application followed by a heavy rainfall and a ground water supply with defective protection at the well or in a nearby sand and gravel quarry or other depression in porous soil.

Much more information is needed both with reference to the frequency and concentration of pest control operations, the effect of rains, the durability of the pesticidal chemicals, and the concentrations likely to cause serious contamination of ground water.

8. Water Quality Criteria Needed - Fortunately many chemicals used for pest control cause quite objectional tastes and odors in concentrations far below any lethal concentration. However, this may not be a sufficient protection. So some determination should be made as to (1) which chemicals may be objectionable ethetically and at what concentrations and (2) which chemicals may be dangerous due to their toxicity and at what concentrations.

Again it would appear desirable to provide two scales for the concentration levels, particularly for those pesticidal chemicals which may be used periodically. One level would be the desirable maximum concentration. The other at a higher concentration level, would be a maximum at which level the water should not be used for drinking or cooking, even as the only supply for a residence - until the chemical concentration is decreased by dilution to a permissible level.

Since most pesticidal chemicals are complex compounds some relatively simple and convenient procedure should be developed by which chemical concentrations can be quickly determined.

Much research is needed to (1) determine the magnitude of the problem of contamination of ground water by pesticidal chemicals (separate from the extensive concern about effect on fish in surface waters); (2) establish the relative hazards of various chemical compounds; (3) set up concentration allowances; and (4) develop concentration measurement procedures.

9. Suggestions for Obtaining Information - Similar research studies as suggested in the foregoing discussion of industrial process waste chemicals (Topic 2c to 2h par. 9).

a) A survey to determine the present status of pest control procedures, particularly in the use of chemicals and the frequency of use, including consideration of the trend in such use of pesticidal chemicals.

b) A determination of the objectionable characteristic of various pesticidal chemicals, as regards taste or odors and toxicity effects, together with a study of methods for determination of chemical concentrations.

c) A study of the effect on pesticidal chemicals in passing through soils with various physical and chemical characteristics.

The proposed researches comprise essentially three distinct classes of study (1) a wide ranging survey (2) a sanitary laboratory bottle study and (3) a sanitary-chemical soils investigation probably using both laboratory test tube type experiment and outdoor lysimeter experiments.

10. Summary - The extremely large use of toxic materials for pest control, together with the considerably experience in large fish kills in surface waters and a limited number of reported incidence of ground water contamination, should warrant consideration of pesticidal chemicals as potential ground water contaminants.

It is possible that the considerable concern over the possibility of toxicity to fish, as indicated by large numbers of articles published during the last ten years, may have overshadowed the potential problems of ground water contamination.

A study specifically related to ground water contamination by chemicals used for pest control would appear warranted.

11. References - Bibliography Items 441 to 462, inclusive.

Topic II-2j. Petrochemical Industries Wastes

Petrochemical industries include two general groups: (1) organic chemical industries which use petroleum, natural gas, or coal, as raw products, and (2) chemical industries which use as their source materials the chemicals produced from petroleum, natural gas, or coal. Petrochemical industries have grown in a phenomenal manner during the past decade (463).

Van Nostrand's Scientific Encyclopedia(442) (p. 1218) contains a brief definition of Petrochemicals:

> "Chemicals derived from petroleum and more specifically substances or materials manufactured from a component of crude oil or natural gas. In this sense ammonia and synthetic rubber made from natural gas components are petrochemicals."

Other writers have included coal as a third natural raw material in the list of original basic sources of petrochemicals (463).

Van Nostrand's Encyclopedia(442) also contains the following informational statements:

> "The major petrochemical substances are - ethylene propylene, butadiene, acetylene, benzene, toluene, styrene, phenol, formaldehyde, acetaldehyde, methyl alcohol, ethyl alcohol, isopropyl alcohol, butyl alcohols, ethylene oxide, ethylene gylocol, acrylonitrile, acetic acid, acetic anhydride, acetone, and ammonia."

> "The seven largest end uses of petrochemicals are those in the rubber industry, the automotive and aviation industries, in plastics, synthetic fibers, agriculture, surface coatings, and explosives."

The foregoing statements suggest a too limited magnitude relative to numbers of petrochemicals and the quantities produced. Data reported by Eliassen Associates(463) in 1957, based on United States Tariff Bulletin "Synthetic Organic Chemicals, United States Production - 1954", give a better indication of magnitude. Two lists of production figures were published with numbers of specific chemicals and total annual production quantities as follows:

List	Number of Chemicals	Annual Production million pounds
1. "Crude Products Derived from Petroleum and Natural Gas"	17	13,446*
2. "Cyclic Intermediates"	225	4,614

*20.60 percent increase over 1953 production.

Many of the organic chemicals listed under the foregoing organic chemicals - Topics II-2a to 2j, inclusive - are petrochemicals or are derived from petrochemicals. Thus, there are duplications under several Topics which will need to be considered in planning research work to determine more specific information as to ground water contamination by organic chemicals or process wastes from organic petrochemical industries.

1. Sources - Most petrochemical industries using petroleum, gas, or coal to produce crude chemical products are relatively large factories with large flows of process wastes, so in general, they are located on large streams. These chemical plants would become a source of ground water contamination only incidentally, or in a few cases where the stream may become the source of ground water replenishment downstream of the chemical plant.

A greater possibility of ground water contamination would be smaller industries located in rural areas which may discharge petrochemicals or derivatives of petrochemicals through chemical losses or chemical process wastes discharged into lagoons, seepage areas, sprayed on land, or discharged into a small stream which supplies a ground water aquifer.

In general, the major sources of petrochemical ground water contaminants would be industries producing or using petrochemicals. Thus, these ground water contaminants would be chemical losses or process wastes associated with thousands of industries. In addition, the end products of petrochemicals may become contaminants, such as pesticides, or fertilizers, which may be widely used for agriculture.

2. Water Quality Effects - The major effect on water quality probably would be a deterioration of the esthetic quality of water by producing an off taste or odor or possibly a color to the water. An unknown number of petrochemical contaminants may be toxic at concentrations below the taste or odor tolerance.

3. Reported Permissible Concentrations - No general limitation would be satisfactory for all petrochemicals. The proposed 200 p.p.b. of CSCFF limitation (392) would not be sufficient for residential projects, where ground water may be the only water supply. Much more information is needed.

4. Experience to Date - Again the huge numbers of articles on surface water problems has obscured any substantial publication of experiences related to ground problems. Some experiences with end products of petrochemicals, such as detergents, pesticides, etc., have been discussed in foregoing sections.

PASSAGE THROUGH SOILS

5. Nature of Movement)
6. Removal of Contaminants) - Information is meager and much research is needed. Some actions of micro-organisms may be factors (465). Previous discussions of the passage of organic chemicals through soil, in general, apply also to petrochemical contaminants.

DETERMINATIONS FROM SURVEY

7. Predicting Contamination - See foregoing discussions, Topic II-2 to 2h (p. 80), Topic II-2i (p. 89) and other organic chemicals.

8. Water Quality Criteria Needed - Criteria are needed to indicate the concentrations of petrochemicals in residential water supplies beyond which the ground water supply must be abandoned - even though it be the only available supply.

Much research is needed along the lines outlined for Topic II-2c to 2h (p. 81) for contamination by industrial process waste waters.

9. Suggestions for Obtaining Information - The four general lines of investigation suggested (p. 81) for Topic II-2c to 2h, Industrial Process Waste Waters apply also to petrochemical ground water contaminants.

10. Summary - Huge numbers and quantities of petrochemicals are being produced at a rapidly increasing rate. Many small chemical plants, or other type of industries using chemicals, now being developed in rural and suburban areas, are likely sources of ground water contamination.

Available information is inadequate and much more research is needed to determine the seriousness of petrochemicals as ground water contaminants, the maximum permissible concentrations, and the effects of passage through soil of various characteristics.

11. References - Bibliography Items 463 to 465, inclusive.

Topic III - Radiological Contaminants

The problem of disposal of radioactive wastes is becoming a definite economic factor. Much material to date has been disposed by underground burial. This has resulted in ground water contamination and is potentially a future problem of some magnitude. A review of literature by Larry M. Ogden is reported in Appendix F.

1. Sources of Radioactive Wastes - Kaufman(511), Straub(496), and Ruchhoff(494) have reported on sources. These reported sources may be classified as follows:

(1) Mining and processing radium and uranium ores
(2) Reactors for radioisotopes production or for power generation
(3) Radioisotopes in research, medical work, and industry
(4) Nuclear weapons

2. Effect on Water Quality - Physiological effects on water users of radioactive particles in water are the major effects on water quality.

3. Reported Permissible Concentrations - Recommendations of permissible concentrations in water are set by the National Committee on Radiation Protection (483), and the Atomic Energy Commission (482). A large amount of research has been and is being done and the permissible concentrations are modified from time to time. Large numbers of radioisotopes are involved, too many to be listed herein.

4. Experiences to Date - Numerous reports are found in the literature. Items (523) (519) (470) (471) (479) (481) are illustrative. The AEC, the several State and Federal Public Health Agencies, and Health Safety Units in many industries are continuously on the lookout for instances of contamination by radioactive materials. Probably no other health hazard has received so much attention.

PASSAGE THROUGH SOILS

5. Nature of Movement)
6. Removal of Radioactive Material) - The literature contains many discussions (472) (475) (479) (484) (485) (490) (491) (492)(493) (496) (503) (504) (505) (513) (516) (521).

The most favorable results seem to indicate possibilities of ion exchange or surface adsorption to retard and remove radioactive particles in their passage through soils. A great deal more research work is needed. Since radioactivity does not change the chemical characteristics of compounds or elements, much of the research knowledge relative to radioactive substances should be applicable also to many other chemical contaminants. No easy, complete, or exact conclusions are yet available.

DETERMINATIONS FROM SURVEY

7. Predicting Contamination - The present art and knowledge is inadequate to predict how far any specific concentration of radioactive material may contaminate ground water. The results of investigations show certain radioactive chemicals may be absorbed or adsorbed by certain types of soils while other chemicals may travel long distances. In general, travel of contaminants can be expected to go down dip. However, topography of the ground surface does not always indicate the direction of underground water flow or the dip of the water bearing strata.

More extensive investigations are needed to determine the effects of various physical and chemical characteristics of soil on the movement or removal of various chemicals or radioactive particles. Most of the suggestions as to procedures given hereintofore for various chemicals would apply to radiological contaminants.

8. Water Quality Criteria Required - The most important water criteria requirements have to do with the permissible concentrations of radioactive particles, their half life, and the possibilities of removal by passage through soils.

The permissible concentrations for radioactive materials are not well known. The extent of permissible exposure specified by either the National Committee on Radiation Protection or the A.E.C. have been changed several times and likely will be changed in the future. However, these agencies are the only present sources for summarized information.

9. Suggestions for Obtaining Additional Information - Ogden (see Appendix F) has suggested a more reliable determination of basic factors relative to locations of well water supplies and sites of potential radiological contamination of ground water. He has outlined nine items of investigation, largely experimental with laboratory and pilot type soil column test units to establish relationship between soil characteristics and the adsorption and leeching of radioactive materials. These proposed investigations are outlined in Appendix F - pages 22 and 23.

10. Summary - Several studies have been made under the support of A.E.C. and by the U.S.P.H.S., but these have been relatively exploratory. Much interest has been displayed by various health agencies and many articles in the literature comprise generalizations of the problem of water contamination by radioactive materials.

There are a few reports on partial studies, but much remains to be done before adequate knowledge becomes available from which to determine the potential contamination of ground water at any specific well location by radioactive matter from any site of radioactive material disposal.

Much basic research is needed to determine the relation of soil types and various radioactive materials. Presently, F.H.A. should endeavor to profit by investigations being made or anticipated by A.E.C., the U.S.P.H.S., and various other health agencies.

11. References - Bibliography items 466 to 523, inclusive.

Topic IV - Biological Contaminants

Biological contaminants are considered in this report to include all living particles which may cause disease or reduce the palatability of ground water, excepting viruses which are considered later under Topic V - Viral Contaminants. In a broader sense biological contaminants should include those organisms which affect the palatability of water as well as those which may be a health hazard.

Many writers have discussed water contamination by biological agents in terms of the diseases which may be caused by them (524) (526) (527) (528). For example, Fair & Geyer(101) (1954) stated:

> "—water-borne diseases fall into five categories —— bacteria, protozoa, worms, viruses, and fungi. —— enteric, water-borne, bacterial infections include typhoid fever, paratyphoid fever (salmonellosis), bacillary dysentery (Shigellosis), and cholera. —— undulant fever (brucellosis) and tularemia have been reported, but are of unusual occurrence. —— reported incidence of water-borne amebic dysentery (amebiasis) has been small. —— eggs of some intestinal worms and the larvae of others undoubtedly find their way —— into water supplies. —— no widespread infections from this source have been reported. ——Infection by the larval form (cercariae) of the blood flukes (schistosomes) is another matter. ——schislosomiasis does not occur in many regions —— because of the absence of a suitable snail host. ——the snail hosts and larvae of certain schistosomes that cause —— a skin disease (cerearial dermatitis) are found in some parts of the country. ——In certain regions of the world, the minute crustacean "Cyclops" contains the larvae of the guinea worm, —— that infects man."

Also Hopkins and Schulze(524) (1954) stated:

> "The most important water-borne diseases are dysentery, chlorea, typhoid fever, and amebiasis."

More recently the Water Supply Section USPHS(530) prepared a memorandum (Appendix J - Notes on Water Borne Diseases) in which eight "commonly known water-borne diseases" were listed, as follows:

1. Amoebic dysentery (amoebiasis)
2. Bacillary dysentery (shigellosis)
3. Cholera
4. Leptospirosis
5. Tularema
6. Typhoid and paratyphoid
7. Undulent fever (brucellosis)
* 8. Yellow jaundice (infection hepatitis)"

*See Topic V - Viral Contaminants

More exactly biological contaminants should include the specific agent or organism which may be potentially the cause of a so-called water-borne disease. Disease producing organisms are frequently designated as pathogens or pathogenic organisms.

Most water-borne disease bacteria can be isolated and observed. However, the determination of coliform organisms has been easier so results of coliform examinations have been used almost universally as indices to probable biological contamination.

1. Sources - Public Health authorities generally have assumed that biological contaminants would originate from sewage. (108) (112) (420). Undoubtedly sewage may be the major source of biological contaminants that potentially may reach ground water.

Some writers have indicated other possibilities, such as secretions and discharges of infected rodents and other small animals; offal from slaughtered animals; drilling mud and lack of supervision during drill wells (564), by drainage from garbage (270) (599) (423); by cemetery drainage (600); by industrial waste waters (568); and others. Certain fungi and algea growths in wells or piping may cause objectional tastes or odors.

2. Effect on Water Quality - In general the hazard to health by causing a disease is the major effect on water quality. However, in some cases the inflow of surface wash or sewage may cause turbidity by color. In an occasional case odors may result from fungi, algea growths, or other micro-organisms.

3. Reported Permissible Concentration - No reports have been found which suggested any specific numbers of pathogenic organisms which should be considered as a permissible concentration. This is due in part to the infrequent direct determination of the pathogenic organism. Usually the concentration of coliform organisms has been limited on the theory that safety of the water is related to the numbers of coliforms (108).

4. Experiences to Data - Many articles have been written descriptive of outbreaks of water-borne diseases traced to underground water supplies - generally through wells, sometimes springs. A major number of these reports probably relate to sewage entering wells, or springs, through underground channels. Frequently access of contamination into a ground water supply may be through defective well construction (564) (569). Much attention is given to this possibility in public health regulations.

Classic illustrations of water contamination experiences, including ground water supplies are given in many treatises on water supply (527) (528). An early (1931) tabulation of upwards of 15,000 cases of typhoid and dysentery under eight categories of access to ground water were published by Wolman and Gorman(529). These have been supplemented by several recent summaries (530).

There is ample experience data on the entrance into underground waters with sewage of specific agents which cause the more commonly listed water-borne diseases. Some lesser known diseases maywarrant some investigation to establish a sounder knowledge of their potentialities in ground water contamination.

PASSAGE THROUGH SOIL

5. Nature of Movement)
6. Removal of Contaminants) - Butler et al[207] reviewed literature and reported on experimental lysimeter tests on five types of soil. They found that size of soil grain was important and that finer soils removed bacteria faster than coarse soils. Also bacterial removal was accomplished by shorter travel than removal of chemicals. They concluded that "---further studies with deeper columns of coarse soils is clearly indicated."

In an old article (1909) Ditthorn and Luerssen[589] reported on B. prodigiosus organisms injected into an aquifier 69 feet from a well. The organisms appeared in the well on 10 consecutive days and were found as long as 30 days after injection had been discontinued. When applied above the water table the bacteria did not appear in a well 58 feet away.

Calwell[491] [590] reporting pit latrine tests found bacteria did not travel as far as chemicals. Distances of travel of coliform ranged from 10 to 35 feet when the latrines penetrated the ground water.

Early (1927) studies by Stiles, Crohurst and Thomas[419] found bacteria traveled 232 feet from sewage polluted trenches. Chemicals travelled 450 feet. Movement was in the direction of ground water flow only and more extensive in wet weather.

Gotaas et al[117] reporting on experimental work in California relative to rate and extent of travel of bacteria as a result of recharge of sewage effluents into water bearing strata found bacteria travelled about 100 feet in the direction of normal ground water movement and about 60 feet in other directions, but found "---This maximum distance of travel is not, however, related to the ground water velocity---". Removal of bacteria with distance was extremely rapid and does not increase at higher rate of recharge, but does depend upon characteristics of the aquifer.

A number of small experimental studies have been reported, but none have covered fully the variables involved. (589) (590) (591) (592) (593) (594) (419) (595) (596.

DETERMINATIONS FROM SURVEY

7. Predicting Contamination - The present art is very defective, some precautions can be taken against potential contamination (a) by avoiding placing sewage disposal areas close to ground water sources; (b) by considering the underlying geology and probable direction of underground water movements; and (c) by providing proper protection seals around wells and springs to keep out surface wash.

However, much more knowledge is needed on the distances of travel of biological contaminants in various types of soils and on methods of determining the direction of flow of underground water, particularly when influenced by drawndown of the ground water table by pumping. In some areas, ground water recharges also may modify the ground water flow pattern.

8. Water Quality Criteria Required - There has been considerable discussion, over several years, as to the reliability of the coliform index for water quality control. A number of less complicated and faster procedures have been proposed. Also it should be feasible to develop more specific tests to show actual presence or absence of biological contaminants for use possibly in addition to the present coliform index.

Further, the present water quality criteria relate primarily to water quality after the water is produced. The F.H.A. should have more specific criteria relating to precautions and examinations to be made before ground water sources are developed by which means the potentiality of contamination may be anticipated. Also some simple methods for checking existing wells would be useful.

9. Suggestions for Obtaining Additional Information - Many qualified researchers have worked on this question and many proposals have been made. It is beyond the scope of this study to attempt any summary of such proposals.

The following general suggestions are submitted, on the premise that urban development and population concentration beyond the limits of municipal water supplies are so rapidly producing hazards to health by potential biological contaminants that positive action is needed prior to construction of ground water supplies, i.e., wells, infiltration galleries, springs, and other means of obtaining underground water;

a. Study of presently available knowledge, including a summary and coordination of unpublished results of ground water investigations presently in progress, to determine (a) the scope of the several investigations; (b) the progress being made; and (c) the areas of needed knowledge now being studied.

b. A review of the laboratory and field techniques and available laboratory facilities with the objective of preparing an instruction manual for field inspectors to guide them and facilitate investigations of the possibilities of biological contamination.

c. A program of laboratory research with small lysimeter type units to study more exactly the relationship between soil characteristics and the travel and survival of biological contaminants.

10. Summary - It appears from the literature that, to date, the emphasis relative to biological contaminants has been on the diseases produced and on the health safety of water by the use of the coliform index applied to ground water supplies already produced, with a minimum of attention to measures to detect specific agents of biological contamination or measures to prevent ground water contamination.

It would appear reasonable to give more attention directly to the specific agents, i.e., the biological contaminants and to develop improve methods of rapid identification.

Also for the F.H.A. the emphasis should be related more specifically to methods and procedures for examinations of the possibilities of trouble with biological contaminants, particularly in connection with proposed water supply projects.

The literature contains articles on many partial studies and extensive discussions based on incomplete knowledge, largely related to water quality and efforts to explain instances of water-borne diseases attributed to underground water supplies without adequate knowledge to properly fix the source of contamination or the proper corrective measures to avoid further outbreaks of disease - oftentimes the possibilities of contamination are not removed, but health safety is made dependent on water disinfection, generally by chlorination.

More knowledge is needed to provide a basis for an instruction manual field inspections and developers with specific yet simple and rapid methods for examination of the possibilities of guarding against biological contaminants.

11. References - See BIBLIOGRAPHY - Topic IV, Items 524 to 600, inclusive.

Topic V - Viral Contamination

Viral contamination is considered - in this report - to consist of the presence of viral particles in water supplies in such concentration that persons using the water, whether on a single occasion or over a prolonged period, develop clinical symptons of which a virus is the causeative agent.

The problem of potential viral infection of ground waters deserves serious consideration for two particular reasons:

(1) Virus diseases may be rare, but they can be extremely serious when they do occur - the frequency of such diseases is increasing.

(2) Present rapid population growth in the United States increases the seriousness of problems of disposal of toxic agents including viruses.

The published evidence is not conclusive as to potential water borne virus diseases. There is still less evidence as to passage of viruses through soil. In this report three major virus groups have been discussed as possible contaminants rather than specific diseases. Laboratory research has tended to define certain serologically related groups of agents, whereas symptons of a particular type of disease (e.g., meningitis) may be associated with a variety of agents.

Berg(40) recently (1958) has proposed that viruses of concern in water contamination comprise:

"1. Infectious heptaitis virus(es)
2. The Enteroviruses
   (1) Polioviruses ---------- 3 types
   (2) Coxsackie "A" viruses---25 types
   (3) Coxsackie "B" viruses----5 types
   (4) ECHO viruses ----------24 types
3. The adenoviruses ----------19 types associated with man."

Earlier (1949) Brown(603) listed "inclusion conjunctivities", "infectious hepatitis", "poliomyelitis", and "prelibial fever" as water borne virus infections.

For the purposes of this report the list of viruses by Berg has been considered the more complete list. Miss Elizabeth C. Maclean has prepared a discussion in some detail, which is included in Appendix H. The following paragraphs summarize very briefly pertinent information taken largely from Appendix H.

1. Sources of Viral Contamination - Generally, sewage is considered the important source of viral contaminants in ground water. (622) (627) (649) (619) (611) (641) (650) (642) (643) (707) (654) (610).

There is a likelihood of contamination by surface wash from barnyards entering farm wells. (605) (704). Viruses have been found in excreta from pigs and farm animals.

2. Effect of Viruses on Water Quality - Viral contamination, as defined above, would render water unsafe pathogenically. The viruses themselves may not produce any effect on the esthetic quality or palatability of the water (602). The more dangerous contamination might include the entrance of viral particles with other materials.

However, the viral contaminating particles may be accompanying by soil and other matter which would also affect the physical characteristics of the water.

3. Reported Permissible Concentrations - No authority has proposed any limit as a permissible concentration of viral infection. Some reports (634) indicate very low concentrations may be dangerous. Other writers (615) (694) suggest the possibility that low concentrations of weak organisms might produce immunity. Gilcreas and Kelly(628) proposed there is a great need for research work on the subject of virus pollution of water.

4. Experiences with Viral Contamination - There have been a considerable number of confirmed experiences with infectious hepatitis in water supplies (625) (602) (632) (634) (648) (656) (649) (687) (658) (653) (633) (644) (631) (679) (603) (615) (606) (646) (617) (663)

Poliomyelitis has not been generally accepted as being water borne, although there are several reported instances where strong indications point to poliovirus being carried by water. (691) (689) (683) (657) (641) (666) (651) (685) (684). Other data have been published tending to discount the possibility of water borne poliovirus diseases. (630) (680) (693) (667) (608) (604) (697). Some published material seems to suggest that poliovirus in water might provide an immunization effect. (676) (694)

Discussions of Coxsackie and ECHO virus contamination of water supplies have only appeared in recent years. Most writers seem to consider water borne virus, in these two groups, unlikely to be sources of diseases (639) (623) (670) (659).

Other viruses have a still more uncertain history than the foregoing. (654) (677) 686) (624).

Methods of isolating viruses are still quite uncertain. In some cases (e.g., infectious hepatitis) there is no present method to propagate the virus in laboratory substances, excepting by human volunteers.

PASSAGE THROUGH SOIL

5. Nature of Movement------)
6. Removal of Contamination) - Due to the extremely small size of virus organisms it would appear, by inference, they might pass through soil more readily than bacteria. Also the passage of chemicals associated with sewage and bacteria might be considered as giving some indication of the probable passage of viruses.

However, meagre data available does not furnish definite nor conclusive information either on the possible passage of viruses through soils or the removal of viruses by soils. Several preliminary experimental studies furnish initial data. (675) (703) (628).

A number of epidemiological studies (647) (615) (646) (609) (662) (617) appear to show that virus do pass through some soils, but no definite relationship has been established either with reference to the type of soil or the travel distance.

The effect of ground water on the survival of virus organisms is another important factor. Studies on infectious hepatitis and poliovirus indicate possibilities of relative long survival period (615) (633) (656) (682) (607) (629) (686). However, these experiments were uncertain and their results inconclusive. Much more information is needed.

Knowledge on removal of virus is relatively unknown. A few small studies seem to indicate a possibility that the resistance of virus to inactivation may be equal to or greater than that of E-Coli (675) (703) (628).

The effect of light, especially sunlight, may be more important than other factors. Much basis research will be needed to determine these questions.

DETERMINATIONS FROM SURVEY

7. Predicting Viral Contamination - A present art of predicting specific viral contamination is non-existant. Available knowledge is only fragmentary and inconclusive. A number of preliminary suggestions for anticipating viral contamination are outlined in Appendix H (page 48), but none are considered sufficiently secure to warrant practical application. In general, coliform tests are considered to be inferential tests for potential virus contamination.

Additional information needed involves many poorly defined factors. (1) an answer to the characteristics of viruses which would be infective to humans; (2) improved bio-assay methods; (3) survival of viruses in soil and in ground water; (4) interreactions of viruses and soils, such as possible adsorption of viruses by soil grains; and (5) probably other aspects which would arise after preliminary studies were started.

8. Water Criteria Needed - The present Public Health Drinking Water Standards(108) rely on the coliform index. There have been experiences which indicate a need for a critical review of this basic philosophy when other biological agents such as viruses, are concerned (618) (657) (628) (629) (705) (706).

9. Suggestions for Obtaining Needed Information - The quantitative study of viral contamination involves many serious problems, including the problem of bio-assay to determine numbers and survival of viral organisms, culture systems are not yet available for many viruses - the infectious hepatitus organisms, for example. Further study of bio-assay procedures may be early items to investigate.

Other possible experimental studies are outlined by Maclean (Appendix H), including (1) assay efficiencies; (2) effect on viruses and salts or other materials in ground water; (3) concentrations of viruses present under practical conditions; (4) interaction of viruses with soils; (5) adsorption of viruses to soil particles; and (6) others.

10. Summary - Infectious hepatitis is a known potential water borne virus disease. Poliovirus and other viruses of the enterovirus group have been found in sewage so may be potential water contaminants. The spread of enterovirus infections by water has not been demonstrated possibly because the etiologic agents have been rarely identified in these virus epidemics.

The problems of viral contamination of ground waters will undoubtedly increase with increase in population concentration and greater demand on ground water supplies.

Presently, the presence of viral contaminants in ground water is only inferred from the coliform index. Generally, the inference is actively followed when specific viral infection is experienced. There is need for proven methods to identify viruses and for research to determine the interaction of viral types and properties with soil physical and chemical properties.

11. References - Many articles have appeared in the literature on various aspects of viruses and viral diseases. The 119 bibliographical items, 601 to 719, seem to be representative of knowledge on viruses and virus diseases, as they may be related to ground water contamination.

BIBLIOGRAPHY AND REFERENCES

The following list of writings contains information pertinent to some phase of ground water contaminants or contamination. References to writings have been made in Part II - Summary Report, and also the sections of Part III - Supplemental Memoranda and listed in this Bibliography in the order in which potential contaminants appear in Table A. Some writings have been referred to more than once in discussing the several contaminants, so more than one reference number may be given to the same article.

Numbering - To avoid the renumbering of references in the several Supplemental Memoranda - some of which were prepared early - the first reference in the following listing has been numbered 101.

I. References for Physical Contaminants

101. Fair, Gordon Maskew and Geyer, John Charles, Elements of Water Supply and Waste-Water Disposal, New York, John Wiley & Sons, Inc., c. 1958, pp. 261-262; 496.

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103. Hopkins, Edward Scott and Schulze, Wilmer Henry, The Practice of Sanitation, Baltimore, The Williams & Wilkins Co., c. 1958, p. 156.

104. Middleton, F. M., Grant, W., and Roger, A. A.; "Organic Chemical Compounds as Cause of Drinking Water Taste and Odors," Industrial and Engineering Chemistry, 48, 269, February 1956.

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GROUND WATER CONTAMINATION

RESIDENTIAL PROJECTS

PART III

SUPPLEMENTAL INFORMATION

December, 1960

GROUND WATER CONTAMINATION

RESIDENTIAL PROJECTS

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APPENDIX A

GROUND WATER CONTAMINATION

Notes on Library Survey

and

Other Informational Sources

December 1959

APPENDIX A

GROUND WATER CONTAMINATION

Notes on Library Survey and Other Informational Sources

These notes comprise a brief report on the sources of published and unpublished information used generally in preparing the following appendices descriptive of various types of ground water contaminants.

The initial library work included a search through abstracts of technical literature prepared by five abstracting agencies, with particular attention to ground water contamination. Abstracts published by a total of over 80 abstracting agencies were reviewed, as well as the journals of the sanitary engineering and allied professions.

Letters were written to State Sanitary Engineers, State Pollution Control Agencies, and to the Regional Engineers of the U.S. Public Health Service. Replies from these sources brought out a number of illustrations of ground water contamination and a number of reports, some unpublished, which would not have been located by the library survey.

Other correspondence with various research agencies has located several reports of value to this research.

Library Work

The library work involved (1) the copying onto 5" x 8" cards pertinent abstract items, from several published abstracts, as an initial basis for the literature survey. Each researcher was assigned one or more abstract publication (such as Chemical Abstracts) and a certain number of years to be covered by the search. In most publications the search was carried back to 1940. This was considered sufficiently extended as an initial start. More extended coverage was obtained from the list of references or bibliographies published with each article.

Later the researchers were assigned a class of contaminants and given the abstract cards which applied. This was the beginning of more extensive study of the writings on various phases of the assigned contaminant. Each class of contaminant became the basis for an extensive library search for writings on that subject.

Thus, at this stage progress could be recorded best in terms of work done on the various types of classes of contaminants, rather than by listing the numbers of published journals searched.

After the pertinent writings were read and notations prepared then the information was abstracted following a uniform outline (see attached illustrative outline) and the following appendices "C" to "H" inclusive, were prepared. The appendices plus additional library reading became the basis for the main summary report.

Number of Abstracting Agencies

A library survey was made by Mr. Kishore Mariwala, at both M.I.T. and Harvary, of reference materials to determine the number of agencies and publications which publish abstracts of technical literature. A total of 80 abstracting agencies was found dealing with technical literature. A list is attached hereto.

A search through the abstracts prepared by the several agencies located five agencies which regularly covered articles bearing on ground water contamination. There are three or four Russian agencies which may cover ground water contamination, but these are written in Russian and no translator has been engaged to study these.

Abstract Publications Searched

Searches were made in the following publications:

	Publication Name	Dates Covered	Reference Cards	
			Total	Aver.Per Year*
1.	Chemical Abstracts	1940 to 1958	327	17
2.	Gr.Brit.Water Pol.Abs.	1947 to 1958	300	25
3.	Pub.Health Engng.Abs.	1953 to 1958	109	18
4.	Biological Abstracts	1927 & 1928, 1942 to 1958	64	4-
5.	Science Abstracts	1956 & 1957	7	3+
		Total	807	

*Approximate yearly numbers of articles.

Thus, the most profitable abstract publications were (1) Chemical Abstracts and (2) Great Britain Water Pollution Abstracts.

The above listed reference cards contained some duplicate references to the same articles and also some references which did not relate to ground water contamination so the 807 apparent references were reduced considerably before a final bibliography was prepared. However, many additional references were uncovered during the library study made of the published writings on different classes of contaminants.

Correspondence with Pollution Control Agencies

Correspondence with State Pollution Control Agencies and the nine Regional Engineers of the U.S. Public Health Service brought out a number of items of interest on the subject of ground water contamination.

Answers to a general inquiry were received from 44 States and territories, indicative of a very actual interest in the subject. Some pertinent items of information excerpted from the answers from the several States agencies are summarized in the following memorandum (Appendix B).

Replies were received from 7 of the 9 Public Health Service Regional Offices. These generally included only a copy of the "Digest of Water Pollution Control Legislation" for the several States in the Regional Area. In some cases the Regional Engineer went to the trouble to transmit our inquiry to the State Engineers. The inquiry to the Public Health Service Offices was general. Many of the replies were routed through a New York Regional Office.

A number of letters were written and replies received,

together with a number of published reports, from various special agencies, particularly in California and Texas. Other published reports on ground water contamination were received from cities, industries, and special agencies, such as Task Force groups of A.W.W.A.

Classification of Contaminants

To provide an orderly study, a classification of contaminants was set up as follows:

I. Physical Contaminants

II. Chemical Contaminants

1. Inorganic

(See Table A for chemicals included)

2. Organic Compounds

(See Table A for chemicals included)

III. Radiological Contaminants

IV. Biological Contaminants

V. Viral Contaminants

Greater Attention to Certain Contaminants

Some of the classifications of contaminants were given greater attention by the assigned research personnel because of special interest than was possible or necessary for all contaminants. These more extensive studies are briefly described in the following paragraphs.

Miss Beth Walden, an experienced library worker, a student at Boston University, prepared the basic information sections of Topic I - Physical Contaminants in greater detail than normally would be required for these contaminant or water quality items. (See Appendix G).

Mr. Richard E. Speece, a graduate student, particularly interested in Sanitary Engineering and a full-time Research Assistant prepared the main parts of Topic II-2a. Detergents and Topic II-2c. Domestic Sewage Chemicals. (Appendix "E").

Mr. Larry M. Ogden, a graduate student in Chemical Engineering and a half-time Research Assistant was especially interested in radiological problems. He prepared the greater part of Topic III - Radiological Contaminants. (Appendix "F").

Miss Zohreh Sarmad, a graduate student in Biology at M.I.T. and Harvard, initiated the library work on Topic IV - Biological Contaminants (Appendix G), but had to discontinue because of pressure of school work.

Miss Elizabeth C. Maclean, who has a B.A. in Chemistry, an M.S. in Biochemistry, a former teaching assistant in biology, and now a candidate for a doctorate in Biophysics, specializing in a study of viruses, prepared a review of literature relative to viral contaminants. She found considerable data on one viral contaminant - infectious hepititis causative organism and lesser data on several other viruses. The comprehensive report on viral contaminants is presented herein after as "Appendix H".

Miss Maclean visited the Taft Center of Sanitary Engineering Center of Research and discussed viral diseases and contamination of ground water with several research people there. She also had the advantage of considerable interest and assistance of the staff of the Department of Biology and also of several public health people with whom she had worked prior to this study.

M.I.T. Staff

Members of the staff who worked on this project included the following:

Dr. Rolf Eliassen, Professor of Sanitary Engineering - General Supervision

Professor Wm. E. Stanley, Professor Emeritus, half-time, Project Director

Mr. Richard E. Speece, Graduate Student in Sanitary Engng, Full-time Research Assistant (spring term)

Mr. Larry M. Ogden, Graduate Student in Chemical Engng, Half-time Research Assistant (spring term)

Part Time Library Searches, included:

Miss Beth Walden, an experienced library research, a student at Boston University
Mr. Kishore V. Mariwala,
Graduate Student in Chemical Engineering
Mr. Michel A. Marbach
Graduate Student in Chemical Engineering
Miss Zohreh Sarmad
Graduate Student in Biology (MIT and Harvard)
Miss Elizabeth C. Maclean, Doctoral student in Biophysics
B.A. in Chemistry, Mount Holyoke College 1952
M.S. in Biochemistry, University of Pittsburgh 1956
Fellow-NIH Training Grant, Ph.D. candidate, Department of Biology, M.I.T., with a thesis investigation in basic virology.

Summary

This project has involved an analysis of published writings through a library survey plus a limited amount of correspondence with health and other governmental agencies. Based on the available literature and our general professional sanitary knowledge suggestions have been prepared outlining additional information needed to prepare water quality standards and to prepare procedures for forecasting probable ground water contamination at any specific location.

In certain cases some general outlines of research work have been indicated. Generally, the research procedures would be related to the facilities available and to the phase of the study to be under them. It has not appeared desirable to attempt to set up a series of hypothetical research programs.

APPENDIX A - Supplement

LIST OF ABSTRACTING AGENCIES

The science libraries of M.I.T. and at Harvard were searched and the following list obtained of agencies which prepare various types of abstracts, of articles in technical publications. A probe search was made in each series of abstracts, with a few exceptions, to determine the agencies which made abstracts of articles in the several fields of interest closely related to ground water contamination. Five agencies covered practically all articles within the scope of writings which frequently included discussions relating to ground water contamination. These five agencies have been listed in the first group in order of the total number of reference cards in the work file.

A second group of about seventy-five abstracting agencies were found abstracting science writings, but which seldom covered articles relating to ground water or ground water contamination, so they were not thoroughly searched. An occasional item may have been overlooked, but probably none of particular value.

Group I - Agencies which Regularly Abstract Articles on Water Pollution

1. Chemical Abstracts - Published by American Chemical Society

   M.I.T. Location - Science and Central Library, Ref. No. 540.01-C51 M.I.T. (327 Cards in the work file.)

2. Gr. Brit. Water Pol. Abstracts - Published by Great Britain Scientific and Industrial Research Department. London - HMSO monthly. (1930 to date)

   M.I.T. Location - Hayden Library, Ref. No. 016-62816, Q78 M.I.T. (300 cards in the work file)

3. Pub. Health Engng Abstracts - Published by U.S. Public Health Service - Washington 25, D.C. (1928 to date)

   M.I.T. Location - Central Library, Ref. No. 016-614, P 97, M.I.T. (109 cards in the work file.)

4. Biological Abstracts - Published by Biological Abstracts Philadelphia, Easton, Pa., Mack Printing Co. (1926 to date)

   Available in 9 sections:

   A. General Biology
   B. Basic Medicinal Sciences
   C. Microbiology (a number of articles were found)
   D. Plant Sciences
   E. Animal Sciences
   F. Animal Production and Veterinary Science
   G. Food and Nutrition Research
   H. Human Biology
   I. Cereals and Cereal Products

   M.I.T. Location - Science Library, Ref. No. 016-57, B61, M.I.T. (64 cards in the work file.)

5. Science Abstracts - Published in two sections by The Institution of Electrical Engineers, Savoy Place, London W.C.2's in association with The Physical Society, the Institute of Physics, the American Physical Society, and the American Institute of Electrical Engineers. Section A - Physics and Section B - Electrical Engineering.

M.I.T. Science Library, Sect. A., Vol. 1-1898 to Vol. 61, 1958

M.I.T. Engineering Library Sect. B - Vol. 1-1898 to Vol. 61, 1958

Very few references to water supply.

Group II - Scientific Abstracting Agencies Searched - No Articles Found

A number of agencies have been preparing abstracts of science papers over recent years. A limited search was made through the published abstracts for most of the agencies. Not enough articles were found to justify the time for reading all abstracts, excepting by five agencies as outlined for Group I. The extent of search is indicated after the name of the abstract and publishing agency.

6. Lehigh University Abstract - Bibliography and abstract of publications of faculty members - Bethlehem, Pa., Annual 1938 to 1948. Nothing found on water contamination.

7. M.I.T. Abstracts of Scientific and Technical Publications from M.I.T. (including doctoral theses) 1927-1931 (Later years)

(Nothing on ground water contamination in 1951-52 nor 1952-53).

8. APCA Abstracts - Air Pollution Control Assn., Wilmercling, Pa. Summary of current literature on air pollution control 1955 to date.

9. Nuclear Science Abstracts - U.S. Atomic Energy Commission, Oak Ridge, Tenn. Technical Information Division, July 15, 1948 to date.

Note: There may be more articles in these than the few cards in our work file. However, the extended lists of references at the end of most publications have furnished ample reference items without searching the Nuclear Science Abstracts.

10. Abstracts of Bacteriology - 1917 to 1925. Later included in Biological Abstracts (See 5).

The dates were too far back so no searches were made.

11. Institut Pasteur Bulletin - Parris, Masson (semi-monthly) at M.I.T. Vol. 1 to 37 (1903 to 1933) and Vol. 56, Jan. 1958 to date. (No pertinent articles.)

12. Excerpta Medica - International Medical Abstracting Services, New York Academy of Medicine Building, No. 2 East 103rd Street, New York 29, N.Y.

A monthly abstract of the world medical literature under 18 sections. Primarily medical, but Section XVII - Public Health, Social Medicine and Hygiene might have an occasional reference to a subject related to ground water contamination.

(None were found in a limited search.)

13. Current List of Medical Literature - National Library of Medicine. U.S. Dept. of Health, Education & Welfare - Public Health Service.

14. International Abstracts of Biological Sciences - Metcalf & Cooper Ltd., London, Pergamon Press for Biological & Medical Abstracts - N.Y. Vol. 1, Jan. 1954 to date. (Vol. 1 to Vol. 5 published as British abstract of Medical Science.)

(Search in 1954, 1956, 1957 found nothing under "ground waters", "contamination", "pollution", or "water".)

15. Botanical Abstracts - Vol. 12, 1923 to Vol. 15, 1926. Later included in Biological Abstracts (see 4) (years too far back to justify a search.)

16. Building Science Abstracts - The building Research Station - Institute of Builders, London, England, Vol. 1 - 1928 to date

(Nothing on ground water in 1948, 1952, 1956 test searches)

17. Ceramic Abstracts - American Ceramic Society 1922 to date

(No reference to ground water in 1949, 1953, 1957 test search)

18. Analytical Abstracts - Society for Analytical Chemists, Cambridge, England. W. Heffert Sons, Ltd., Vol. 1, 1954 to date.

(Articles deal with analytical chemical determinations, but not to contamination of water.)

19. British Chemistry Abstracts - London Bureau of Abstracts.
Sect. A - Pure Chemistry & Physiology, Vol. 1, 1926 to 1953
Sect. B - Applied Chemistry, Vol. 1, 1926 to 1953. Ceased publication 1953

(Did not search - appeared to cover unrelated field)

20. Gas Abstracts - Institute of Gas Technology, Chicago, Illinois. Vol. 1, 1945 to Dec. 1945 (at M.I.T.). A monthly review of current literature relating to the gas industry.

(Did not search)

21. Hungarian Technical Abstracts - Magyer muszaki, Lapszemle - Budapest, Hungarian Technical Library (No. 2, 1951 to No. 6, 1951).

(Did not search)

22. Chemistry Abstracts (Russian) - "Referativny: Zhursral Khimia" Moskva izdatelstvo Akademi Nauk (SSSR) (semi-monthly) No. 1, 1956 to date.

(Did not search)

23. Review of Physical Chemistry of Japan. Physical Chemical Society of Japan - Kyoto Imperial University (Vol. 11, 1937 to Vol. 16, 1942 and Vol. 21, 1951 to date in M.I.T. Library

(Nothing on ground water in 1957, 1955 nor 1951)

24. Japan Scientific Research Institute Abstracts at M.I.T. Vol, 1, 1928 to Vol. 16, 1943, Vol. 17 to 19 not published Vol. 20, 1950 to date. Vol. 1 to 16 issued at Tokyo Institute of Physical and Chemical Research.

(Nothing on ground water in Vol. 20, 1950, Vol. 23, 1953 or Vol. 27, 1957.)

25. Anotated Bibliography of Economic Geology - prepared under auspices of the National Research Council - Economic Geology Publishing Co., Lancaster, Pa. At M.I.T. No. 1, 1928 to date.

(Separate titles on ground water - salinity - sea water intrusion — nothing on contamination)

26. Engineer's Digest - London Engineers Digest Ltd. from Vol. 10, Jan. 1949 to date. This digest absorbed the American Edition (see below)

(Nothing on ground water 1957, 1955 or 1953 test search).

27. Engineer's Digest - American Edition 1943 to 1949 - ceased publication Oct. 1948. (See #26 above)

28. Industrial Engng. & Eng. Digest - Technical Literature Co., N.Y. Vol. 1-1907 to Vol. 14, 1914 - ceased publication Sept. 1915. (Too old for search)

29. Engineering Abstracts - Inst. of Civil Engrs. London - Supplement to minutes of proceedings - No. 1 - 1919 to No. 76 - 1937. Beginning Jan. 1938 published in four sections, but ceased publication September 1939. (Not of interest)

30. Engineering Abstracts - National Physical Laboratories - 1936-1937-1938. (Not of interest)

31. Engineering Abstracts (Polish). Polska Bibliografia Analityczana Mechanika - Warszawa, Polska Akademic Nauk. Vol. 1, 1955 to Vol. 2, 1956 - Abstracts in polish with added titles in English. (Did not translate)

32. Purdue Univ. Engng. Abstracts - Staff publications and student theses - 1955/56, 1956/57. (Did not search)

33. Food Science Abstracts - HMSO, London, Vol. 1 - 1929 to Vol. 29 - 1957. Ceased publication in 1957. (Did not search)

34. Food Technology - Periodical with selected abstracts. Inst. of Food Technology, Champaign, Ill. No. 1 - 1947 to date. (Did not search)

35. Fuel Abstracts - HMSO - London. No. 1 - 1947 to date. (Did not search)

36. Fungi Abstracts - Review of applied mycology from literature on plant pathology. Vol. 37 - 1958 to date at M.I.T. (Did not search)

37. Geological Prospecting Abstracts - U.S. Geological Survey, Washington, D.C. (1952 to 1954 at M.I.T.) (Did not search)

38. Geology Abstracts - Published in "Earth Science" of Midwest Federation of Mineralogical Societies, Revere, Mass. At M.I.T. - Vol. 4 - 1949 to Vol. 5 - 1951; Vol. 8 - 1955 to date. (Did not search)

39. Geological Abstracts - Geological Soc. of America (quarterly) Vol. 1 - 1953 to date.
Sub-titles "Ground Water", "Hydraulics of Ground Water", "Quality of Ground Waters".
(Found no references to contamination in brief search - more extensive research should be considered.)

40. Geodesy Abstracts - Zentralblatt fur Geophysik, Meteorologie & Geodosie - Berlin. Abstracts in English, French and German - June 1937 to 6/7 1944. (Did not search - too old for initial study.)

41. Geology Abstracts (Russian) Referativry: Zhurnal Geglogia Moskva Godgesltekhizdat - 1956 to date. (Did not translate)

42. Highway Research Abstract - Highway Research Board - Washington, D.C. - At M.I.T., Vol. 18 - 1948 to date. (Did not search)

43. Road Abstract - Dept. of Scientific and Ind. Research and Ministry of Transport - London - at M.I.T., Vol. 17 - 1950 to date (Vol. 1 to 16 were issued as supplements to journal of Inst. of Municipal Engineers) (Did not search)

44. Hydraulics at Univ. of Iowa - Abstracts of staff research and student theses 1919 to 1938 and 1939 to 1949. (Did not search)

45. Archives of Industrial Health - Am. Med. Assn. monthly. Includes Abstracts. Vol. 1 - 1950 to date. (Search 1954, 1955 and 1957 - nothing on ground water contamination.)

46. Abstract of Liberature on Industrial Hygiene - a supplement to Journal of Industrial Hygiene and Toxicology. Vol. 1 - 1919 to Vol. 55 - 1957. (Search 1952, 1955, 1957 - Nothing on ground water contamination)

47. Review of Applied Entomology - Imperial Inst. of Entomology Series A - Agricultural. Vol. 34 - 1946 to date. Series B - Medical & Veterianary - Vol. 1 - 1913 to date (Did not search)

48. British Scientific Instrument Research Assn - Bulletin - Vol. 1, 1946 to date. (Did not search)

49. Iodine Abstracts and Review - Iodine Educational Bureau, Ireland. Vol. 1, 1949 to date. (Did not search)

50. Aluminum Laboratory Abstract Bulletin - Kingston, Canada. Vol. 21 - 1950 to date. (Did not search)

51. National Research Council - Abstracts on Prevention of Deterioration. Published by Prevention of Deterioration Control, Washington, D.C. Vol. 1 - 1946 to date. (Did not search)

52. Applied Mechanics Review - Am. Soc. of M.E., Easton, Pa. Vol. 1 - 1948 to date. (Did not search)

53. Abstracts of Soviet Medicine - Excerpts Medica Foundation, Amsterdam. Vol. 1 - 1957 to date. (Did not search)

54. British Medical Journal - Epitome of Medical Literature, Vol. 1 - 1922 to date.
(Searched 1951, 1952, 1957 - nothing on Ground Water Contamination)

55. British Cast Iron Research Association Bulletin - Includes bibliography, abstracts and patents. (Did not search)

56. Metallurgical Abstracts - London Institute of Metals. Vol. 1 - 1934 to date (Did not search)

57. Metallurgical Engng. Digest - Chemical Catalog Co. Reinhold Publisher, N.Y. - Vol. 1 - 1929 to Dec. 1944 (Did not search)

58. Referativny: Zhurnal Metallurgia Moskva. (Russian Metallurgy Abstracts) No. 1 - 1956 to date. (Did not translate)

59. German Metallurgy Abstracts - Zeitschriff für Metallkunde - Berlin. Vol. 1 - 1911 to date. (Did not search)

60. Abstracts of Literature - Milk and Milk Products - Jour. of Dairy Science - Baltimore, Md. 1936 to date (Did not search)

61. Minerological Abstracts - The Minerological Society, London - Quarterly. Vol. 1 - 1920 to date
(Search - 1947-49 and 1953-55 - Nothing on Ground Water Contamination)

62. Nutrition Abstracts & Reviews - Imperial Agricultural Bureau Council - The Medical Research Council and The Reid Library, Aberdeen University Press, Vol. 1 - 1931 to date
(Did not search)

63. Nutrition Reviews - (monthly) Nutrition Foundation, Inc. Vol. 1 - 1942 to date. (Did not search)

64. Lawrence College Institute of Paper Research - Bibliography and Abstracts - Vol. 1 - 1930 to date. (Did not search)

65. Technical Assoc. of Pulp & Paper Industry - Abstracts of papermaking. (Did not search)

66. Dissertation Abstracts - Guide to dissertation and monographs available in microfilm. Vol. 1 - 1938 to date - M.I.T. Hayden Library (Did not search)

67. Am. Chem. Soc. Abstracts financed by Petroleum Research Fund - Vol. 1 - 1954 to 1956.
(Search 1957, 1954, 1953 - Nothing on Ground Water Pollution)

68. Inst. of Petroleum Journ. - Abstracts - London, Vol. 1 to date.
(Search 1951, 1954, 1956 - Nothing on Ground Water Contamination)

69. World Petroleum - Russell Palmer, N.Y. Abstracts of World's Oil Literature. (Did not search)

70. Russian Physics Abstracts. Academy of Science of the U.S.S.R. (Ordelenic fiziko-makematich eskilch nauk Referaky Nauchno - isstedoratd silch rabot moskva) 1945 to date.
(Did not translate)

71. Physics Express - Comprehensive digest of current Russian literature with physics topics.
International Physical Index Corp., N.Y., Vol. 1 - 1958 to date.
(Did not search)

72. Reporativny: Zhurnat Fizika Moskva. Izdatel 'stvo Akademi navk S.S.S.R., No. 1 - 1954 to date. (Did not search)

73. Physiological Abstracts - London Physiological Society - Vol. 1 - 1916 to 1937 - Censured publication December 1937.
(Did not search - too old)

74. Bulletin of Hygiene - London Bureau of Hygiene & Tropical Diseases. Vol. 5 - 1930 to Vol. 30 - 1955.
(Did not search)

75. Paris Inst. Technique du Batiment et des Travaux Publics Circulaire (Public Works Abstracts), Vol. 10 - 1948 to Vol. 18 - 1957.
(Did not search)

76. Rubber Abstracts - Hood Rubber Co., Vol. 1 - 1927 to Vol. 18 - 1944.
(Did not search)

77. SCIRD Abstracts - Commonwealth Scientific Industrial Research Organization - Melbourne, Australia. Vol. 1 - 1952 to date.
(Did not search)

78. Current Abstracts of Scientific & Technical Literature.
Vol. 7 - 1953 to date.
(Nothing on ground water contamination.)

79. France - Research Scientifique Centre National de la Bulletin Signaletique. Vol. 1 - 1940 to date.
(Did not search)

80. Société Chimique de France - Bulletin, Paris Société.
1859 to date (100 years)
(Did not search)

81. Water Purification - New York Sanitation Department Research in Selected Problems in Sewage Treatment
(Nothing on ground water contamination)

APPENDIX B

GROUND WATER CONTAMINATION

Correspondence Data - State Health Agencies

December 1959

DSR 7-8110

GROUND WATER CONTAMINATION

Summary of Information in Letters from State Health Agencies

Introduction

Under date of January 5, 1959 an inquiry was sent to the State and Territorial Sanitary Engineers in 51 States and territories requesting information as follows:

I. Copy of any regulations or guidance memorandum on ground water contamination.

II. Any results of routine or special investigation of ground water contamination.

III. Any new or special laboratory tests to judge water quality.

IV. Copies of any unpublished data.

Replies were received from 44 states. Pertinent data taken from the letter replies are summarized in the following items:

Alabama - (Lts 2/3/59 from W. H. Gilmore, Asst. San. Engr.)

"...two cities have ordinances...private wells. ...Copies enclosed...regulations of private well drilling operations...Huntsville. ...sources of water...in limestone... caverns. ...the construction of septic tanks is strictly regulated." "...Huntsville...site of the Army's missile works." "City of Montgomery...has ordinance...to safeguard City's well field,..." "...no state regulations..."

"...work...by the Lockheed Aircraft Research Center near Atlanta, Ga.---radioactive wastes disposed in soakage pits..."

"...six articles relative to early studies sewage pits (1930)...made by Mrs. E. L. Caldwell...Field Research Laboratories...were printed in Jour. of Infectious Diseases...1937-38."

Alaska - (Ltr 1/27/59 from Amos J. Alter, Chief, San. Engng.)

I. "...Act..., provides for the regulation of ground water contamination."

II. "...no specific studies..." "We plan...a survey... possible contamination by detergents." "Further monitoring...areas adjacent to proposed nuclear reactor sites,"

III. "...no laboratory work..."

Arizona - (Ltr. 1/21/59 from T. A. Kolb, San. Eng.)

I. "...Act..., prohibits pollution of ground water."

II. "...no reported contamination of any ground waters."

Arkansas - (Ltr. 1/7/59 from G. T. Kellogg, Chief, San. Eng.)

I. "...Act...controls water pollution and salt water injection."

II. "...ground water recharge...by means of surface water..." Ref. Sneigedocki - Paper in Proc. Ark. Wat. and Sew. Conf., Univ. of Ark.

III. "no...new lab. tests or techniques; have found... need of suitable tests...in...organic phosphate insecticides."

California - (Ltr. 3/23/59 from H. T. Riegel, Utilities Kaiser Steel. Re: Water recovery.)

I. "...Water Recovery System...papers..." "Recommend ...for further information write to Raymond V. Stone, Santa Ana Regional Wat. Pollut. Control Board..., Riverside, Calif. ..."

(Ltr. 3/9/59 from Finley B. Laverty, Asst. Chief Engr., L. A. Co. Flood Control Dist., Re: Pollution Travel.)

II. "No.., specific investigations relative to travel of pollutants... Research project...sewage reclamation... final report 4/1/59...will...forward...copy...suggest... contact...San.Eng'g. Research Lab., UCLA."

California (contd.)

(Ltr. 3/4/59 from F. R. Bowerman, Asst. Chief Engr., County San. Distr. of L.A. County, Calif. Re: Sewage Reclamation.)

III. "...Reports of water reclamation, prepared in 1949 and 1958" were enclosed. "...Studies on the travel of alkyl benzene sulfonates thru sandy soils in... recharge of ground water thru injection wells. ...not yet...published...but...strongly indicative of good removals of ABS in the soil."

(Ltr. 2/3/59 from Paul R. Bonderson, Exec. Officer, State Wat. Pollut. Control Board.)

IV. "...forwarding...SWPCB Publication No. 6 and No. 11 ...Water Quality Criteria...reprinted...both numbers incorporated Addendum No. 1...transmitting... letter...for disposition..."

(Ltr. 2/6/59 from Max Bookman, District Engr., Southern, Calif. District, Re: pollution from inorganic substances.)

V. "...Enclosed..." "Investigation...of Chromium Waste Dischrage...and Oil Brine Penetration..." ...Pollution of wells...result of chrome wastes in... Chino Basin Area...under investigation." "1952 investigation...on Possible Boron Pollution..." "...for further information...contact...Dennis O'Leary, San Diego Regional Wat. Pol. Control Bd.--- Industrial Waste Surveys." "...suggest...write to Linne Larson, Los Angeles Regional Wat. Pol. Control Bd. ..."

Colorado - (Ltr. 1/7/59 from W. N. Gahr, Engr., Div. of San., Colorado Health Dept.)

"No" to all questions." ...suggest look for viruses."

Connecticut - (Ltr. 1/15/59 from Frederick O. A. Almquist, Prin. San. Engr.)

I. "...General Statutes authorize...State Dept. of Health to supervise all public water supplies...Sources of supply...treatment...revisions...qualifications. ...would not approve...well supply within 50 ft. ...of body of water...nor 200 ft. from...sewage disposal..."

Connecticut (contd.)

II. "...Investigations...concerning...chromium contamination...and...detergent contamination..." "material enclosed."

III. "No"...new tests...although...likely that tests for detergents should be standardized."
Ref. "Underground Waste Disposal and Control," J.AWWA, 49, 1339, Oct. 1957; and Report on "Synthetic Detergents in Ground Water" by Suffolk County Board of Health, Long Island, N.Y.

Delaware - (Ltr. 1/14/59 from Donald Harmeston, Dir., Div. of San. Eng'g.)

I. "...Water Pollution Law...regulates ground water."

II. "No" ref. routine investigations.

III. "No" ref. new tests. "Suggest contact Alpers, N.J." "...results of tests...show detergents in...drinking water."

Florida - (Ltr. 2/4/59 from David B. Lee, Dir. San Eng. Bd. of Health).

I. "...Statutes...and regulations...prevent contamination." "...No regulations on strictly individual or private water supplies."

II. "Investigation...individual water supply...detergents in laundry waste water...domestic supplies...results are covered in...Radiological Background Studies... in progress..."

III. "No...new tests...molecular membrane filter technique may become more useful..."

IV. "Radiation progress reports enclosed."

Georgia - (Ltr. 1/30/59 from W. H. Weir, Dir., Water Quality Div.)

I. "Guidance and advice...sanitary items...location and construction of underground sources."

II. "Special ground (soil) studies for...disposal...radioactive wastes at Georgia Nuclear Lab. reactor site... for Lockheed Aircraft Corp...may be classified..." "Similar studies...for Savannah River Project...river interstate with Georgia...operator Dupont..."

Georgia (contd.)

III. "No" Ref. Tests developed. "Not particularly aware of any" ref. need of new tests methods.

Hawaii - (Ltr. 1/20/59 from B. J. McMorrow, Dir., Div. of San.)

I. "...regulation...prohibiting construction...which will contaminate a potable water supply...in no case located within a horizontal distance of fifty feet of a stream, well, spring or body of water...No regulation...relative to...prevention of contamination of domestic water supplies...from underground sources."

II. "...no special investigations."

III. "...methods for expediting detection...of...E. Coli by...Boric Acid Lactose Broth at 43°C...in progress. Reprints of early reports enclosed."

Idaho - (Ltr. 1/15/59 from Vaughn Anderson, Chief, Eng'g. and Sanitation Sect.)

I. "...compiling data on...problems of discharging... Types of waste water into crevassed lava formations and effect of...discharge on domestic wells. Contamination...widespread...because of the practice of disposal of waste waters into holes drilled in lava formations...Principal contaminant...bacterial..."

Illinois - (Ltr. 1/23/59 from C. W. Klasson, Chief San. Eng.)

I. "...No regulations on...State level for domestic water wells against possible contamination."

II. "...Investigations of contamination due to heavy metals from a plating plant...discharged into... sewage disposal pit...and gained access to... private wells; and...pollution...due to break in... gasoline supply line."

III. "No" Ref. new tests.

Indiana - (Ltr. 1/8/59 from G. G. Fassnacht, Chief Water Supply Sect, Div. San. Eng'g.)

Indiana (contd.)

I. "...Enclose letter" Re: Gasoline in the Pierceton Public Water Supply from Ltr. from Max Barrett, San. Eng. dated 5/9/56.

Note: A large number of investigations, partially completed, were discussed verbally during a visit to offices of Bd. of P.H.)

Iowa - (Ltr. 1/2/59 from A. L. Bennett, Pub. Hlth. Engr.)

I. "...Standards...recommend minimum distance between... well and...sources of contamination..."

II. "...investigated...wells...contaminated by...oil products...industrial wastes...sewage wastes... chemical wastes...briefly described results."

III. "...fluoride test...to determine...source of water leaks."

(Ltr. 12/29/58 from P. J. Houser, Dir., Div. Pub. Hlth. Eng'g.)

I. "...Investigation...of ground water contamination by fluorides to determine whether seepage from a... lagoon is entering the ground water...obtaining information on nitrate content...but to date no definite information."

Kansas - (Ltr. 2/17/59 from Russell L. Culp, Chief, Wat. Supply Sect., Div. of San.)

Re: Chlorides

II. USPH Standards "Chlorides should not exceed 250 ppm." "...arrived at solely on the basis of taste...areas in Kansas...500-700 ppm...no harmful physiological effect...but tourist or visitors...detect...salty taste...Little information on...physiological effects of consumption of saline drink-water. ...work done on...basis of total dissolved solids without regard to...specific ions. ...Principal unanswered question is that concerning...physiological effects of waters containing...1,000 to 5,000 ppm of total dissolved salts... ...they...produce minor gastric disturbances, especially in those not accustomed to their use... marginally acceptable as regards taste...as drinking

Kansas (Contd.)

water or...as a base for other beverages. Other adverse effects...when...used for cooking. Potatoes, carrots, and other vegetables...boiled in water having high total solids content...remain hard and will not cook thoroughly." "I agree with...1200 to 1400 ppm as...level which begins to produce discernible physiological effects. ...We use 250 ppm 'desirable maximum,' 500 ppm 'usable'...should add 800-1000 ppm limit 'unacceptable' or 'unsatisfactory'... ...Hazard in mentioning only the upper limit in standards, since...polluters...claim...they are not damaging or polluting...until maximum value is reached."

"...Our high chloride waters also...high in sodium content. ...heart, kidney and liver... patients...must use low sodium waters. ...indirect consideration...to think about. ...if higher limit placed on chloride concentration...problem of relating chlorides to...total solids content...or to other ions."

(Copy of ltr. 2/3/59 from Russell L. Culp, Wat. Sup. Sect., Div. San.)

II. "...Detergent concentrations...8-13 ppm of total product...frothing...in plant and...from...tap. ...made flocculation and settling more difficult."

(Copy of ltr. 1/7/59 R. L. Culp to Joe Neil, USPHS)

II. "...Kansas State Board of Health...geologists... problems involved in proper disposal of oil field brines...studies of ground water pollution...also cases of surface pollution. ...pollution of emergency wells...below Wichita...wells near river bank...heavily contaminated with synthetic detergents...from river which contained treated Wichita sewage. ...Wells abandoned, new one constructed at greater distance from river. ...instances where city or private wells...contaminated with gasoline leakage from underground bulk storage tanks."

"...also...cases where private...wells and septic tanks were located very close together... resulted in synthetic detergents...pumped from water supply well."

(Copy of ltr. 1/15/59 from R. L. Culp, Chief, Wat. Sup. Sect., Div. of San.)

Kansas (Contd.)

I. "...State Board of Hlth. does have jurisdiction of contamination of underground water supplies. ...state statutes do not distinguish between ground and surface water with regard to pollution."

II. "...Oil Field Section...geologists...contamination by oil field brines. ...contamination by detergents and bacteria where septic tanks or laterals located within a few feet of...well or cistern. Both private and municipal wells...contaminated by leakage from underground gas storage tanks. Some at distances of several hundred feet. ...emergency wells...nearest..river contaminated with detergents from treated sewage. ...Solved by abandoning and constructing new ones at greater distance."

Louisiana (no signature

I. "...State Sanitary Code (regulates) water."

II. "...investigation...in Lafayette...suggest...write to James Love, Supt., Water Treatment Plant.

III. "No" new tests.

Maryland - (Ltr. 3/4/59 from Robert M. Brown, Chief, Bur. of Environ. Hygiene)

I. "...domestic wells...in vicinity of Hagerstown. ...contaminated by industrial waste discharges... Excerpts from reports...attached."

"fissured limestone deposits... Improper sewage disposal installations...as a result...household sanitary wastes...introduced directly into water bearing strata... Caused...difficulty in developing uncontaminated sources of supply for residential usage...and...protecting existing wells from...encroachment. ...no formal study taken."

(Ltr. 2/13/59 from Joseph T. Singewald, Jr., Dir., Dept. Geology, Mines and Water Resources)

II. "...industrial area...local chemical contamination due to leakage of surface water and infiltration of salt water due to over-pumpage... ...described in our Bulletin 4 on geology and Ground-Water Resources of the Baltimore Area, 1952."

"...widespread contamination from pollution sources in housing developments."

Maryland (contd.)

(Ltr. 1/28/59 from J. R. McComas, Pub. Hlth. Engr., Dept. of Hlth)

I. "...Rules and Regulations govern individual water supplies and sewage disposal systems."

II. "...no coordinated or tabulated inventory of ground water contamination."

Massachusetts - (Ltr. 2/4/59 from Worthen H. Taylor, Acting Chief San. Eng.)

I. "General Laws authorize Dept. of Pub. Hlth. 'to supervise, examine and control all sources of water supply'...

II. "...Lawrence Experiment Station, Div. San. Eng'g... chemical and physical analyses of all public water supply ground-water sources... "Special investigations of detergents and chemical wastes as required. Radioactivity measurements...being made on ground-water sources... Eng'g. reports...ground water contamination... available in this office. Suggested...you...read these here."

III. "...new test methods for viral organisms...badly needed." Ref.: Coogan, George J., "Gross Pollution of a Semi-Public Water Supply," Sanitalk, 2, No. 4, 1954.

Michigan - (Ltr. 1/15/59 from T. L. Vander Velde, Chief, Water Supply, Div. of Eng'g.)

I. "...no legal jurisdiction...recommendations...protection of wells from bacterial contamination..."

II. "...typhoid outbreak associated with domestic well... reprint enclosed...also investigation...chromium contamination of...well field...other cases...written...Lynn Miller a member of Committee on this subject...Amer. Water Works... ...Recommend write Miller, Jones, Henry and Williams, Consulting Engrs., Security Bldg., Toledo."

III. "no new tests... ...question...as to adequacy...coliform tests...in view of...new information on viral organisms."

Minnesota - (Ltr. 1/22/59 from F. L. Woodward, Dir., Div. of Environ. San.)

I. "...Standards...location and construction...to prevent contamination..."

Minnesota (Contd.)

II. "Investigations common...for bacteriological contamination...ground water supplies...in southeast of state... underlain with limestone formations...creviced, cavernous, fractured or otherwise faulty...in places... exposed to surface...ready entrance...surface drainage and other contamination." "Special surveys have been made relative to radioactive substances and chemical wastes."

III. "No special lab. tests...developed."
"Enclose article...from...Johnson Nat'l Drillers Jour. ref. ...ground water pollution..."

(Copy of
(Ltr. 1/20/59 from F. L. Woodward to Glen Hopkins, Regional Dir., Dept. Hlth; Ed. and Welfare)

I. "...faulty geological formations...expose ground water to contamination...studies...disclosing...contamination... conclusions described:"

a) "Studies (using) chemical tracers...made following typhoid outbreaks...fluoresce in dye...in exposed faults...visible in water...from suspected ground-water sources 1900 ft. away...6 hours later... extremely high coliform count...typhoid organisms ...isolated."

"...gastro-intestinal illnesses...sewage systems ...contaminated...alcohol solutions of dye...visible in water...from well in 15 hours and 3 hours in another study..."

b) "Bacteriological studies showing rapid communication between surface and underground water and direct contamination of ground water by sewage: ...gastro-intestinal illnesses...well contaminated...following heavy surface runoff...limestone formation."

"...studies of 8 other municipal supplies... clearly demonstrated...relationship between the most probable number of coliform organisms in...ground water...and incidence of heavy surface run-off..."

c) "Bacteriological studies...ground water supplies in geological formations...suspected...unsafe: ... bacteriological, physical, and chemical studies...

Minnesota (Contd.)

indicated...ground water formation...affected by rapid communication between bodies of surface water and water-bearing underground formations."

d) "Studies of chemical contamination...ground water: ...gasoline tastes and odors...pollution by chemicals from a pole-treating operation...pollution ...by urine waste from...zeolite softening plant."

Missouri - (Ltr. 1/13/59 from John H. McCutchen, Dir., Bur. Pub. Hlth. Eng'g.)

I. "Water Pollution Law."

II. No studies.

III. No new tests.

(Copy of Ltr. 12/31/58 from Jack Smith, Exec. Sec'y., WPB to Joe Neel, Biologist)

I. No studies on ground water contamination.

Montana - (Ltr. 1/8/59 from C. W. Brink, Dir., Div. Environ. San.)

I. "State Board Hlth. regulation...cesspool, etc. water tight...permitted within 100 ft. of...well."

II. "No studies since 1942 Petroleum Products Traveling Through Soil...report...no longer available."

III. "No new tests...use...Standard Methods."

Nebraska - (Ltr. 2/10/59 from T. A. Filipi, Dept. of Hlth.)

I. "No information...recharge of ground water with surface water run-off...developing irrigation..."

Nevada - (Ltr. 1/12/59 from W. W. White, Dept. of Hlth.)

I. "Water pollution control regulates supplies."

II. "...wells polluted from adjoining sewage works..., subsurfaces chemically saturated from industry."

III. "No new tests...use dyes, soft, but could use an easy and positive tracer material."

New Hampshire - (Ltr. 1/9/59 from Francis V. Lariviere, Assoc. San. Eng.)

I. "...Regulation...adopted by State Board of Health, but authority lies in the local Health Official..." "...no construction...within 75 ft. of well...without approval."

II. "...no special investigation...some experiences...with detergents."

New Jersey - (Ltr. 1/30/59 from Robert G. Shaw. Dir.)

I. "...potable water standards...regulate construction."

II. "...no special investigations..."

III. "No...new or special lab. tests."

New Mexico - (Ltr. 1/8/59 from Chas. C. Caldwell, Dir.)

I. "...Public Health Regulations...govern supplies and disposal."

II. "...two studies; ground water..., surface...include consideration of chemical wastes and radioactive wastes... by U.S. Public Hlth Service; ...Report on Investigation of Ground Water Pollution, Grants-Bluewater, New Mexico, Aug. 1957."

"...chemical analyses in chemical wastes from...uranium mills. ...high nitrates...eliminated by conversion of major mill to...sodium chloride process...study still on... high chloride content in...underground strata...recharge well into an aquifer...six uranium mills...each poses... problem...in waste disposal. ...encouraged recirculation and concentration."

III. "No new lab tests."

New York - (Ltr. 1/29/59 from Wallace Sanderson, Asst. Dir.)

I. "...development of swab test for...isolation and identification of viruses in sewage...unless contamination of... domestic supply...was very severe...doubt whether...tests ...sensitive to isolate and identify viral contamination of ground water..."

"...done considerable work...not yet...successful...in method to test...difference between gasoline...and natural gas contamination of...ground water supply. ...possibly...

New York (Contd.)

gas chromatic analysis...in our report on...pollution of ground water by fluorides...; 1955 Purdue Conf. on Stream Pollution."

(Ltr. 1/14/59 from George W. Moore, Chief, Wat. Supply Sect.)

I. "...River Board of State San. Engs. ...plans and specifications...and...public health service pamphlet on...development ...and protection."

II. "...special investigation by Suffolk County Health Dept., ...presence of detergents in Water Works Journal, Dec. 1958. ...Suffolk County Health Dept. and Wat. Pollut. Control Board...study of...pollution of private supplies due to discharge of laundry wastes...1958...study not completed."

III. "...letter referred to Sanderson." "...enclose copy of Barium in Public Water Supplies for Determination of Strontium and Barium...summary of....lab. report... publ. in Wat. Wks. News."

North Dakota - (Ltr. 2/11/59 from Otmar O. Olson, Asst. Dir., Div. Wat. Sup. and Pol. Control)

I. "...State Dept. of Hlth. ...prevent pollution of underground waters..."

II. "...data collected on farm wells as a base line for further evaluation, specifically for chlorides, sulfates and total solids. ...(not enclosed)"

III. "No new lab. tests."

(Ltr. 1/9/59 from Olson to Hopkins, USPH)

I. "...limited studies on ground water contamination... have gathered data on potential problems...that...in the future...may become essential..."

Oklahoma - (Ltr. 3/23/59 from Harold L. Malone, Dir., Div. San. Eng'g.)

I. "...Oklahoma Corp. Commission...controls pollution..."

II. "...analyses of well supplies showing radioactivity enclosed."

(Ltr. 3/20/59 from Dr. Hassler to Clark)

I. "...research...attempt to isolate viral contaminants from

Oklahoma (Contd.)

Lake Hefner Reservoir...also...attempting methods for... isolation and identification of viruses from water..."

II. "...methods for detection of pathogenic viruses...being studied..."

"New test methods for the isolation and identification of viruses from water are badly needed."
"...have done limited amount of work on detergents in ground water...salt water pollution, oil refinery waste pollution, and oil field wastes..."

(Ltr. 2/13/59 from Harold Malone, Dir., Div. San. Eng'g.)

"...are attempting to collect data of interest...will be forwarded at later date...by direction of Commissioner of Hlth..."

Oregon - (Ltr. 1/8/59 from Kenneth H. Spies, Deputy State Engr.)

I. "...Oregon laws...no disposal system...located within 50 ft. of a well, State Board of Hlth. ...specify...no sewer...located within 10 ft. of a ground water supply, any sewer...10-15 ft. from well...constructed of cast iron pipe with watertight joints..."

II. "...investigation...contamination by industrial wastes ...contained high concentration...calcium sulphate... As a result...ground water so hard that...unsuitable for domestic purposes. ...In report by Tranger, F. D., U.S. Geol. Survey..." (Requested 1/23/59)

(Ltr. 1/9/59 from Curtiss M. Everts, Chief San. Engr.)

III. "...no new lab. tests."

Pennsylvania - (Ltr. 3/4/59 from Arthur Lehmann, Chief Sew. Sect.)

I. "...Sanitary Water Board...regulates subterranean disposal of wastes,...Act...controls...water pollution..."

II. "...pollution...due to...well...construction, ...due to ...geologic structure and...discharging sewage into underground waters...we...believe...bacteriological and viral contamination is quite widespread...endeavoring to establish firm legal grounds for preventing such discharges."

Pennsylvania (Contd.)

III. "...Attached...memo...two tests used...in detecting very small amounts of chemicals in tracing contamination of underground waters."

Rhode Island - (Ltr. 1/9/59 from Walter J. Shea, Chief, Div. San. Eng'g.)

II. "...no reports...Tendency for synthetic detergents to appear in private wells...where home methods of sewage disposal are used...We have...listing...of chemical analysis. ...if of interest...we will make it available..."

South Carolina - (Ltr. 1/20/59 from Thomas P. Anderson, San. Eng'g. Wat. and Sew. Sect.)

I. "State Board of Hlth. Laws regulates water supplies."

II. "...no studies"

South Dakota - (Ltr. 2/6/59 from J. E. Powell, District Engr.)

II. "Enclose inventory, publ. and unpubl. data on characteristics saline surface and ground water."

Tennessee - (Ltr. 1/2/59 from Julian R. Fleming, Div. San. Eng'g.)

I. "we have none"

II. "none to my knowledge

III. "No special tests"

Texas - (Ltr. 3/26/59 from Robert Littleton, Chief Engr.)

II. "...forwarding...7 reports...contamination ground water..." (File: II-2-a(1)-Brines.)

(Ltr. 3/4/59 from McD. D. Weinert, Chief Engr.)

I. "...Texas Board Water Engineers...regulate underground waters."

(Ltr. 3/13/59 from Arthur Barbeck, Chief Engr.)

I. "...enclose...Chronology of Regulations in Fresh Water Production - which declares Railroad Commission of Texas relies on Board Water Engineers."

Texas (Contd.)

II. Enclose report - "Salt Water or Brine Disposal in Texas," 1957.

(Ltr. 1/27/59 from G. R. Hlezik, Assoc. Dir. San. Eng'g.)

I. "...abatement...contamination...by Texas Board Water Engineers...and Oil and Gas Division, Texas Railroad Commission; ...attach Sanitation Law."

II. "...no recent routine or special studies by this dept. but several by...state agencies listed above..."

III. "...use of membrane filter, ...spectrophotometry, tracer radioactive materials...establishment...water quality standards...to organic materials...need some consideration..."

Utah - 2/59 from Lynn Thatcher, Chief, Bur. San.)

...ate Dept. or board...prevent...contamination."

I ...no special studies...U.S. Geol. Survey Office, Salt ... City...work on chemical contamination...suggest contact directly."

III. "...no special lab tests ...new test methods needed... for viral organisms..."

Vermont - (Ltr. 1/7/59 from Edward Tracy, Chief, Bur. Environ. San.)

I. "...statutes...prohibit use...contaminated water... includes, without doubt, ground water..."

II. "...No special studies..."

Virginia - (Ltr. 2/9/59 from E. C. Meridith, Dir., Div. San. Eng'g., to Gillism, Pub. Hlth. Service)

I. "...no sanitary regulations...regarding contamination... ground water..."

Washington - (Ltr. 2/25/59 from Wilson Bow, Engr. in Charge, San. Eng'g. Sect.)

I. "...no specific rules...permit...for wastes...required... by State Pollution Control Commission..."

II. "...State Dept. Hlth...problems regarding legal implications of private wells and sewage lagoons...court action... present time."

III. "...new test methods needed..."

West Virginia - (Ltr. 1/28/59 from Gerald Meyer, Dist. Geologist)

II. "...chief contaminant...ground water...brine from deep horizons...by (1) leakage...(2) disposal...(3)...upward leaking from briney zones...via fractures...or...movement... (4) encroachment... neighboring ground-water supplies... affected by...acid and irony waters...but little information available regarding...effect of these waters on ground water supplies...other contaminants...industrial waste...and... induced infiltration of contaminated river water... bacterial pollution...indicated by high nitrate and chloride determinations...especially in limestone area...low incidence water borne diseases...indicates...bacterial pollution... not a serious problem... I refer you back to Mr. Millar whom you originally contacted..."

(Ltr. 1/27/59 ... aul Price, Director and State Geologist)

II. "...principal po[illegible]ant...salt brine...part natural... part poor plugging...enclose list of our publications..."

(Ltr. 1/14/59 from J. H. Millar, Dir., Div. San. Eng'g.)

I. "...pub hlth laws...no regulations...ground water contamination...but steps could be taken to require abatement of... pollution..."

II. "...areas limestone...unsafe...wells...grossly polluted... shown by milky wastes or apple seeds coming out of faucets... No special examinations."

Wyoming - (Ltr. 1/30/59 from Earl Lloyd, State Engr.)

I. "...ground water law...became effective...March 1, 1958 operated only for short time..."

II. "...no special investigations...contamination Casper, Wyoming...no detailed information."

(Ltr. 1/19/59 from Arthur Williamson, Dir., Div. Environ. San.)

I. "...underground law...enforced by State Engineer...covers pollution...ground water sources..."

II. "...shallow aquifers...contaminated...diesel oil, crude oil, phenolic wastes...detailed information...not available..."

States who haven't replied as of 4/23/59

Kentucky	Not received 4/23/59
Maine	
Mississippi	
Puerto Rico	
Wisconsin	
No. Carolina	
Ohio	

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CIVIL AND SANITARY ENGINEERING

Room 1-372

CAMBRIDGE 39, MASS.

January 5, 1959

Ref. DSR 7-8110: Ground Water Contamination Studies

We would appreciate whatever available information you may be able to send us, as outlined in the enclosed memorandum. Possibly you could furnish some reports or memoranda, or refer us to some publication bearing on, or to someone with knowledge of, the investigation of a specific ground water contamination problem.

Very truly yours,

Wm. E. Stanley
Professor of
Sanitary Engineering
Emeritus
Project Director

Enclosure

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF CIVIL AND SANITARY ENGINEERING

CAMBRIDGE 39, MASS.
January 5, 1959

GROUND WATER CONTAMINATION STUDIES
Research Project No. DSR 7-8110
1959

Introductory Statement - We have a research project sponsored by The Federal Housing Administration in progress to survey available literature and other sources of information in the public health, sanitary engineering, ground-water resources, and other pertinent fields, on the contamination of ground water by physical, chemical, bacteriological, or viral organisms; together with related information on the nature of the movement and the nature and extent of removal of contaminating substances in passage through subsurface materials, or in the ground water.

It is one objective of this letter inquiry to locate sources of recent knowledge which might not be found by a library survey now underway.

Information Desired - Any available information along these lines:

I - Does your Department or Board, or any municipal water supply department in your jurisdiction, have a regulation, or guidance memorandum, relative to the prevention of contamination of domestic water supplies taken from underground water sources?
Could we have a copy of any available items?

II - Have any routine or special investigations been made of the physical, chemical, bacteriological or viral contamination of domestic water supplies obtained from ground-water sources? Especially any investigations relative to detergents, radioactive substances, virus organisms, or chemical wastes?

III - Has your department, or any municipal or private laboratory, developed new or special laboratory tests useful to judge domestic water supply quality with reference to possible contamination by physical, chemical, or bacteriological substances, including viral organisms?
Are new test methods needed?

Cont'd on p.2.

Branch, or Section, Concerned - Is there a sub-division of your Sanitation Division which is especially interested in ground water supplies for isolated residences or sub-divisions? To whom should our future correspondence be directed?

Library Survey of Literature - Any available references relating to ground-water contamination would be appreciated.

We expect to make an orderly search in one or more libraries. However, the time available for the searches and required study is limited.

Copies of Unpublished Data - If useful pertinent summarized data are available which could be copied by Thermo-fax, Verifax, or other means, at a reasonable cost, kindly advise.

Wm. E. Stanley
Project Director

APPENDIX C

GROUND WATER CONTAMINATION

Topic I. Physical Contaminants (or Physical Qualities)

December 1959

APPENDIX C

GROUND WATER CONTAMINATION

Topic I - Physical Contaminants

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GROUND WATER CONTAMINATION

Topic I. Physical Contaminants

Many writings on water quality include a class of water characteristics designated Physical Characteristics or Physical Qualities of water, which generally include the following:

a - Turbidity

b - Tastes and Odors

c - Color

d - Temperature

Turneavre and Russell[5] under "Physical Examination" state:

> "These tests, which relate to the attractiveness of a water, include odor, taste, color, turbidity, sediment and temperature."

The AWWA Manual[15] includes this significant statement:

> "Aside from the factor of safety, a public water supply may be unsatisfactory..., because of the presence of suspended matter ... or because of objectionable odors or flavors."

Sometimes the chemical qualities of acidity, pH, and alkalinity are also included but these are chemical and not physical so will not be discussed in this section.

None of these items are water contaminants, but rather may be the results of or indices of contamination by organic materials from soil or other sediment carried by water.

However, the foregoing physical qualities are so commonly included whenever the contamination of water is discussed, it appears desirable to review a selected few of the large number of discussions of these quality items using the same general outline

as used for the other several classified types of water contaminants.

To provide a better understanding of the significance of these several water quality characteristics, a number of selected definitions of them, or the method of measuring them (i.e., the qualities or physical characteristics) have been briefly reviewed.

Definitions

Turbidity - There are many discussions as to the meaning of this term: Turneavre and Russell[5] give a brief clear statement:

> "Turbidity. This is a term used to describe the presence of substances in a water which interferes with its clarity."

Standard Methods[16] includes the definitive statement:

> "Turbidity should be clearly understood to be an expression of the optical property of a sample (of water) which causes light rays to be scattered and absorbed rather than transmitted in straight lines through the sample."

Babbitt[12] writes:

> "...turbidity is a measure of suspended matter in water. It is aesthetically undesirable and may indicate the source of the water."

Fair and Geyer[1] write that:

> "Turbidity in water consists of clay, silt, finely divided organic matter, microscopic organisms, and similar substances. Soil erosion is responsible for most of the turbidity in natural waters."

McKee[7] provides a more scientific definition by stating:

> "The turbidity of a water sample is a measure of the extent to which the intensity of light passing through is reduced by the suspended matter. Although in some of the literature the terms 'turbidity' and 'suspended solids' (or other equivalent words...) are used almost synonymously, the degree of turbidity is not equal to the concentration (or quantity) of suspended solids, but is an expression of only one effect of suspended solids upon the character of the water."

Brown[2] presents a brief clarifying definition:

> "Turbidity is a measure of the effect that suspended or colloidal materials have in disturbing clarity or diminishing the penetration of light. It is actually a measure of appearance, ..."

Brown[2] also points out that:

> "Turbidity is often confused with color or suspended solids; however, turbidity is a measure of the extent to which the intensity of light passing through is reduced by suspended matter and not a measure of substances in solution (true color."

Tastes and Odors - These esthetic water qualities are sometimes considered together, sometimes separately. Beverage specialists combine them in the term "flavor."

Standard Methods[16] includes the long definitive statements:

> "There are several kinds of sensations to which terms 'taste' and 'odor' are loosely applied. First, there are the true tastes, of which there are only 4: salty, sweet, sour, and bitter. These correspond to localized sensitive areas on the tongue. Second, there are irritating sensations: the 'hotness' of chili, the 'coldness' of mint, the astringency of alum, the irritation of corrosive gases. These are responses of the mucous membranes. Finally, there are the true odors, sensations which are experienced only when the odoriferous matter comes in contact with the olfactory tissue high up in the nose. ...All of these sensations are subjective: there is no way to describe a taste or an odor without reference to the experience of a human being... Therefore, all descriptions of tastes and odors must be in terms of comparisons...with which... the reader is familiar."

Hopkins and Schulze[3] state the situation thus:

> "It is difficult to distinguish between taste and odor since these senses are so closely related. In the discussion of control procedures the contaminants producing taste and odors will be considered without differentiation."

Ruchhoft, C. C., et al,[6] conclude as follows:

> "Taste properties of virtually all organic substances in water are actually odor properties, although the levels of threshold perception may differ."

McKee[7] states the situation more completely, as follows:

> "Problems of odor and taste are very complex because the senses of smell and taste are intimately related and their responses are often difficult to differentiate clearly. In addition, it is frequently difficult, if not impossible, to identify the specific cause of an odor or taste, for many substances can cause what appears to be the same effect, or because mixtures of substances may be involved."

McKee[7] further suggests that:

> "odorous substances in water must be vaporizable in order to be smelled. While such substances may often also be tasted, the sense of smell is generally much more acute than that of taste... and in water-works practice the separation of odor and taste is rarely made."

However, McKee[7] proposes:

> "While taste responses are often difficult to differentiate because the senses of taste and smell are closely interrelated, certain non-volatile substances dissolved in water can cause tastes without causing odors. To some extent, therefore, the subject of taste-producing substances in water may be discussed independantly."

Color - This characteristic of water has two distinctive variants.

Standard Methods[16] includes a rather positive statement:

> "The expression 'color' shall be defined to mean 'true color' - that is, the color that is due only to substances which are actually in solution, and not to suspended matter. The 'apparent color' shall include... also that due to suspended matter."

McKee[7] presents a good clarifying statement:

> "In water-works practice, color of water is considered to be only that attributable to substances in solution after the

> suspensoids have been removed by centrifuging, because an accurate determination of color in water containing suspended matter is not possible. However, the color of water with low turbidity is substantially the same as that of clear water... In field work, the color of water may be compared with that of glass discs calibrated to correspond with colors on the platinum scale."

Temperature - This physical quality of water really needs no definition - it is the amount of heat in the water as measured by a thermometer. Both the centigrade and the fahrenheit scales are used for recording the degree of heat in the water. One quantitative measure of heat is the Btu, which is that amount of heat required to raise one pound of water one degree fahrenheit. So the degrees of temperature of water indicate the number energy units, in the form of heat, which have entered the water, above or prior to the measurement.

1. Sources of Physical Qualities

All four of the qualities - turbidity, tastes and odors, color, and temperature represent something added to chemically pure water (H_2O). The sources from which these characteristics come are too numerous to fully record herein. A few illustrative sources have been studied, as outlined in the following.

Turbidity Sources

According to Standard Methods[16] the cause of turbidity is:

> "The turbidity of water is caused by the presence of suspended matter, such as clay, silt, finely divided organic matter, plankton, and other microscopic organisms."

Fair and Geyer[1] write that:

> "Turbidity in water consists of clay, silt, finely divided organic matter, microscopic organisms, and similar substances. Soil erosion is responsible for most of the turbidity in natural waters."

Salvato[11] relative to sources states:

> "The presence of turbidity in well or spring water indicates inadequate protection from surface wash and possible bacterial contamination. In drilled wells turbidity may be caused by improper development, iron, microscopic growths, or failure to cement grout the annular space."

McKee[7] states:

> "The turbidity of water is attributable to suspended and colloidal matter, the effect of which is to disturb clearness and diminish the penetration of light....caused by micro-organisms or organic detritus...; silica... or other mineral substances including zinc, iron, and manganese compounds...; clay or silt...; or sawdust, fibers, or other materials, ...as a result of natural processes or erosion or ... the addition of domestic sewage or wastes from various industries, such as mining..., dredging..., logging..., pulp and paper manufacturing... and others."

Brown[2] writes, probably with main thought to surface waters:

> "Natural waters are subject to widely fluctuating turbidity and normal causes are microorganisms, organic detrius, silica, various mineral substances, clay, silt, etc."

Tastes and Odors - Sources

The sources or causes of tastes and odors in drinking water are many. Quite generally these qualities derive from some cause rather than a specific source. Surface waters are more troubled than ground waters.

Salvato[11] writes:

> "Tastes and odors in water supplies are due to oils, minerals, gases, organic matter, and other compounds and elements in the water. Some of the common causes are: oils and products

of decomposition exuded by algae and some other microorganisms; wastes from gas plants, coke ovens, paper mills, chemical plants, canneries, tanneries, oil refineries, and dairies; high concentrations of iron, manganese, sulfates, and hydrogen sulfide in the water; and high concentrations of chlorine."

Salvato[11], relative to hydrogen sulfide odors, states:

"The sources of hydrogen sulfide are both chemical and biological. Water drived from wells near oil fields or from wells that penetrate shale or sandstone frequently contain hydrogen sulfide. Calcium sulfate, sulfites, and sulfur in water containing little or no oxygen will be reduced to sulfides by anaerobic sulfur bacteria or biochemical action, resulting in liberation of hydrogen sulfide. This is more likely to occur in water at a pH of 5.5 to 8.5,... Organic matter often contains sulfur which when attacked by sulfur bacteria in the absence of oxygen will release hydrogen sulfide. Another source of hydrogen sulfide is the decomposition of iron pyrites or iron sulfide."

Salvato[11] also states:

"Some materials in water cause unpleasant tastes and odors when present in excessive concentrations, although this is not a common source of difficulty. Iron and manganese for example may give water a bitter, astringent taste. In some cases sufficient natural salt is present, or salt water enters to cause a brackish taste in well water. ..."

"Other causes of tastes and odors are sewage and industrial or trade wastes. Sewage would have to be present in very large concentrations to be noticeable in a water supply. ...trade or industrial wastes introduce in water suspended or colloidal matter, dissolved minerals, phenols, vegetable and animal organic matters, harmful bacteria, poisons, and other materials that produce tastes and odors.

Babbitt and Doland[13] write:

"Odors and tastes in water may result from any one or a combination of such conditions as the presence of microorganisms, either dead or alive, dissolved gases, such as hydrogen sulphide, methane, carbon dioxide, or oxygen combined with organic matter; mineral substances such as sodium chloride, iron compounds, carbonates and sulphates of other elements; and phenols and other tarry or oily matters, ... Some tastes, such as those imparted by dissolved oxygen or carbon dioxide, are desirable."

"An increasing cause of disagreeable tastes in water is pollution by acid mine wastes and by industrial wastes, of which coal and wood distillation form a large part. These tastes are characteristically medicinal or phenolic, are detectable in extremely dilute concentrations of the order of one part per billion, ...and are difficult to remove."

McKee[7] reports tastes and odors in water:

"are associated with the presence of any of a great variety of objectionable substances, particularly living microscopic organisms or decaying vegetation, including weeds, ...bacteria, fungi, ...actinomycetes ... and algae, ...decaying organic matter, ...sewage and industrial waste products."

McKee[7] also lists as responsible for tastes and odors:

"halogens, sulfides..., ammonia..., turpentine..., phenols and cresols..., picrates..., various hydrocarbons and unsaturated organic compounds..., mercaptans..., tar and tar oils..., detergents..., algicides..., insecticides and weed killers..., and innumerable other, many of unknown identity."

McKee[7] further reports:

"The extremely disagreeable tastes imparted to chlorinated water by phenol, cresol hydrocarbons of the benzene series, anthracene and napthalene can be detected at concentrations far below the odor threshold; possibly one-fiftieth to one-hundredth of the quantity detected by odor can be distinguished by taste."

Hopkins and Schulze[3] state largely relative to surface waters:

"Sources of tastes and odors are found in heavy infestations of microorganisms, decaying vegetation and trade waste pollution from coke oven wastes, discharge from creosoting works, gas plants and oil refineries, and other industrial operations. ...The chlorophenols produced by the addition of chlorine to water carrying phenolic wastes ... are the worst offenders ... The most common origin of tastes in a water supply is the decomposition of dead microorganisms, especially algae... Excessive concentrations of these organisms frequently occur during periods of warm water and, if these are killed by chlorine disinfection or copper sulfate treatment, or if they die from natural causes, they may produce obnoxious tastes. Taste from decomposition of organic compounds in vegetation is also a factor."

Standard Method[16] includes the statement:

> "Odors in water are caused by volatile substances in concentrations which may be too small to detect by conventional analyses,..."

Fair and Geyer[1] relative to taste (alone) write:

> "Tastes in water are generally due to the presence of dissolved salts. Iron salts and sulfates are particular offenders. True tastes may be produced also by algae that contain a taste principle and by industrial wastes. The intensity of such tastes is often magnified by chlorine either through the destruction of the responsible organism and liberation of its taste principle or through the formation of reaction products with this principle or with substances that are contained in industrial wastes. Examples are the bitter, cucumber-like taste produced by the golden-brown alga Synura ... and the iodoform or medicinal taste that has its source in phenoloid or comparable substances. The phenolic tastes are very disagreeable and cause widespread consumer complaints. Minute concentrations of the offending substance -- (1 ppb) the upper limit for phenolic compounds (as phenol) set by the Public Health Service Drinking Water Standards may be responsible. Phenols, cresols, and allied substances find their way into water from industrial works, such as coke by-product plants and gas works."

> "Taste intensity can be measured in the same manner as odor intensity. Sodium chloride is detected in concentrations from 300 to 900 mg/=L of NaCl and becomes objectionable enough to curtail water consumption when its concentration reaches 1,000 to 1,500 mg/l. There is reason to assume that the sulfates of sodium as well as the chlorides and sulfates of potassium, clacium, and magnesium possess threholds of detection and refusal of like order of magnitude."

Odor Sources

Also relative to odor (alone), Fair and Geyer[1] write:

> "Odors in water are caused by volatile substances associated with organic matter, living organisms, principally algae and related organisms, and gases such as hydrogen sulfide. ...The chlorination of water may produce odors of its own or intensify those of odor-producing agents. Since the keenness of odor preception varies with individual observers, and with

fatigue of the olfactory nerves in the same observer, odor measurements are by no means absolute. Heating of water generally intensifies the odor. The nature of the odor is commonly noted. Often this gives a clue to the nature of the substances or living organisms responsible for the odor."

McKee[7] writes:

"Odors can be caused by volatile substances in concentrations too small to be detected by ordinary analytical techniques; therefore, reliance must be placed upon the sense of smell in spite of its subjectivity and lack of precision."

McKee[7] lists potentially offensive industrial wastes:

"...pulp and paper, explosives, petroleum, gasoline, rubber, wood distillation, coke and coal tar gas, tanneries, meat-packing and glue, chemicals and dyes, milk products, canneries, beet-sugar, distilleries, and other food products."

Color-Sources

According to McKee[7]

"color in water may be of natural mineral or vegetable origin caused by metallic substances such as iron compounds...; humus material...; peat...; and algae, weeds, or protozoa... Water may also be colored by inorganic or organic soluble wastes from many industries including: nail works, mining, explosives, pulp and paper, chemicals, and others."

Babbitt and Doland[13] write:

"Color in water is usually due to organic matter in colloidal suspension, but it may be due to mineral or organic matter in solution, as a colloid, or in suspension. The coloring materials may be procured ... by ground waters through the solution of minerals. ...A yellow tinge may indicate an iron-bearing water colored when the iron was thrown out of solution either by oxidation or through the release of carbon dioxide."

Babbitt[12] writes simply:

"Color is caused by colloidal particles in water."

Salvato[11] relative to color sources states:

> "Water which has drained through peat bogs, swamps, forests or decomposing organic matter, may contain brownish or reddish stain due to tannates and organic acids dissolved from leaves, bark, and plants."

Fair and Geyer[1] write, generally, but possibly with more thought to surface water:

> "Color is imparted to natural waters by dissolved or colloidal substances extracted from leaves, peaty matter, and the like."

Temperature - Sources

Temperature in underground water supplies is not generally a problem compared to frequent temperature contamination of surface waters. However, some of the same temperature sources which affect the temperature of surface waters have affected ground waters.

McKee[7] writes:

> "Temperature changes...may result from natural climatic phenomena or from the introduction of industrial wastes, such as distillery effluents or discharges of cooling waters used by many industries."

Turneavre and Russell[5] state:

> "The temperature of waters from deep wells rises as depth is increased."

Gotaas[17] in connection with a study of injection of sewage into ground water reported a curious phenomenon:

> "Since normal ground water temperatures are less than that of injected sewage... heat must be... generated... A decrease in B.O.D. of some 8 ppm ... could ... produce ... the observed temperature rise..."

"...the ground water (discharged from wells) was found to range from 18.5°C ... to 18.1°C ... The temperature of the water and sewage previously injected ranged from 17.1 to 17.6°C. ...the discharged test well water is always the warmer,..."

2. Effect on Water Quality

There is no clear distinction between the physical characteristics - turbidity, tastes and odors, color, and temperature - if used as (1) parameters of quality or (2) as indicators of potential pollution.

Thus, the AWWA Manual (p.29) states:

"...a public water supply used for domestic ... purposes should be clear, pleasant to the taste, of reasonable temperature..."

and the Joint Committee[18] (1945) recommended:

"Water for drinking and culinary purposes...clearness, softness, freedom from objectionable taste and odor, and low temperature are desirable."

Turbidity Effects

Ehlers and Steel[19] write:

"In wells and springs, ...a sudden increase in the turbidity after a rain indicates a very dangerous condition, particularly in a limestone region."

Turneavre and Russell[5] also write:

"Frequently the presence of turbidity indicates surface pollution though at times wells in certain formations may be silt bearing."

Babbitt and Doland[13] write more specifically:

"Sediment producing visible turbidity is ordinarily composed of fine particles of sand and clay and, as such, it is not particularly detrimental to the potability of the water... A turbidity indicating surface runoff would suggest possible pollution and might cause condemnation of the water source."

Effect of Tastes and Odors

Most writers refer to objectionable tastes and odors as though they are self evidently undesirable. Also reference is more generally made to odors rather than to tastes.

Standard Methods[16] includes the statement:

> "Odors in ... may be associated with the presence in the sample of pollution or other objectionable matter..."

Babbitt[12] writes:

> "Noticeable odors are undesirable aesthetically and are almost invariable indicative of pollution or other undesirable conditions."

Babbitt and Doland[13] write:

> "the odor of water changes with temperature, sometimes not being noticeable when the water is cold."

McKee[7] discusses odors and tastes:

> "Disagreeable odors and tastes in water are associated with the presence of any of a great variety of objectionable substances..."

Salvato[11] writes, relative to tastes or odors in water (surface?) from sewage:

> "...the dissolved oxygen in the water receiving the sewage would most probably be used up, with resultant nuisance conditions. ...the billions of bacteria introduced, many of which would cause illness or death if not removed or destroyed before consumption, are the greatest danger in sewage pollution."

Relative to industrial wastes, Salvato[11] states:

> "the wastes from steel mills and coal distillation (coke) plants have proved to be the most troublesome in drinking water, particularly in combination with chlorine. Tastes produced have been described as 'medicinal', 'phenolic', 'iodine', 'carbolic acid', and 'creosote'."

Color - Effect on Water Quality

Color may be considered with regard to its source, natural or from industrial wastes. A very general view relative to sanitary considerations is stated by Babbitt[12] as follows:

> "It is undesirable aesthetically, having no sanitary significance other than indicating the source of the water."

Fair and Geyer[1] write more comprehensively effect of color:

> "It is quite as harmless as tea and consists of tannins, glucosides, and their derivatives as well as iron compounds and other substances. Natural color is most intense in water draining from swamps. It is reduced by storage or aging of the water and by the bleaching action of sunlight. Industrial wastes may contain dyes and other coloring substances of varying hues that are not measured by the standard test for color."

McKee[7] furnishes a more specific statement:

> "In domestic water, color is undesirable from esthetic considerations and also because it may dull clothes, or stain food and fixtures.... Color is undesirable in water for laundries...; ice-making...; dairy products...; bottled beverages...; photography...; textiles...; pulp and paper...; and other uses."

Temperature - Effect on Water Quality

In recent years temperature pollution of surface waters has become an important consideration at many places. However, temperature effects on the quality of ground water has been given very little attention. Some illustrative statements are as follows:

McKee[7] writes:

> "The temperature is important, and sometimes critical, for many uses of water. It affects the palatability of water, treatment processes, the value of water for many industrial uses, including cooling processes... ."

Fair and Geyer[1] present a more scientific appraisal of temperature measurements:

> "Temperature measurements are important not only for their sake, but also because they identify the magnitude of the density, viscosity, vapor pressure, and surface tension of the fluid, the saturation values of solids and gases that are dissolved in it, and the rates of chemical, biochemical, and biological activity such as corrosion, BOD, and growth and death of microorganisms."

McKee[7] writes that:

> "Increased temperatures may stimulate growth of taste-and-odor producing organisms in... Sometimes a drop in temperature has stimulated growth of some organisms. ...In general the survival time of infectious bacteria, cysts of E. histolytica, and ova of parasite worms is reduced as temperature of the contaminated water increases...E. typhosa and coliform organisms survive for longer periods at lower temperatures, ...and pathogenic organisms have survived for a year under ice. Bactericidal effects of disinfectants are generally increased by an increase in the temperature of the water."

3. Reported Permissible Concentrations

The concentrations of the physical qualities considered permissible is quite variable, and depends largely upon past experience of the water users. In some areas physical characteristics are accepted which are far inferior to physical qualities generally demanded.

Turbidity Concentrations

Possibly turbidity is the most critical of all of the four physical qualities, which are being considered. A ground water with variable turbidity may be more objectionable than a uniform turbidity, particularly if the turbidity appears during or following rains.

Public Health Service Drinking Water Standards[8] specify*:

"the turbidity of the water shall not exceed 10 ppm (silica scale)..."

*A foot-note states:

"The requirements relating to turbidity and color shall be met by all filtered water supplies. Turbidity and color limits for unfiltered waters ... should be based on reasonable judgment and discretion, giving due considerations to all the local factors involved."

Thus, the 1946 edition of the Drinking Water Standards side steps any specific limitation on unfiltered waters.

Salvato[11] gives a more definite statement:

"...the public demands a sparkingly clear water. This implies a turbidity less than 1 part per million (ppm); ... A turbidity greater than 15 to 25 ppm would justify treatment of the water."

Goudey[14] suggested indices for classification of ground water as follows:

Class AA	(Excellent)	Turbidity less than 5 ppm
Class A	(Good)	" " " 10 "
Class B	(Limited)	" " " 25 "

There is a dearth of literature on ground water turbidity, but any amount of turbidity over 10 to 15 ppm should cause the ground water supply to be suspect.

Tastes and Odor Concentrations

Much has been written on tastes and/or odors, largely with reference to surface waters. However, the basic factors are the same regardless of whether the source is surface water or ground water.

Public Health Service Drinking Water Standards[8] contains merely the statement:

> "The water shall have no objectionable taste or odor."

Salvato[11] is also very general with the statement:

> "Odor should be absent or very faint for the water to be acceptable...the taste should not be objectionable."

Salvato[11] is more specific in the statement:

> "Phenols in concentrations of 0.2 parts per billion in combination with chlorine will impart a phenolic or medicinal taste to drinking water."

The AWWA Manual[15] includes a useful statement on odors:

> "The extent to which odors...to produce a uniformly palatable water will...depending upon just how objectionable the specific odor is and just how critical the consuming public may be. Baylis states: 'No definite odor threshold figure may be set for the quality of the water desired by the public...when hot odor threshold is more than two, a few consumers...are able to detect odor."

Also the statement:

> "Concentrations of one part phenol to 500 million parts of water will cause very disagreeable tastes..."

McKee[7] writes:

> "The threshold odor number equals the volume of the dilution divided by the volume of the sample in the dilution. In the literature...are also found many references to the ... lowest concentrations, in ppm giving perceptible odor and/or taste. The variety of odors possible is almost numberless and although many descriptive terms have been assembled... these are still ...inadequate."

McKee[7] has listed a number of taste thresholds taken from literature as follows:

Substance	Approx. taste threshold reported (ppm)
Calcium Carbonate	500-200
Calcium Chloride	(150-350
	(500
Calcium Sulfate	250-900
Chlorides	300-900
	300
	400
Chlorine (residual)	0.05
Copper	less than 5
	more than 1.5
	1.5-5.0
Iron and Manganese	(0.5
	(20
Iron Carbonate	0.3
Iron Humate	0.5
Magnesium Chloride	168
	200-750
Magnesium Nitrate	500-800
Magnesium Sulfate	400-600
Potassium chloride	350-600
Potassium hydroxide	1-50
Salicyl	0.001
Sodium Carbonate	15-75
Sodium Chloride	(200-400
	(500-550
Sodium Hydroxide	1-50
Sodium Nitrate	450-800
Sodium Sulfate	250-500
Sucrose	5000
Quinine	less than 50
Zinc	40

It will be noted that quite a range of threshold values have been reported for some items.

Color Concentrations

McKee[7] reports:

> "The U.S.P.H.S. Drinking Water Standards of 1946[8]... limit the color of acceptable filtered water to 20 ppm ... For unfiltered water and for raw-water sources no requirements are set... other than reasonable judgment and discretion based on local factors."

McKee[7] also writes:

> "Various interstate agencies limit the color in the raw water to be used as sources of drinking water to values ranging from none to 100 ppm."

Salvato[11] states:

> "Color should be less than 5 to 10 ppm, although persons accustomed to clear water will notice a color of only several ppm and might object to it."

Goudey[14] proposed classes for ground water

Class AA	- Excellent	Color less than 10
Class A	- Good	Color less than 20

Fortunately, natural ground waters generally do not contain sufficient color to be objectionable.

Satisfactory Temperature Range-Degrees

Babbitt[12] writes:

> "The most desirable temperature... is 50 to 55°F. Ranges between 45° and 70°F. are used with satisfaction, with some extremes up to 90°F."

Babbitt and Doland[13] write:

> "The most desirable range of temperatures for ... water supply is between 40° and 50°F. Natural waters are seldom found below 40°F. As the temperature rises above 50°F. the water becomes less palatable and less suited to certain uses such as air conditioning. Temperatures above 80°F are undesirable, and above 90 to 95°F the water is unfit..."

McKee[7] writes:

> "Many state and interstate water-pollution control agencies place restrictions on temperatures or allowable temperature increases... for drinking purposes, water with a temperature of 50°F. is usually satisfactory. Temperatures of 100°F. or higher are usually objectionable..."

4. Experience to Date

Many papers have been published descriptive of experiences with pollution of ground water by sewage, industrial wastes, chemicals, garbage dumps, oil wells, and others in which the physical qualities of turbidity, tastes and odors, color, and temperature were related problems.

Gotaas[17] et al (pages 20-21) summarized many instances of reported experiences of underground travel of bacteria and chemicals. Chemicals travel much farther than bacteria. In general, chemicals frequently result in tastes and odors, color, and sometimes temperature changes.

Since turbidity, tastes and odor, color, and temperature are in effect indices of or the result of chemical and other pollutions we have not attempted to list up any series of published experiences wherein these physical qualities are considered incidentally in the discussion of the more specific chemical, bacterial, or other contaminant.

PASSAGE THROUGH SOIL

5. Nature of Movement

The published experience relative to physical qualities must be considered on the basis that the physical qualities may be the result of chemical, bacteriological, or other contamination.

Turbidities are not generally found in ground waters, except in creviced rocks, unless there are source of surface water pollution, or some chemicals which will cause colloidal or suspended material to form in the ground water.

The soil, above the water bearing strata, will filter out much of the surface turbidities unless there are direct channels from the surface into the water supply well or spring. The residue of turbidity is quickly removed in the fringe area of the ground water strata.

Tastes and odors, particularly tastes, being due to matter in solution would sometimes pass through the soil above the ground water, excepting many organic compounds are subject to oxidation as it passes through the soil which would reduce the odor or taste. Other organic compounds, such as phenols, petroleum products are less likely to be affected by the soil so may enter the ground water, with their taste producing characteristics, which may become quite pronounced if the water is chlorinated.

Color, due to colloidal substances, may be reduced rapidly by passage through soil. Some artificial dyes may persist for long distances. Gotaas et al[17] report an experience where dye added to sewage travelled 300 feet in 24 hours. Color in ground waters, due to natural or to artificial causes, is unusual in unpolluted wells or springs. However, certain chemicals in water, such as iron or manganese, may cause objectionable color formation, as soon as the water is exposed to air. This effect may well obscure the color reducing effect of soil.

Temperature in ground water is generally low due to the cooling effects of the underground soil. There are a few natural hot water wells or springs where the hot water rises from deep in the earth.

Except for well-known natural hot water wells or springs, any high temperatures would be evidence of pollution. A few cases have occurred, but they are rare and the cooling effects of the soil are quite definitely above the ground water and in the fringe or capillary strata just above the ground water, so ground water temperatures remain fairly constant.

6. Removal of Physical Contaminants

The present situation has been summarized by McKee(7) as follows:

> "In estimating the anticipated concentrations of pollution in ground water, with due allowances for dilution, an engineer must recognize that certain substances will pass through soil with little or no physical, chemical, or biochemical changes, whereas other substances will be removed or altered markedly. Chemical and physical-chemical phenomena that may affect pollutants include oxidation, reduction, precipitation, adsorption, dissociation, dissolution, and ion exchange."

Changes that occur as water passes through the soil, physical, chemical, biological and bio-chemical, have not been studied sufficiently to be well understood. The California State Water Pollution Control Board and also the Texas State Board of Water Engineers have sponsored some research projects which have resulted in a number of reports.

However, these reports have not included conclusive evidence which would be generally applicable.

Generally, turbidity and color are filtered out as surface water percolates down through soil above the ground water. However, if there are large underground passages - such as crevices in laminated rocks - both turbidity and/or color may travel long distances and enter the ground water. Dilution by clear ground water would likely dilute the turbid or colored water and thus, in time, reduce the concentrations to acceptable limits.

Babbitt and Doland[13] write:

> "Color may be removed, as other colloids are removed, by adsorption and by chemical precipitation, possible followed by sand filtration. No one method will remove all colors. ..."

The causes of tastes and odors are so extensive there are possibilities of contamination of ground water by taste or odor producing materials which may not be removed by passage through soil.

Salvato[11] writes relative to brackish tastes as follows:

> "It is not possible to remove the salt in the well water without going to a great expense. Elimination of the cause by sealing off the source of the salt water, ground water fresh water recharge, or controlling pump drawdown is sometimes possible."

There are chemical contaminants, generally from industrial processes, which are not removed or reduced by passage through soil. In many cases dilution with the moving fresh underground water may reduce concentrations to below permissible limits.

However, many experiences have shown the contaminated water in slugs or streams flowing with the ground water without much dilution.

Removal of temperature is a cooling process so hot water would lose temperature, generally, as it passed through soil or flowed along with ground water. However, objectionable temperature may be due to the entrance of objectionable industrial waste waters, in which case chemicals rather than temperature may be the major problem (as discussed in following appendices covering other topics).

7. Predicting Physical Qualities Degradation

The present art of predicting the possibility of degrading the physical qualities of ground water is reasonably well developed with reference to two types of underground soil conditions (1) In very coarse gravel and boulders having little or no covering of fine grained soil.

In such underground formations turbid or colored waters are likely to travel down hill for considerable distances. Also various chemicals which cause tastes and odors would likely be objectionable for long distances downstream of the point of entrance of contamination.

Additional information and experience data are needed to determine the effectiveness of barriers of fine grained soils, or the distances of travel of the contaminating agents through soils of different degrees of fineness. These data may involve chemical and biochemical reactions between various chemicals in water and the characteristics of the soil, both physical and chemical.

8. Water Quality Criteria Required

The techniques for determining turbidity, color, and temperature of water are well established. The techniques for measuring tastes and odors are not well established.

McKee[7] states relative to taste determination as follows:

> "Standard methods for the examination of water and sewage* ...does not prescribe a procedure for taste determination."
>
> *Reference to Tenth Edition.

He[7] also writes:

> "For unfiltered water and for raw-water sources, no requirements are set by the U.S.P.H.S., other than reasonable judgment and discretion based on local factors."

State and Interstate agencies have adopted systems of classification and standards for surface waters and, in some cases, ground waters with values of turbidity ranging from 5 to 250 ppm.

McKee[7] notes:

> "most commonly the limits of turbidity are expressed in general terms."

There is a need for more specific designation of the limits for physical qualities of ground waters, in order that waters of uncertain quality might be more definitely prescribed.

9. Methods for Obtaining Additional Information

The more complete information on physical qualities of underground waters presently desirable and quite necessary in the foreseeable future may be obtained by a series of researches along the following lines:

1. A study of the concentrations of turbidity, tastes, odors, color, and temperature for underground waters which should be prescribed definitely in a revision of Public Health Drinking Water Standards.
2. A study of the relationship between underground soil or rock characteristics and the travel of the physical qualities of water. It is probable that some items, such as tastes, odors, and color may require a coordinated study of the chemical or biological agent which causes the objectionable water quality.
3. The available measurement techniques for physical qualities in ground water should be reviewed and revisions made for the next edition of Standard Methods. There should be a standard measurement technique for both tastes and odors. presently no standard measurement method for tastes is available.

10. Summary

The physical qualities of water determined by measurements of turbidity, tastes and odors, color, and temperature represent evidence of contamination when found in ground waters. In the foregoing sections the physical characteristics have been considered as contaminants. They also may be considered as evidence of contamination by soil or chemicals.

In general, these five physical qualities should be considered as indices of contamination. Greater attention should be given to

them in future ground water analysis. Some standard determination for tastes in water should be developed.

More specific standards should be included in Public Health Drinking Water Standards than presently included, as to allowable concentrations of turbidity, tastes, odors, color and possible temperature.

Presently available data is insufficient on which to determine the concentrations of the five physical qualities which would represent a safe ground water supply.

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APPENDIX D

GROUND WATER CONTAMINATION

Topic II-1a. Chloride Contaminants

December 1959

APPENDIX D

GROUND WATER CONTAMINATION

Topic II 1a. Chloride Contaminants

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APPENDIX D

GROUND WATER CONTAMINATION

Topic II-1a. Chloride Contaminants

Prior to the time of bacterial examinations, chlorides were used as an index to possible sewage contamination of ground water, but it was necessary to know the natural chloride concentration in local waters. In more recent years disposal of salt water from oil wells or intrusion of saline water or sea water into ground water aquifiers has resulted in many problems of chloride contamination of ground water.

1. Sources of Chloride Contamination

Sources of chlorides may be (1) brines from oil wells or from industrial processes (2) intrusion of saline water or sea water due to lowering of ground water, and (3) other sources. Brown[1] stated:

> "Chlorides in natural waters may also be derived from sea water contamination of underground supplies, agricultural salts spread on fields, from --- sewage, and from a limited number of industrial effluents."

McKee[2] summarized chloride sources as follows:

> "Chlorides are found in practically all natural waters. They may be of natural origin or derived, (a) from sea water contamination of underground supplies,
> (b) from salts spread on fields for agricultural purposes,
> (c) from human or animal sewage, or
> (d) from industrial effluents, such as those from paper works, galvanizing plants, water softening plants, oil wells, and petroleum refineries."

Winslow and Kister[3] wrote relative to ground waters in Texas:

> "Saline ground water occurs as connate water or as other saline water that entered an aquifer in the geologic past and has not been flushed from the aquifer; as the result of solution of soluble materials in aquifers by percolating ground water; as a result of salt-water encroachment into aquifers ---- or as the result of concentration by evaporation, especially in the vicinity of dry lakes. Most of the aquifers in Texas contain saline water in some parts, and a few are capable of producing large quantities of saline water. ----Saline water is widely distributed in the underground reservoirs, streams, and lakes of Texas. In north-central and west Texas, in large areas where no potable water is found, the water ranges from slightly saline to brine."

Winslow et al[4] wrote on sea water intrusion in Texas:

> "Before large-scale ground water withdrawals were begun, the hydraulic gradient sloped gently toward the coast. Then, as large quantities of water were withdrawn, a large cone of depression was established, the hydraulic gradient was reversed, and salt water began to move slowly toward the centers of pumping. The rate of movement of salt water is very slow and the closest salt water is ---- 5 miles from centers of pumping in the deeper sands. However, the threat of salt-water intrusion is present and the rate of advance of the salt water should be watched by means of strategically placed observation wells. ----other less probable sources of salt-water contamination include upward movement of salt water from below vertical movement around salt domes or along faults, downward seepage from surface sources, and contamination through leaking wells."

Winslow et al[4] also wrote:

> "The surface disposal of oil-field brines is another possible source of contamination. If the brine is placed in surface pits, at least part of it will sink into the ground and may contaminate the shallow aquifers, particularly if the pits are in the outcrop of the sands."

Todd[21] recently published the following statement:

> "Salts are added to ground water passing through soils --- products of soil weathering---. Excess irrigation water --- may contribute substantial quantities of salt. Water passing ---- contains saline concentrations several times --- applied irrigation water. ---soluble soil materials, fertilizers, ---absorbtion of salts by plants---modify salt concentrations ---. Factors --- soil permeability, drainage facilities, amount of water applied, crops, and climate. --- high salinities --- in soils and ground waters of arid climates --- poorly drained areas, --- contain high salt concentrations. --- badlands implies lack of productivity resulting from excess salt ---"

2. Effect of Chlorides on Water Quality

The question of chlorides as contaminants involves some complicated relationships. The Public Health Service Drinking Water Standards - 1946 states:

> "Chloride (Cl) should not exceed 250 ppm."

However, many water supplies with substantially higher concentrations have been used over several years with no apparent health problems.

McKee[2] prepared a comprehensive statement:

> "Although for drinking purposes water with a chloride concentration up to 1,000 ppm may be physiologically safe, low concentrations of some chlorides would be objectionable in domestic supplies because of taste and soap-destroying power ----. Chlorides may also be disadvantageous in domestic and industrial waters because they accelerate corrosion in pipes, boilers, and other fixtures. Chloride concentrations as low as 20 ppm to 100 ppm have been reported to be corrosive. The effect of chlorides in water on the solution of lead is still not clearly established; it has been reported that concentrations below 500 ppm do not affect plumbosolvency and that in some cases chlorides actually decrease plumbosolvency.

---Chlorides in drinking water are generally not harmful to human beings until high concentrations are reached, although chlorides may be injurious to some people suffering from diseases of heart or kidneys. Restrictions on chloride concentrations in drinking water are generally based on palatability requirements rather than on health. Chlorides in water may impart a salty taste of concentrations as low as 100 ppm, although in some waters 700 ppm may not be noticeable. ---the tolerance of chlorides by human beings varies with climate and exertion, and chlorides lost through perspiration may be replaced by chlorides in either diet or drinking water. From hot dry areas have come reports that chloride concentrations up to 900 ppm have not been harmful, and Rudolf[28] believes that even 1000 ppm is harmless. Chloride limits, both those in use as standards and those recommended for use as possible standards, vary over a wide range. It is believed that the source of the chlorides may be a more important factor for drinking water than their quantity and that any sudden increase in the chloride content of a supply should be suspected as a possible indication of pollution and should be investigated further."

Brown[1] discussing quality criteria stated:

"Chlorides are of greatest significance in that such compounds affect the palatability of water, have soap destroying power, accelerate the corrosion of metals, and adversely affect industrial operations and products."

3. Experiences With Chloride Contamination

There have been many instances of chloride contamination of wells - especially in the oil fields. Several mid-western and western states have set-up special laws in an effort to protest ground water supplies from chloride contamination.

Shamburger[5] describing an experience in Clemville, Texas wherein analysis showed chloride contamination ranging from 940 to 4000 ppm, stated:

"Analyses of water from three allegedly contaminated wells ----revealed chloride concentrations of 940, 1,100 and 4,060 ppm. These concentrations are too high for human consumption. ----these 3 wells lie within an area of less than one-third square mile. ----Wells slightly updip from and others considerably downdip from the principal pit disposal area are indicated to be uncontaminated. ---disposal of brine over a period of many years, primarily in areas updip from and north of town, is causing well pollution---. Jointed clay and loosely cemented sand underlying disposal pits favors downward movement of brine to the water table at a slow rate. Movement of brine downdip to areas considerably removed from disposal pits would therefore require much time, possibly several years."

Shamburger(6) discussing stream contamination by brines from underground source in Texas fields stated:

"Gas and oil associated with springs and seepage from old core holes indicates that subsurface leakage from wells tapping oil-and gas bearing strata is responsible for the artesian flowing pressure and consequent contamination of California Creek, possibly augmented by the effects of brine injection wells. ---Possible causes of observed artesian leakage are; (1) natural high pressure in shallow strata containing native, non-commerical accumulations of brine and hydrocrabons, (2) disposal of brine under high pressure through injection wells, and (3) leakage from producing oil reservoirs."

Shamburger(7) discussing an experience in Wilson County, Texas, where normal ground water chloride concentrations were less than 100 ppm stated:

"Analysis of a well indicated contamination from a source, or sources, containing considerably greater concentrations of salts, particularly sodium chloride --- water from this well contains approximately 1,100 ppm chlorides under heaviest conditions of pumping, and approximately 600 ppm --- under minimal conditions of pumping---"

Shamburger[8] describing another water well contamination experience in Runnels County, Texas, stated:

> "Pollution caused by brine percolation from surface pits may reach serious proportions in northern Runnels County. In other parts of the county, well pollution merely reflects the natural salinity of ground water --- well pollution is from brine that percolates from earthen disposal pits and from interformational leakage of brine through defective or inadequate casing in producing wells and exploration holes. ---Water samples contained excessive chloride ion from normal human consumption, according to quality standards of the U.S. Public Health Service ---. Pollution in some wells --- noticeable in periods of low rainfall ---. High chloride figures are considered indicative of pollution of the natural ground-water supply."

Shamburger[9] also reported a fifth experience, in Victoria County, Texas, where he made a reconnaissance of well water contamination in the City of Victoria:

> "Disposal of brine through surface pits located near many shallow wells ---. Most of the samples contained from 1,200 to 1,700 ppm ---. The pits --- brine directly into the upper water sands through which it moves with the ground water to wells tapping the sands."

Martini[10] reporting on salt water contamination experiences in Germany wrote:

> "There are three types of salt water which cause difficulty in Germany: (1) salt ground water in districts near the coast and in islands; (2) salt ground water in the vicinity of rivers polluted with saline industrial waste waters; and (3) ground water which has leached salt from underground formations."

Ulbrich[11] reporting on later (1958) investigations of German experiences in limestone districts with largely arable land and in limestone and sandstone districts along the Rhone Valley, compared to wooded land, found values of chlorides were always

less in wooded districts than for cultivated or inhabited land. He reported chloride was high in a mining district. He concluded that high chloride concentrations in mountain waters were signs of pollution. Relative to one experience he reported:

> "In one district high concentrations of chloride were caused by deposits of rock salt."

Noring[12] relative to an early study (1951) of a German experience wrote that the chloride content of ground water may increase by 13-26 ppm; and the sulphate content by 4-9 ppm. In a number of cases the high chloride content was caused by penetration of artificial fertilizers and not by contamination by manure or sewage.

Vinck[27] in a more recent discussion relative to The Schleswig-Holstein area reviewed questions of cause, extent, and control of salt content in ground waters.

Bacon, et al[13] in describing several experience with salt water contamination in California wrote:

> "at relative shallow depth --- in coastal basins, saline waters have been found overlaying deeper strata of better water. In some cases where proximity to the ocean suggests sea-water intrusion as the cause of degradation of the deeper water, the true cause is infiltration of --- perched saline waters." Samples in San Diego County contained up to 10,000 ppm of chloride. ---water at a depth of 100 feet in the vicinity contained about 500 ppm. ---chloride in the water pumped from this well increased from 518 to 720 ppm --- in eight months --- two factors - the interconnection of strata through the gravel envelope and the development of a differential head through pumping from the deeper strata - were responsible for the invasion. Since the avoidance of differential head would in this case,

and in most similar situations elsewhere, preclude any substantial use of the ground water, the only feasible remedy is the establishment of an impervious seal between the zones. Wells with gravel envelope throughout the unfilled abandoned wells are dangerous in any situation where quality varies widely in different strata."

Bacon et al[13] also reported:

"Investigations made by the Division of Water Resources show that degradation of fresh water supplies from sea-water intrusion has occurred in thirteen major and minor ground water basins along the coast and inland bay areas. --- the direct cause in all instances may be attributed to over-pumping, which has reversed the normal seaward slope of the water table or the artesian-pressure surface. Furthermore, seven other ground-water basins are threatened."

Shafer, R. A.[14] with reference to experiences in Southern California wrote:

"---an investigation of changes in the quality of ground water from 1931 to 1946-52 by the engineers of the San Bernardino County Flood Control District (Southern California) has disclosed numerous areas in the basins of Riverside and San Bernardino counties where the salinity of ground water has increased significantly. Many of these foci of pollution can be readily associated with farming and industrial practices or the disposal of sewage wastes in the areas in which they occur. For others the causes are obscure. ---the phenomenal increase in urban and industrial development now occurring, and the necessary resort to the use of more saline imported waters to supplement the native supplies, will inevitably accelerate the rate of degradation of basin ground waters. ---the solution of the problem appears to require prevention rather than cure, for it is doubtful that pollution once established in the deep basin waters could be flushed out."

Tolman and Poland[15] relative to experience in Santa Clara County, California, wrote:

"Over-pumping, especially at Palo Alto, has drawn down the pressure gradient --- the wells in this area are pulling water from the gravel despoits under the bay, and if the

thick upper layers of clay had not been penetrated by wells which were later allowed to fall into disrepair, there probably would have been no serious salt-water contamination ---. From 1907-08 to 1929 water from the well nearest the bay increased in chloride concentration from 27 ppm to 3,000 ppm ---.

"It will probably be difficult to seal completely all the wells within the tidal lands, and advance of contamination will probably be checked completely only when and if water recharge --- brings the water-level in the wells above sea-level. It will be very difficult, if not impossible, to remove by recharge any salt water which enters the lower aquifers in the meantime. ---Ground-water depression was limited to areas underlain by dense blue clay ---. No sinking --- occurred within areas where water-table conditions exist, or in areas underlain by more than 40 per cent of sand and gravel."

Piper and Garrett(16) after studying salt water contamination in the Long Beach-Santa Ana area in California wrote:

"---the potential saline contaminants are the connate waters in the rocks of tertiary age, oil fields brines and oil-refinery wastes, and fluid industrial wastes. The connate waters are sodium chloride brines ranging about from 10,000 to 39,000 ppm of dissolved solids. They have been tapped by several thousand oil wells, but there is no evidence that they have moved upward into any fresh water body."

Piper and Garrett(16) relative to experience in Orange County, California, also wrote that by 1944 the ground water from one well:

"---increased in chloride content to about 18,000 ppm; thus, --- in the preceding twelve years water as salty as that of the ocean had advanced at least a quarter of a mile. ---the inland reach of the contaminated waters --- is exceeding irregular. The greatest reach presumably is by fingers or tongues of the contaminant drawn toward --- heavy withdrawal, probably in the lower part of the aquifer. Toward the coast --- fingers --- merege into --- continuous front behind which contaminated water occupies the aquifer from bottom to top. Within the inland-probing fingers ---, in a belt now roughly from 0.2 to 0.5 mile wide, the contamination seems to have progressed only through the first stage; --- derived

> locally from the connate-water bodies of the San Pedro formation, the chloride content is less than 1,000 ppm ---. Beyond that belt --- the waters --- grade, locally within as little as 0.1 mile, into a composition essentially identical with --- ocean water. Available data suggest that this three-dimensional pattern has persisted during the inland march of the contamination front since the early thirties."
>
> "In the twelve years ending with 1944 the contamination front progressed into the Santa Ana Gap as much as 0.7 mile and water of ocean composition progressed at least one-fourth mile. Thus, ---the average rate of advance was about 200 ft. a year --- for 50 ppm of chloride, and about 135 ft. a year for the highly contaminated water --- for 10,000 parts of chloride."

Winslow et al(4) relative to the experience in Harris County, Texas, stated:

> "The most serious --- contamination of the fresh-water sands --- is by lateral migration of salt water up the dip. The deepest sands --- heavily pumped --- contain salt water a few miles down the dip. A hydraulic gradient --- from the salt water toward the area of withdrawal and --- salt water must be moving towards the areas of pumping. ---Although the rate of movement of the salt water is --- slow, the interface --- may lie closer to pumped areas than is believed."

Parker(17) after a study of salt water contamination in southern Florida wrote:

> "The water is hard, sulpherous, and in southeastern Florida, is generally so corrosive that it is unfit for use. ---the source of salt water contaminating the ground water in southern Florida may be the ocean, or sea water that entered the water bearing formations prior to recent time."

Parker(17) also describes experiences in Florida incident to construction of drainage canals:

> "Most of the salt water contaminating the shallow ground water in the coastal areas is derived from the ocean,

> either through canals and natural waterways, or through lateral and/or vertical movement at depth in the aquifer ---Before drainage began, salt water from the ocean was held in check by the high head of fresh water on the land ---. As a consequence of the cutting of the canals the water table was lowered ---. Salt water is heavier and denser than fresh water --- when salt and fresh water meet they tend to remain separate, with a comparatively narrow zone of diffusion between the two --- thus, when salt water moves upstream in a canal or river it creeps along the bottom. ---the amount of salt water that escapes --- into adjacent rocks is dependent upon --- capacity of the rocks --- to transmit water - presence ---. a layer of silt which --- a relatively impermeable seal -- height of water table adjacent --- these conditions lead to salting of some areas --- other areas remain unsalted. ---when salty water --- reached --- the (Miami) canal --- it penetrated downward---."

Brown and Parker[26] reported on experiences with salt water encroachment in limestone at Silver Bluff, Florida, which covers another area of salt water contaminations.

4. Reported Permissible Concentrations

The permissible concentrations of chlorides in drinking water may be related to (1) the question of the safety of the water source or (2) the amount of salt which may be taken into the body over a prolonged period of time.

Schneider[18] considering the first question in review of a paper before a meeting of Water and Sewage Technicians at Wiesbaden stated:

> "Variations in the contents of salts were related to the geological formations rather than to local pollution, and no conclusions could be drawn from them regarding the sanitary condition of the water. He found that analysis

of water from a well is not sufficient for determining its suitability for domestic use without a knowledge of the composition of the ground waters of the district."

McKee[2] discussing chloride concentration stated:

"The U.S.P.H.S. Drinking Water Standards of 1946 recommend that chlorides do not exceed 250 ppm. In other agencies or other countries, the criteria for chlorides have been given at values ranging from 10 ppm. to 500 ppm."

In connection with the saline water conservation program - some attention has been given to the question of what salt concentration constitues saline water.

Tullis et al[19] have defined saline water as:

"Waters which contain 1000 ppm or more of dissolved solids or which contain 60 per cent or more of cations as sodium (Na)."

Winslow and Kister[3] also used the above definition. They classified Texas waters as follows:

Description	Dissolved solids, in parts per million
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	more than 35,000

Winslow and Kisler[3] also stated:

"Water used by many small communities, farms and ranches is in the slightly saline range. Water of this class has been --- somewhat unsatisfactory but generally not harmful. ---Water having a dissolved solids content ranging from 3,000 to 10,000 ppm --- described as moderately saline, is unsatisfactory --- and is rarely used for domestic supply."

Culp[20] has presented a helpful discussion of chloride (by letter) stating:

> "---the 250 ppm (Drinking Water Standards) value for chlorides was arrived at solely on basis of taste. A few persons can detect a chloride taste in water --- as low as 170 ppm. ---majority --- can detect --- 250 ppm --- a few --- may not notice --- until --- 500 ppm or more ---. Our experience --- bears out these --. So from --- aesthetics at least, I --- agree with the Drinking Water Standards --- several areas in Kansas --- contain as much as 500 to 700 ppm ---. Persons living in --- communities use --- without --- objection ---, but tourists and visitors --- detect the salty taste --- every few public supplies having --- in excess of 1,000 ppm --- are used only for sanitary purposes and fire-fighting --- other water for drinking and culinary purposes."
>
> "Actually --- little information --- physiological effects --- of saline drinking water --- principal unanswered question --- effects --- 1,000 to 5,000 ppm of total dissolved solids. ---Known to produce minor gastric disturbances --- are only marginally acceptable as regards taste, --- other adverse effects --- for cooking. Potatoes, carrots --- when boiled --- remain hard and will not cook thoroughly. I agree --- 1200 to 1400 ppm ---level which begins to produce discernable physiological effects."
>
> "In Kansas most --- high chloride waters also high in sodium content. ---patients --- common diseases of heart, kidney and liver are --- on restricted sodium therapy -- must use low sodium water."
>
> "In -- public water supplies we use 250 ppm as the 'desirable maximum' and class --- 500 ppm of chlorides as 'useable' waters."

Barksdale[22] describing an experience in New Jersey of salt water contamination in wells two or three miles from the source of the salt water wrote:

> "--- the situation --- is unusual --- salt water has gained access to the sand at points up the dip from the pumped wells. ---Increased pumping and --- deepening of channels for navigation --- caused the major intrusion of salt water.

---the salt water is advancing through the sand toward the pumped wells in waves of high salinity followed by somewhat lower salinity. ---as long as the pumping is continued each crest will probably be higher than the one before it, because water of higher salinity found near the salt-water intake will be drawn toward the pumped wells. ---the sand is covered by a layer of clay so that salt water cannot escape ---. If some means could be devised to shut out any additional salt water it might be possible to remove the salt water --- already in the sand by pumping and --- restore the usefulness of the sand."

PASSAGE THROUGH SOILS

5. Nature of Movement

Considerable research may be needed to establish clearly the nature of movement of chloride waters. Probably there may be different effective factors above and below the ground water table. To date the published data is meager and uncertain.

(a) Above ground water - not sufficient data are available. Some investigations in Texas and in California provide some theory and limited measurements. In general, the literature indicates a premise that salt water percolates directly downward.

Shamburger(8) reporting an investigation in Texas with reference to movement in soil stated:

"---brine disposed in earthen pits --- in permeable or semi-permeable alluvial materials either percolates downward to shallow water tables or it infiltrates porous zones above the zone of saturation and may seep into surface drainage ways before it reaches the water table."

Shamburger(8) also stated:

"---brine is probably moving in the shallow subsurface due to artesian leakage from wells --- infiltration from --- disposal pits--- brine will rise until static flowing

> equilibrium is established in the well --- invade shallow, water bearing zones penetrated by hydraulic gradient of the invaded water bearing zone --- it is possible that brine --- can --- pollute wells and surface drainageways a considerable distance ---."

Shamburger, Jr.[8] discussing a brine disposal pit near a well which handled about 150 barrels per day wrote:

> "This brine percolates downward through 40-50 ft. of unsaturated, permeable sand to the water table and then moves along with the ground water to points of natural or artificial discharge. ---the normal direction of ground water movement --- is --- from the pit toward the well. Therefore, the brine is transported to or near the --- well where it is received --- as a mixture of brine and ground water, resulting in an increase in the concentration of all normal constituents of the well water."

b. Movement of Saline Water in Ground Water

Some studies in Texas and in California give a few clues to the question of movement of salt contaminants in ground water. Shamburger[8] discussing investigations in Runnels County, Texas, proposed a theory of movement as follows:

> "---the movement of brine in fresh ground water is not known ---. Seemingly it will settle to the base of fresh water due to higher specific gravity and move down-gradient in well defined courses coincident with lowermost avenues of permeability. Therefore, it may move in 'slugs' or 'tongues' enveloped by fresh water with a brackish transition zone between, due to slight diffusion of brine at the liquid interface. It is possible for brine moving in this manner to encounter some wells and miss others in a particular area."

Shamburger[5] discussing brine disposal in Clemville, Texas, applied the same theory:

> "Brine infiltrating through --- percolates downward to the first water-saturated sand lentil where it becomes a part of the ground-water body, moving along the established hydraulic gradient and settling to lowest points within the reservoir. The brine is believed to move in 'tongues' rather than diffusing throughout the reservoir --- wells

which occur along or near these established channels of brine flow may become contaminated, depending upon the radius of influence of pumpage from each well. Such phenomena may account for existence of contaminated wells near uncontaminated wells of similar depth."

Shamburger(9) discussing a study of contamination of wells in Texas stated:

"Brine disposal pits --- constructed so brines will move rapidly into the underlying sediments. ---these brines are introduced into fresh water sands underlying the area at relatively shallow depths. Several pits --- brine into the sub-surface at points --- the normal hydraulic gradient --- to move it into --- the wells. ---Some wells --- unaffected by contamination because the brine is believed to move in well defined courses, or channels, some of which encounter wells and some do not. Also, wells which are completed in the top of a particular sand may not have sufficient pump capacity to alter brine movement along the bottom of the sand."

Winslow, Doyel and Wood(4) discussing movement of salt water contamination wrote:

"Lateral migration through the formations is the most likely source of contamination ---. ---As pumping continued, the hydraulic gradient became steeper and the rate of movement of the salt water increased. ---the velocity of water through a sand depends on the permeability and porosity of the sand and on the hydraulic gradient ---. At a gradient of 18 feet per mile, it would take about 16 years for the water to travel one mile --- as the rate of pumping increases, steeper hydraulic gradients will be established and the rate of movement of salt water toward the areas of withdrawals will increase. ---As a result of --- different gradients and differences in permeability, the advance of salt water probably will be in the form of an irregular front, with tongues advancing more rapidly in sands in which the greater hydraulic gradients exist or in which the permeabilities are higher."

Winslow, Doyel and Wood(4) also wrote:

"the movement of ground water around salt domes and along faults is not well understood and some of the apparent contamination may be the result of lack of circulation rather than actual contamination from the salt or underlying salt-water sands."

Oberzill[23] has discussed some study of the water supply of St. Polton at Spratzern which is furnished by six wells lying across the line of the ground water flow and salt contamination. The ground water surface was reported to lie about an average of 6 in. below the ground surface. At distances of 50 to 500 meters from the south boundary of the well field are a number of gravel pits which expose the surface of the ground water and in some cases penetrate several meters below the ground water surface. Salt deposited in the furthest pit was found to move completely through the intermediate pit and into the wells, moving at a rate of about 25 meters per day. The added salt appeared almost quantitatively in the water drawn from the well field. The paper stated that for protection, all gravel pits within a distance of 500 meters south of the well field should be abandoned and existing open pits should be filled to a depth of 1 meter above the highest ground-water level and provided with a soil and grass cover.

California Department of Public Works[24] has reported on an experimental "Oil Field Brine Investigation" in Orange County which brought out a number of items of information relative to movement of salt contaminants through soil - no definite distinction was made as between movement of salt above and movement with the ground water. Much of the information probably applies more definitely to movements of salt solution in soil above the ground water.

Some abstracts from the report follow:

> "During the first 24 hours of operation, percolation rates dropped from 4.40 to 2.77 foot per day. Approximately 72 hours after inception of operation, the percolation rate had diminished to 2.35 feet per day.---"

> "The steady state of percolation was evident after 75 days of operation with a mean rate of 0.15 feet per day. Ultimate low rates of percolation were traceable to the apparent separation of the fines of the soil as well as deflocculation produced by chemical changes down to 0.0125 feet per day during first period of operation. Then they remained relatively uniform, varying from 0.0085 feet per day to 0.0208 feet per day. ---Penetration rates at the terminus of the curve were of the order 0.018 feet per day."

The report shows fluctuations during the first phase of tests due to rainfall or seepage:

> "Unfortunately, some uncontrollable runoff reached the sump resulting in low or negative percolation calculations for intervals of rainfall."

Another comment of value to future studies, related to brine in surface lagoons:

> "---The disposition of brine from surface disposal sites is similar to that of rainfall, runoff, and irrigation water; that is, it is affected by transpiration, evaporation, and percolation. Transpiration may be eliminated for quality reasons as being insignificant. The principal factors, then, are evaporation and percolation."

Some effort was made to determine the effect of the chemicals in brine on percolation rates. A summary statement was as follows:

> "Throughout the initial --- investigation of percolation rates --- a gradual decrease was noted. Over a long period, the rate tended to approach equilibrium. The geochemical agent responsible for the decrease appears to be primarily base exchange with calcium and magnesium replacement accomplished by a high sodium brine, the net result of the exchange reaction is deflocculation and lowered infiltration rates ---. ---A substantial decrease in per cent sodium by the addition of calcium to the brine, resulted in a significant change in percolation."

As to the removal of chlorides the report states:

> "Throughout the series of experiments, no significant change in chloride concentrations were observed. Percolate from both 2½ ft. and 5 ft. collecting trenches indicated no substantial chloride change during any phase of the operations. ---the major import of the test findings tends to point out the potential of chloride as a pollutant to ground water inasmuch as no appreciable change occurs during percolation through soil. Barring physical barriers, the available chloride would, in all probability, eventually find its way to ground water from surface pollutants."

6. Removal or Reduction in Chloride Concentration

Chloride contamination might be improved either by removal of the chloride ions or a reduction in concentration down to an acceptable concentration by dilution with fresh water.

The actual removal of chlorides from contaminated water as it moves through the ground is unlikely. Most writers have indicated that chlorides are not removed by passage through soil, either above or in the ground water.

Reduction in concentration appears to be accomplished only by dilution with water of low chloride content. Since the permissible concentration is relatively high (500 to 1000 ppm) and the normal chloride content of most waters relatively low (20 to 50 ppm or less) there is a good possibility of improvement in chloride contaminated underground water, except that diffusion of high chloride water is slow. The contaminated water appears to move as a tongue or stream of high salinity water.

Some published comments on these two phases of chloride contaminates follow.

The Fifth European Seminar[25] on ground water pollution reached some general conclusions on purification through natural fine sand, one conclusion:

> "Some polluting substances are not removed in the ground at all. Of those, salts such as chlorides have given the most trouble. The quantities of chlorides discharged into the ground should be so regulated that, after dilution, by the time a source of supply is reached, their concentration will not make the water non-potable or unfit for any other essential use."

Winslow et al[4] discussing conditions in Harris County, Texas, wrote:

> "If, however, the brine is injected into deep salt-water sands through properly constructed wells, there is very little danger of contamination."

Piper and Garrett[16] analysing wells in the Long Beach - Santa Ana area wrote:

> "The proportional amount of contaminant in the yield of an individual well can be controlled with substantial effectiveness through exploration ---, by determining the position of the interface between fresh-water and contaminant, and by securely plugging the well above that interface; also, by limiting the withdrawal sufficiently to keep the interface below the plug."
>
> "In addition, it would be necessary to plug all abandoned wells and repair existing wells in which inadequate or defective casing permit contaminants to circulate into the fresh-water aquifer from overlying or underlying zones. ---"
>
> "It is desirable for all abandoned wells when being plugged to be filled completely with impermeable material, so that even after the casing has disintegrated no permeable conduit exists to connect one water-bearing zone with another.

Shamburger, Jr.[8], relative to wells in Runnels County, Texas, stated:

> "Brine disposal pits have been partly supplanted by injection wells in several areas of the county where wells have been polluted. However, earthen pits --- have been dug to permeable alluvium which is tapped by water wells ---. Brine disposal under these conditions is apt to pollute ground water ---, and should be prohibited. Abandonment of these pits should relieve or end pollution which is caused by surface disposal ---".
>
> "Proper containment of artesian salt water --- is essential to pollution abatement. All wells penetrating brine under artesian head should: (1) have adequate surface casing, (2) be heavily mudded if completed for oil production, and (3) be plugged at the base of the surface casing, at a point immediately above the uppermost artesian salt water, and above all oil production zones, if abandoned."

Parker[17] discussing salt water contamination from canals in Florida, stated:

> "---salty water in the ground under the canal --- continued to sink toward the bottom of the aquifer and to create a salt water mound. By dilution with the overlaying and surrounding fresh water, it was drawn toward the well field, the mound of salty water finally became entirely isolated from its original source and the water of greatest chloride content came to be at the bottom of the aquifer. ---the salty water is continually but slowly being diluted by fresh ground water, and also is being removed by pumping from the well field. If no further contamination occurs through the canal the final stage will be reached with a return to original conditions."

DETERMINATIONS FROM SURVEY

The literature on chloride contamination is extensive, especially with regard to ground water contamination by brine disposal from oil wells. More recently problems of salt water intrusion from sea water have arisen in Florida and California. Some suggestive ideas from the library survey are outlined in the following paragraphs.

7. Predicting Chloride Contamination

The present art of predicting chloride contamination is based largely on fairly extensive investigations including laboratory analyses of water samples from numerous bore holes under four situations as to source of contamination:

a. Efforts to dispose by lagooning salt brines from oil wells and industrial processes, using or producing salty waste waters. Experience has shown that such lagoons quite generally permit salt water to leach into or overflow into underground water bearing strata. Accordingly, if there is little or no impervious strata above the aquifer chlorides will sooner or later reach the ground water, generally down stream of the lagoon area. Chlorides are not removed by passage through soil.

b. Many oil wells permit salt water from deep strata to rise and frequently find its way into ground water supplies from higher strata of fresh water. Most State laws require abandonded oil wells to be sealed and the well filled to guard against salt water leakage. The sealing of oil wells sometimes is incomplete, or a large amount of salt water reached the fresh water strata before sealing of the wells was completed. In this case the ground water may be excessively contaminated along narrow bands or slugs of water, which in due time or at sufficient distances may become diluted with fresh water until the salt concentration is reduced below a permissible concentration. This can be determined only through expensive underground explorations by bore holes or jet borings.

c. Many lagoons for storage of salt brines permit salt waters to reach the adjacent ground water. Abandonment of the lagoon may still leave salt contamination for several years until fresh water dilution eventually reduces concentration of salt below permissible limits. Frequent tests of the ground water, especially down-dip of the contamination, may determine when or where a permissible chloride concentration is reached.

d. Areas in Florida, and possibly at other places where canal construction has permitted sea water to flow inland and seep into underground fresh water strata may be improved by construction of special barriers to keep back the salt water and then pumping out the highly concentrated contamination until dilution by fresh water reduces the chloride content belong a permissible maximum concentration. This requires extensive investigations.

e. Intrusion of salt water into ground water strata especially near seashores has occurred in many places. Extensive studies in Southern California indicate two methods to abate chloride contamination (1) by reducing the pumpage from the area near the ocean, and (2) establishment of a fresh water barrier by pumping fresh water into the water bearing strata to form a ridge of fresh water to hold back the salt water. Either of these methods would be expensive and would require covering large areas with the protective measures.

Thus, the forecasting of contamination by chlorides for any particular location would involve a study of previous experiences in nearby existing wells or a very expensive underground survey by borings and laboratory analyses of water samples, with the wells or observation borings extending over a considerable area up-dip of the proposed well or between the proposed well and any known source of chlorides.

Substantial additional information on underground water mineral content at any given proposed well site before any forecast of potential contamination can be made without quite expensive geophysical surveys, including underground explorations by observation wells or bore holes.

Since the concentration of chloride is the important factor and chloride concentration is reduced by dilution with fresh water

some method is needed for determining the relative volumes of fresh water vs saline water contamination, the rates of underground flow, the direction of flow, the rate of spreading of the contaminated water into, hence dilution by fresh water, and the production of chloride at the source of contamination.

Possibly in due time refinements in the seismic refraction, the electric resistivity, or some similar geophysical exploration by an acoustical or electric method may be made to permit detecting salt concentrations in ground water from the ground surface without test wells or possible from a limited number of existing wells in the vicinity of the proposed well site.

Many well supplies, particularly small residential supplies, often are from underground pools of limited volume. In this case information would be needed on the source and rate of recharge together with completed or observed data on the relative total recharge into the underground pool compared with the inflow of chloride. An inflow of chloride solution greater than the inflow of fresh water would doom any water bearing strata in due time.

8. Water Quality Criteria Needed

The present public health standard for chloride should be revised to indicate a more realistic maximum concentration under different conditions relative to the effects of combinations of minerals or organic compounds in the water together with the chloride ion plus the determination of the effect of chlorides on people with different tolerances.

9. Methods for Obtaining Information Needed.

a. Predicting contamination methods could involve, initially, a research project on reviewing the work actively in progress by several state and federal agencies. The objectives of each research program in progress would be to determine, (1) the progress being made, (2) the near future programs proposed, and (3) the probable value of the results of current investigations to the Federal Housing Administration.

Such a research investigation of current state and federal investigations would be done largely by correspondence, plus a visit or two, plus a study of published reports, plus analyses of unpublished data and memoranda; and a studied correlation of information from all sources with reference to the needs of residential housing.

Probably the results of such initial research investigation would indicate areas in which more specific research must be done to meet the needs peculiar to ground water supplies for houses.

This initial analyses of existing data should include a study of a number of facets of the movement of chlorides into the ground water including the following items:

(1) Rate and characteristics of travel of saline water relative to soil characteristics.

(2) Effect of concentration of salinity, if any, on flow rates through various soil types.

(3) Rate of diffusion of salt into ground water as indicated by the spreading of the concentration of salt out from the original stream (or "tongue").

(4) Distances of travel through various soils with various water contents before the concentration of salt is reduced to permissible concentrations.

(5) Any evidence of removal of salts by combination, absorption, or adsorption by any soil types. (To date no specific evidence has been found in the literature.)

b. Original Experimental Research - Pilot Plant Scale - to determine basic principles of the travel of chlorides through soils of various characteristics. This should be considered as a supplement to the foregoing study of results and data being developed by current State and Federal investigations.

The objective of this experimental work would be to use a series of lysimeters constructed with different soil types to determine both hydraulic and geochemical reactions on a small enough scale that various influential factors may be determined and controlled to learn the relative influence of each.

10. Summary

There has been a great deal of contamination of underground waters by chlorides due to a number of reasons:

a. Brine disposal from industries
b. Salt water disposal in oil fields
c. Underground bodies of salt water
d. Intrusion of sea water along coast lines due to reduction in level of fresh water by pumpage.

The effects of these causes has become so important in certain states that special State Agencies have been set up in an attempt to control the basic problem.

Much investigative work has been done, but much more needs to be done. It appears likely that the increase in problems of

ground water contamination by chlorides may soon become important enough to H.F.A. activities that research work should be given consideration.

One aspect of the suggested research would be to review a large volume of data already available in files and publications of various agencies. After this is done it might well be desirable to initiate basic research by means of experimental pilot plant work.

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APPENDIX D

CHEMICAL CONTAMINATES

GROUND WATER CONTAMINATION

Topic II-1c. Nitrate Contaminants

December 1959

APPENDIX D

GROUND WATER CONTAMINATION

Topic II-1c. Nitrate Contaminants

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APPENDIX D

GROUND WATER CONTAMINATION

Topic II-1c. Nitrate Contaminants

Introduction

Contamination of water supplies by nitrates has been a serious problem in certain mid-western rural areas. Kay et al[1] stated:

> "The ingestion by infants of water containing large amounts of nitrate is known to cause methaemoglobinaema."

Schmidt[2] in 1956 stated:

> "Very young infants, usually less than two months old, may acquire methemoglobinemia as a result of ingesting water high in nitrates. The ingested nitrate may oxidize a portion of the hemoglobin to methemoglobin with consequent loss of oxygen transport and oxygen exchange in the blood; --- and death may occur."

Nitrate-poisoning of cattle by nitrate water contamination has also been experienced and a report was presented on this in 1951 by Ellis et al[3].

Several writers have suggested that most cases of methemoglobinemia ("Blue Babies") occur in rural areas where well water supplies predominate. Thus, the question of nitrate contamination becomes an important problem in contamination of ground water.

Maxcy[4] has described the effect of nitrate contamination:

> "Methemoglobinema designates the presence of methemoglobin in the blood. Some portion of the heme in the oxyhemoglobin molecule has been oxidized, ferrous ions being converted into ferric ions. Oxygen is so firmly bound that it cannot function in respiration. The color of the blood is changed from the normal deep red to a chocolate brown, giving a cyanotic tint to the skin."

McKee[5] summarized his study of the literature as follows:

> "Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. Since the disease often does not occur even where the water is very high in nitrate contents, however, it seems likely that not all infants are susceptible to nitrate poisonings, but that some are predisposed to it by physiological conditions such as low gastricacidity or other unknown factors."

Cornblath and Hartmann[6] concluded that:

> "---only infants who have a gastric juice pH higher than 4.0 and nitrate-reducing bacteria in the upper gastro-intestinal tract develop methemoglobinemia."

They wrote that prevention could be accomplished by adding lactic acid to the nitrate containing formula to inhibit bacterial growth in the upper gastro-intestinal tract as well as by prohibiting the ingestion of nitrate.

Horn[7] supported the above theory of Cornblath and Hartmann.

Maxcy[4] suggested that the cause of methemoglobinemia may not be due alone to:

> "---the age of the infant, quantity of water ingested, and concentrations of nitrate nitrogen used for dilution of formula, but that there is a difference between nitrate nitrogen derived from organic and inorganic sources. Or that it is necessary to have present some additional factors derived from biologic activities in the soil or in the well water ----"

Ewing and White[20] stated:

> "The history of our 2 cases illustrate the fact that methemoglobinemia is a cumulative poisoning taking some days or a week or two to develop. Once the ingestion of nitrates has been stopped the disease is self-limiting."

Faucett and Miller[8], Metzler et al[9], and others[10], [11] have discussed other phases of variations in severity of the effect of nitrates on infants.

Todd[48] in his book states, relative to salinity of ground waters:

> "Nitrates only rarely an important natural constituent; high concentrations may indicate sources of past or present pollution."

1. Sources of Nitrate Contaminants

There appears to be several possible sources of abnormal nitrate concentrations in ground water supplies.

McKee[5] has prepared a summary statement as follows:

> "Nitrates are the end product of the aerobic stabilization of organic nitrogen ---. Nitrates also occur in percolating ground waters as a result of excessive application of fertilizer or leachings from cesspools. ---or directly by inorganic industrial wastes, but such sources are relatively insignificant."
>
> "---nitrates are seldom abundant in natural surface waters, for they serve as an essential fertilizer for all types of plants ---. Photosynthetic action is constantly --- converting them (nitrates) to organic nitrogen in plant cells. In deep ground waters, however, this action is not possible and, ---- excessive and deleterious concentrations of nitrates are often found."

Nitrates

Metzler and Stoltenberg[9] discussing the character soils relative to nitrates in ground water stated:

> "---damp soils --- lose considerable amounts of nitrates during the winter because of leaching ---. A seasonal variation in the nitrate content --- basis of peak --- bacterial activity and times when leaching --- is greatest. ---supports --- contamination of shallow improperly protects wells, --- does not --- answer --- source of high nitrates found in deep properly sealed wells."

Siemens and Mallet[12] wrote:

> "Unusually dry seasons with unusually low ground water tables might promote the leaching out of nitrates ---."

Waring[13] in an early (1948) paper observed, relative to source of nitrates:

> "Current studies in Illinois, Minnesota, and Iowa seem to show that by far the largest portion of waters with high nitrate content is from dug wells."
>
> "---because high nitrate incidence --- highest in dug wells, --- the source of the nitrogen must be of surface origin. ---plant life is the chief source, particularly clover and legumes."

George and Hastings[14], Waksman[15] and Ullrich[16] have discussed the role of bacterial action in nitrate formation. George and Hastings[14] also pointed out that waters with high nitrates generally contain large amounts of chloride and sulphate. Ullrich[16] observed that nitrates were always less in wooded districts than in cultivated or inhabited land.

Ellis et al[3], from an extended study of nitrates in farm soils, reported:

> "---Whereas the levels of nitrates in ground-water --- below the fields (under fallow, corn, etc.) were either of a low order or negative, the levels of nitrates in ground-water below the farm steads --- show highest nitrate concentration --- were the privy, the barns, the hen-houses, and house-yard ---. It was concluded that privies, barns, barnyards, pig pens, poultry yards, and corrals --- the chief source of excessive --- nitrates in the shallow ground-water."

2. Effect on Water Quality

The effect of nitrate contamination is the occasional case of methemoglobinemia in very young infants. There seems to have been no serious effects on adults. In some cases nitrate concentrations as high as 638 ppm were reported, in a record from Oklahoma on 415 wells, with no reported cases of methogobinemia.

Cox et al[17] summarized a questionnaire sent out by a Committee of the A.P.H.A. which recorded data on nitrate content of wells ranging from 11 ppm to 974 ppm (in Michigan) in records from 47 states. The Committee report did not find any effect on water quality other than a possibility that some well waters may be unsafe for infant feeding formulas.

McKee[5] summarized the effect with the statement:

> "Nitrates are poisonous ingredients of minearlized waters, with potassium nitrate being more poisonous than sodium nitrate ---. Excess nitrates cause irritation of the mucous linings of the gastro-intestinal tract and bladder with symptoms of diarrhea and diuresis --- one liter of water containing 500 ppm of nitrate can cause such symptoms."

Wise[22] discussing a study during the 1948 polio epidemic suggested a possible relationship between the incidence of poliomyelitis and the concentration of nitrates in the drinking water.

Ewing and White[20] stated:

> "Popular belief that boiling water makes it safe is misplaced in the case of nitrate contaminations for the nitrates contamination remains the same."

(It may become more concentrated with prolonged boiling.)

3. Reported Permissible Concentrations

The record of incidence of methemoglobinemia has not been definitely related to any specific concentration of nitrate. So permissible concentrations are really mere arbitrary limits set by some health authorities. The U.S. Public Health Service Drinking Water Standards[49] includes no reference to nitrates.

There appears to have been occasional confusion in the use of the terms nitrate-nitrogen and nitrates. Thus, 10 ppm as nitrate-nitrogen is equivalent to 44 ppm as nitrates. Some writers do not clearly state the unit used.

Kay et al[1] stated that in Manitoba Province:

> "An empirical maximum safe upper limit was set at ten parts per million nitrates(in terms of nitrogen)."

Cox et al[17] concluded (in 1951) from results of a wide questionnaire:

> "---it is impossible at this time to select any precise concentration of nitrate in potable waters fed infants, which definitely will distinguish between waters which are safe or unsafe for this purpose."

McKee[5] recorded (in 1954) from Caballero[18], the following:

"Standards for drinking water adopted as guides in various American countries recommend the following concentrations of nitrate as the maximum permissible:

Venezuela	0.5-10 ppm
Brazil	7.4 ppm
Dominican Republic	20 ppm
Mexico	22 ppm
Uruguay	228 ppm

McKee[5] also summarized data on permissible concentration in published writings up to the time of his report (1952) by the following:

"Most cases, however, have been associated with the use of water containing 50 ppm or more of nitrate-nitrogen (17, 23); and concentration of 10 to 20 ppm (13, 23, 11, 24); 30 ppm., and 100 ppm (25) of nitrate nitrogen have also been associated with methemoglobinemia. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 to 20 ppm. of nitrate nitrogen should not be used for infants. (25, 24, 26, 11, 27, 28, 13, 23, 29)."

"Reported as nitrates, concentrations of 20 ppm (30), 70 ppm. and up to 619 ppm. (8, 25) have caused severe cyanosis among infants. Water may be considered to be good hygienic quality and safe for infants if its nitrate content does not exceed 10 ppm. (31, 32); or 20 ppm. (33, 34)."

McKee[5], in 1954, added to his original summary (above):

"Tolerance levels for nitrate nitrogen or for nitrate in drinking water have not yet been established definitely. Recommendations have been made that a centration of 10 ppm as nitrate-nitrogen (equivalent to 44 ppm. as nitrate) should be the maximum permissible limit (14); and in another instance that 10 ppm as nitrate should be the maximum permissible limit. (35, 36)."

Nitrates

A number of writers have offered their opinions as to upper limit of nitrate concentration for infant feeding.

a. Comly[11] concluded that the upper limit should be 10-20 ppm.

b. Bosch et al[19] found that methemoglobinemia occurs when concentrations were over 10-20 ppm in the water used for infant feeding formulas and there is a spontaneous disappearance of the disease in 24-28 hours after changing the water for the formula.

c. Cornblath and Hartmann[6] suggested a safe value of 10 ppm.

d. Ewing and White[20] suggested that 20 ppm nitrate should be a maximum concentration.

e. Waring[13] considered that 10 ppm nitrate N would be safe.

f. Medovy[21] suggested a safe value should be 10 ppm.

g. Walton[26] stated a qualified conclusion as follows:

> "The permissible nitrate-nitrogen concentration in water which may cause infant methemoglobinemia when used in a feeding formula is dependent on the individual susceptibility, the increase in nitrate-nitrogen concentration due to boiling of water, the quantity of boiled water consumed per day per unit weight of infant. The duration of exposure to the high nitrate water, and possibly other factors."

h. Ewing and White[20] stated:

> "---that nitrates should be regarded as a potentially dangerous contaminant of drinking water, and that 20 ppm. should be regarded as the highest acceptable figure in water used for preparing an infant's milk mixture."

4. Experience to Date

The literature appears to relate the effects of nitrates only to methemoglobinemia in infants.

Metzler and Stoltenberg[9] stated the occurrence of the disease:

> "---appears to be relatively widespread - at least through the central plains states."

Ewing and White[20] reporting the history of two English cases stated:

> "So far as we know, no cases of well-water cyanosis have been reported in adults, but in view of the heriditary nature of achlorhydria one wonders if a similar mechanism may not operate in some cases of 'familial idiopathic methe'."

Waring[13], in an early (1948) review, stated:

> "---high nitrate contents were not found in municipal waters, but were prevalent in many rural supplies---."

Waring[13] also reporting an industrial contamination at Warren, Ohio, initiated by difficulties in obtaining ammonia-free distilled water, he stated:

> "---10 ppm nitrate-nitrogen content of the river water was the result of manufacture of ammonium nitrate at an arsenal now employed in a highly concentrated fertilizer -- nitrate dust escaped in the production --- constituted serious industrial explosive hazard."
>
> "---the experience at Warren has served to alert the department to the possible hazards from industrial wastes which can impart dangerously high nitrate contents to waters used as drinking supplies."

The New Mexico Department of Public Health[37] reported on experiences with nitrate contamination in wells from uranium ore milling plant wastes of the Anaconda Company:

> "---the waste is discharged to a lagoon --- in use since 1953 --- an estimated 11.7 acre feet per day --- was escaping by seepage---."

Nitrates

The New Mexico report indicates that analytical data were obtained from seven shallow wells and a deep well and stated:

> "Nitrate-N of wells within 1.7 miles of the plant averaged 3.4 and 7.5 ppm. before 1955. At distances of 3 miles or more it averaged between 1.2 and 4.8 ppm. ---of six wells, two showed marked increases to 15 and 16 ppm. ---the two wells with maximum nitrates were among the three of the shallow wells closest (2.5 and 5.3 miles) to the waste lagoon ---. In May 1957 two wells in the shallow aquifer and three in the deep aquifer had nitrate-N in the range of 15-19 ppm."

Rosenfield and Huston[29] reported the medical aspects of 146 cases of methaemoglobinaemia in Minnesota attributed to water supplies with concentrations of nitrate-N over 20 ppm.

Schmidt[38] reported on soil survey (in 1951) in Southern Minnesota, including 39 water supplies at 26 sites in which he stated:

> "Cases of methemoglobinemia induced by well waters high in nitrates have been reported principally in the mid-western United States and the central Provinces of Canada (4, 26).---Several writers have suggested that nitrate formation in normal agricultural soils may contribute significantly to nitrate accumulation in rural well water (4, 9, 39, 29)."

Ellis et al[40] reported on investigations (1951) into questions of high nitrates in water and fodder in Neepawa area of Manitoba in which they stated:

> "Medical officers --- had reported --- bluish color of skin (i.e., methemoglobinemia) --- in young bottle fed infants ---. The second problem --- nitrate-poisoning (winter of 1950-51) of cattle in the Neepawa district."

Nitrates

Kay et al[1] reported that a case (in the fall of 1946) of cyanosis in an infant ingesting water from a well found to contain 150 ppm nitrate and over 100 water samples from physicians lead to a study of nitrates in ground waters. He summarized the study:

> "---first phase of the project, it appeared that approximately one-third of all rural well water in Manitoba contained an excessive amount of nitrate, potentially hazardous to young infants."

Kay et al[1] presented:

"Reports from other centers --- Table II -- for Comparison -

TABLE II - Correlation of Surveys

Location	Percentage of all Wells Tested		
	Nitrate*	Bacteria#	Coincidence
Manitoba	33	31	14
Saskatchewan	31	60	20
Iowa **	76	--	--
Ohio	5	--	4
North Dakota	15	--	--
Illinois	29	--	--

Notes: *Nitrates greater than 10 ppm (N)
#Water containing B.coli
**Suspect wells only. Others are based on a general survey

Kay et al[1] endeavored to correlate N. with other constituents.

"The results --- Table III -- wells were grouped --- nitrate content --- examined -- other constituents.

TABLE III - Wells Grouped According to Nitrate Concentration

Nitrates	Less than 10 ppm	10-100 ppm	100-200 ppm	Over 200 ppm
Total Alk. Aver.	296	404	380	409
Chloride "	202	124	263	384
Sulphate "	458	780	652	1060
Total Hardness Aver.	644	782	1924	2582
Total Solids "	1411	1814	3724	13382

From Table III, Kay[1] concluded:

> "Since each constituent rose with nitrate content, no precise conclusions can be reached as to the source of Nitrate --- Bibliography (see 41, 42, 43, 31, 13)."

George and Hastings[14] reporting on extended analyses of nitrate content of ground water in Texas found four reported cases of methemoglobinemia, but considered that probably many cases were not reported and possibly some cases were not recognized. They found municipal wells less than 60 feet deep containing abnormal nitrate and that:

> "---pollution definitely is not sufficient to account for the high concentration of nitrate---. Probably more than 95 percent of wells yielding abnormal nitrate waters are less than 200 feet deep --"

> "In Texas abnormal nitrate is found in water from formations of all geologic ages ---the formations that yield water high in nitrate do not necessarily contain large amounts of organic material."

> "Nitrate is not the predominent anion in most waters --- high in nitrate concentrations."

George and Hastings[14], explaining the Texas experience, stated:

> "Natural waters do not ---- 5 to 10 ppm. NO_3 --- those containing more than 20 ppm nitrate --- called 'abnormal' -- abnormal nitrate --- all parts of Texas --- three samples contained 1440, 1610, and 1950 ppm nitrate --- many waters ---abnormal nitrate are highly mineralized."

They reported that in Coleman County 58 out of 133 waters tested had more than 20 ppm. nitrates.

Abbott and Voedisch[44] reported on nitrate content in North Dakota waters, indicating 84.9% with nitrate N concentrations 0 to 10 ppm. and 15.1% with over 10 ppm. nitrate N.

Nitrates

Van Heuvelen[31] reported on nitrates in waters in North Dakota; Dugan[27] furnished data for Kentucky; McGuire[45] reported on Michigan experience; and Everloff[46] discussed 25 cases in Illinois of disease in infants with two deaths where water had nitrate N concentration of 24 to 252 ppm. Weart[55] also discussed the Illinois experience. Early (1940) Nebraska experience data were published by the State Department of Health[56] and by Delris[57].

Bosch et al[41] reporting on the Minnesota experiences listed 139 cases of methemoglobinemia with water sources from 125 dug wells and four drilled wells. He also presented a map showing wide distribution of nitrate contaminated waters over the State of Minnesota.

Johnson Nat. Drillers Journ.[58] brought the problem of nitrates to the attention of well drillers.

The committee report by Cox et al[17], based on a questionnaire to state departments of health, showed that reported nitrate concentrations, varying from 11 to 976 ppm, were found in 47 states. Twenty states reported rural wells with more than 20 ppm nitrate N. Shallow wells were the chief source of high nitrates in 19 states out of 25 states, while high nitrates were reported by deep wells by 5 states out of 25. Nearby sources of nitrate pollution were reported as significant by 12 out of 22 states reporting on this aspect.

The reported questionnaire results indicated that high nitrate waters were more prevalent and widely distributed than reported cases of methemoglobinemia. Thus, in Texas there were reported many wells

with nitrate N concentration from 22 to 266 ppm with no cases of the disease reported; in Oklahoma 415 wells with an average of 28 ppm (max. 638 ppm.) nitrate N with no cases of disease reported.

deRobillard[50] reported that over a wide area in Madagascar wells contained nitrates up to 1143/1 $NaNO_3$ (190 ppm of nitrate N).

Harper[51], discussing infant cyanosis in Virginia (1949), reported many severe cases of methemoglobinemia caused by nitrate contamination of well waters with nitrate N concentrations ranging from 70 to 619 ppm.

Carlisle[52] presented a medical report (1950) on two cases of methemoglobinemia in Texas which were associated with well waters with nitrate concentrations of 54 ppm and 620 ppm.

Johnson et al[53] reported a study of rural wells in Iowa with results summarized as follows:

Percent of Wells	Concentration of Nitrate-N
60%	Less than 10 ppm
24.4	10 to 50 ppm
9	51 to 100 ppm
6	100 to 600 ppm

Faucett and Miller[8] reported a medical study in Kansas of 2 cases of methemoglobinemia with water having 70 ppm of nitrate and a third case with water of 300 ppm.

Robertson and Riddell[39] reported on 12 cases of methemoglobinemia near Regina, Saskatchewan, (Canada) where all wells contained over 75 ppm nitrates with 2 deaths (water with 275 ppm and 298 ppm). Over 2000 samples of well water were analyzed with results as follows:

Percent of samples	Nitrate N
68.6%	less than 2.26 ppm
12.6%	2.26-11.3 ppm
13.5%	11.3-67.8 ppm
5.3%	over 67.8 ppm

Clarke[54] concluded, in an early (1954) study of geochemical data, that though pollution of ground water generally increases the nitrates, abnormal nitrate concentrations do not necessarily indicate pollution.

Campbell[59] presented a discussion of medical experiences with methemoglobinemia due to well water.

PASSAGE THROUGH SOIL

A number of papers reported on the theoretical aspects of production of nitrates by soil nitrification. There is considerable evidence to show that nitrates in well waters have been produced by biochemical action of the soils.

5. Nature of Movement - The movement of nitrates through the upper strata of soils is greatly affected by the biochemical action of soils.

Nitrates

Schmidt[2], as a conclusion to a considerable soil study, stated:

> "The rich soils of southwestern Minnesota present nearly ideal conditions for soil nitrification, limited normally by the release of ammonium nitrogen from the soil organic matter."

Schmidt[2] explained the mechanics of soil nitrification:

> "Ammonium nitrogen is transformed --- under appropriate soil conditions by --- specific autotrophic nitrifying bacteria of the zenera Nitrosomonas and Nitrobactor."

He also stated:

> "Soils obviously contaminated with organic nitrogen by livestock had the highest nitrifying capacities."

Robertson and Riddell[39] discussing rural nitrate contamination stated:

> "Nitrates are --- end products of bacterial decomposition of animal or vegetable matter. --level of nitrate content --- guide to degree of contamination of a well ---. Barnyard pollution of rural wells is not uncommon --- bacterial decomposition of the humus of the soil must be suspect -- source of nitrates --- deep drilled wells --- such contaminated drilled wells are rare."

Thus, it appears that travel of water through some soils would increase rather than decrease the nitrate concentration.

Metzler and Stoltenberg[9] discussing factors affecting nitrate formation wrote:

> "---salt content of the soil influence --- nitrification, ---calcium and magnesium salts necessary for the neutralization of the nitrites --- potassium salts and phosphates necessary for the growth of all bacteria speed -- nitrification -- oxygen --- nitrifying bacteria --- reason the nitrification increases --- after a field is plowed. Oxygen --- in damp soils where moving ground water is changed --- active nitrification exists --- while under stagnant conditions it does not."

Nitrates

They also observed:

> "Damp soils lose --- nitrates during the winter because of leaching. ---Bacterial activity is greater in thawed soils --- recently frozen --- much nitrate formed in fall is lost through leaching."

Butler et al[47], discussing movements of chemicals through soil, wrote:

> "Where clay is present, cation exchange will take place until an equilibrium is established between the soil and the applied liquid --- studies of travel --- through Hanford soil at Lodi showed --- nitrates increased very markedly ---"
> (in the 13 feet of soil depth observed).
>
> "---two distinctly different aspects of pollution travel --- (1) the movement --- above the ground water table; and (2) the movement --- with ground water. ---The chemical --- sewage is little altered --- after the initial ion-exchange equilibrium has been satisfied, except --- substance that undergo --- bacterial action."

Also:

> "Chemical pollutants travel farther and faster than do bacterial pollutants in the ground water. ---distances varying from a few feet to several miles, and from 2 to 30 times as far as coliform bacteria---"

New Mexico Department of Public Health[37] reported, relative nitrate pollution from Anaconda Company's lagoon:

> "---the well showing greatest increase in nitrates was --- 1.5 miles from the ---- lagoon. ---the evidence that nitrates --- progressed farther in the underlying aquifers that --- other constituents of the wastes is in agreement with findings elsewhere. This is accounted for by the selective --- ion exchange capacity of natural soils --- less than it is for other inorganic constituents ---. Ultimately, as --- ion exchange capacity --- becomes exhausted, --- other constituents of the wastes will show increases in the adjacent wells. ---the estimated seepage (percolation) rate of 0.17 feet per day --- is typical --- fairly tight soils. ---the selective ---ion exchange -- accounts for the apparently limited penetration of other constituents --- in contrast to -- extensive penetration of the nitrates --- found elsewhere that nitrates travel both faster and farther in ground water than ---other constituents."

George and Harding[14], considering the effect of water movements, wrote:

> "--with ferrous iron and nitrate-reducing bacteria available in the earth, it would be reasonable to expect a reduction in the nitrate content of the percolating ground water as it moves from the shallow sands to the artesian reservoirs ---- nitrate reduction through ion exchange is a possibility."

6. Removal of Nitrates

The literature includes little or no definite data on removal of nitrates by passage through soil, either above or below the ground water table, excepting the above surmises. There is some evidence that nitrates may be decomposed or reduced by bacteria, which is offset by evidence that other bacteria oxidize ammonium and nitrites and produce nitrates.

Some writers have considered the possibility that some ion exchange takes place with some types of soil. However, the leaching of nitrates from soils into the underground water may be more condusive to increasing the nitrate content of ground water.

Kruger[42] indicated that it is both practical and possible to artificially reduce the nitrate content of well water to a safe level for use as potable water by an anion exchange resin.

DETERMINATIONS FROM SURVEY

The literature is extensive with many articles by public health experts, medical experts, geologists, and public health engineers who have reported fragmentary information with many hypothetical conclusions as to the sources of nitrates, the causes of variations and the possibilities of increase or decrease, but no conclusive evidence has been found.

7. Predicting Nitrate Contamination

There is evidence that shallow wells in close proximity to organic polluted surface soil are likely to be contaminated with nitrates due to soil nitrification, unless water percolating through the upper soil can be kept out of the well.

Many deeper well waters with high mineral content have a high nitrate content. This can be determined by mineral analyses of water from wells adjacent to a proposed well. Such a highly mineralized water is likely to extend over a considerable area in any aquifer, so other water strata should be sought at lower or higher levels, which is not always possible.

Down dip drainage water from a cesspool or septic tank and sewage disposal field percolating through some soils may contaminate wells with abnormal nitrate concentration at distances generally considered safe against sewage bacterial pollution. A study of the organic content of the soil should help determine this possibility.

8. Water Quality Criteria Needed

The current (1946) Public Health Service Drinking Water Standards (49) do not include any limitation on nitrates. The experience reported in the literature indicates a definite need for some criteria as to a limiting concentration of nitrate-nitrogen.

Such criteria cannot be as simple as to arbitrarily set a maximum nitrate-N concentration, as there are many water supplies with high concentrations of nitrate which have never caused any reported physiological troubles.

Accordingly, additional research will be needed to determine the cause factors. This may require a combination of nitrate concentration with other chemical characteristics of the water as the basis for the new water quality criteria.

It is possible that any water quality criteria relative to nitrates may involve advice as to the use of high nitrate water should no other source of water, with less nitrates, be available.

Also the needed water quality criteria might include a prescription of water treatment to reduce the nitrate-nitrogen concentration.

9. Suggestions for Obtaining Additional Information

A large part of the published information on effect of nitrates is now several years old. Much new information must have been developed over the last five or more years not yet published. The last summarization of available information was a review of literature[26] in 1951 and a APHA questionnaire[17] also in 1951.

Accordingly, a number of investigational steps are suggested:

1. An initial step, to obtain additional information, would be an extended inquiry to uncover a probable large amount of unpublished information, which quite likely now exists. This should be more extensive than any general questionnaire to overloaded publich health officials.
2. A second step would be a summary of the present known information on medical methods to overcome the physiological effects of high nitrate-nitrogen content of drinking water.

3. A third step would involve a study of household water treatment units, including experimentation, to determine if a practical household water treatment unit might be a practical procedure. Since high nitrates are often combined with high mineralization such a water treatment process might also improve the water quality by reduction of the total solids content.

10. Summary

Literature on nitrate contamination of ground water shows many well water supplies in the central states, especially in rural areas, have been contaminated with nitrates, some to quite high concentrations. Frequent cases of cyanosis, or methemoglobinemia disease have occurred in bottle fed babies.

There is substantial evidence that high nitrate concentrations are due sometimes to natural sources of nitrates. There is possibly greater evidence, in other areas, that nitrate concentrations in ground water are the result of soil nitrification of organic nitrogen derived from soil pollution by human or animal wastes.

A number of cases have been reported of industrial wastes as the source of nitrates or of organic nitrogen. There are possibilities of a larger number of nitrate contamination by industrial wastes in the future with the great increase in numbers of industries with chemical wastes.

However, the number of cases of nitrate contamination of ground water due to industrial wastes will be relatively small in comparison to the wide spread areas with high natural nitrate concentrations and areas contaminated by soil nitrification.

Nitrates

Chemical contamination of ground water by nitrate-nitrogen contaminates is likely to increase with larger concentrations of pollution without proper sewerage facilities. Also greater demand on underground water bearing strata may bring nitrate contaminates from greater distances.

Certain state public health departments have set up regulations, or advisory instructions which, more or less arbitrarily, limit nitrate content of water supplies to 10 or 20 ppm, as concentrations considered safe in water to be used for preparing bottle feeding for very young infants. The Public Health Service Drinking Water Standards do not cover the question of nitrates.

Considerable research would be justified in order to develop proper methods of predicting nitrate contamination, determining water quality criteria, and determining methods for protecting against or possibly removing nitrate contamination of ground water.

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APPENDIX E

CHEMICAL CONTAMINANTS

GROUND WATER CONTAMINATION

Topic II-2a - Synthetic Detergent Contaminants

December 1959

APPENDIX E

GROUND WATER CONTAMINATION

TOPIC II-2a - SYNTHETIC DETERGENT CONTAMINANTS*

INTRODUCTION

The increasing use of synthetic detergents, commonly called "syndets", as a household cleansing agent, has ushered in certain problems concerned with the treatment of domestic sewage. Neither municipal sewage treatment plants nor home septic tanks have been able to completely remove the syndet from the sewage and a substantial undegraded fraction is carried out in the sewage plant effluent. In the case of home septic tanks, the effluent usually leaches into the ground water, and thus serious problems of ground water contamination by syndets have arisen. There is evidence that the syndet contamination problems are rapidly increasing.

According to McKinney (1) in 1945, 150 million pounds of syndets were manufactured accounting for less than 10% of the total production of soaps and syndets combined. The production of syndets had increased 10-fold to about 1.5 billion pounds by 1951. In 1957, syndets captured about two-thirds of the total soap and syndet sales and it is estimated that the 1962 production will be 3.5 billion pounds. Approximately 80% of the total syndet production is for household type detergents.

*This appendix prepared largely by Richard E. Speece, Research Assistant.

Simpson [2] stated that the development of syndets for industrial and domestic consumers has been hailed as resulting in a great saving in soap costs where hard water supplies exist. Advertising has been so extensive that syndets have been carried into almost every home - whether its water supply is hard or soft.

Flynn, et al [3] pointed out that the composition of syndets is quite variable. The amount of the surface active agent, surfactant, ranges from 20% to 40%, with an approximate average of 25%. In addition, syndets contain 30% to 50% of a molecularly dehydrated phosphate, mainly a sodium tripolyphosphage, and a maximum of about 10% anticorrosion sodium silicate, a small percentage of condensed amines as foam stabilizers, a minor fraction of optical bleach, and a fraction of about 1% of carboxycellulose, to prevent redeposition of soil on fabrics.

Moss [4] states that as much as 70% of all surfactants used in household detergents are alkyl benzene sulfonates, ABS, derived from polypropylene. McKinney and Symons [5] found that ABS could not be completely degraded by the activated sludge process. Flynn's [6] experience on Long Island indicates the ABS is not completely broken down in septic tanks.

Kiker [7] estimates the number of septic tank installations in the United States to be about six million, while according to Babbitt [8] only about one-half of the population of the United States was served by sewer connections in 1956. These figures emphasize Flynn's [6] opinion that since the effluent from the

septic tank contains undegraded ABS and leaches into the ground water, there potentially a very serious problem of ground water contamination.

1. Effects of Syndets on Water Quality - The experience of the Suffolk County Department of Health [6] indicates the most commonly received complaint relative to individual well water supplies is an off-taste. Housewives in 26 homes were interviewed relative to the taste of their water in one neighborhood affected by syndet contamination of the well supplies. Frothing or foaming of the water is also a common complaint. Most frothing appears at about 1.0 ppm, but varies with the brand of syndet used. The survey results indicated that about 10% of those with syndet concentrations of less than 1.0 ppm reported an off-taste and 100% of those with syndet concentrations of 1.5 ppm or more reported an off-taste. Syndet concentrations in the wells varied from 0.25 to 2.5 ppm.

Flynn, et al [3] state that the rather wide variance in the ingredients in the various detergents on the market make difficult the establishment of a threshold, or any definition of taste applicable to all syndets.

Stokinger and Woodward [9] write that surfactants are a closely related series of substances with complex structures. Toxicity classification is determined when sufficient toxicity information is available on such a series. It is shown that anionic surfactants, as a group, are practically non-toxic, but the alkyl aryl sulfonates are more toxic. The cationic surfactants,

as a group, are highly toxic and limiting water concentrations would need to be set accordingly. Nonionic surfactants are moderately toxic. Stokinger and Woodward[9] state that significant departure from the basic structure of the group should be excluded from toxicological relationship with it.

Acute toxicity of the cationic group of syndets was put by Stokinger and Woodward [9] at generally below 1 g/kg of weight for an oral lethal dose for animals. An oral lethal dose of 2-7 g/kg for animals would be assigned to the nonionic syndets, and 12-40 g/kg as an oral lethal dose of anionic syndet.

The four broad categories provide only an approximate assignment of limiting concentrations; however, Stokinger and Woodward [9] consider such a datum often may be necessary for immediate control of a particular pollution problem. They conclude that the limits for a great number of organic compounds will not be dictated by toxicologic considerations, but will be based on unesthetic qualities imparted to the water by the organic substances.

Flynn, et al [3] question the significance of syndets as a vehicle to transport bacteria, viruses, or other pollutants through greater distances than such pollutants might travel normally, but state that the phosphates present as a builder in the syndet may enhance the medium for bacterial growth in ground water.

2. Sources of Syndet Contamination - According to Flynn, et al [3] syndets are sold in different forms. Their uses extend to light and heavy duty cleansing agents in liquid and powder form, scouring

powders, a greater application by commercial laundries, and more recently to toilet bars. These syndets all will be released with the waste water and pass to the septic tank in the case of houses not connected to a municipal sewer system.

Kiker (7) states that studies at the Robert A. Taft Sanitary Engineering Center showed that none of seven brands of household detergents interfered with normal septic tank slude digestion when used in quantities representing average household uses for all purposes. However, not all of the syndet is removed in the septic tank, but part is carried with the sewage effluent as it leaches into the ground water.

Flynn, et al (3) report the case of a commercial laundry disposing of waste water to leaching pits where the soil is porous and minicipal sewer connections are not available.

Neel and Hopkins (10) report the case of syndet contamination of ground water originating from a raw sewage lagoon at Kearney, Nebraska.

3. Experiences to Date - Flynn (6) said that in 1955, spot checks were made on wells located throughout Suffolk County on Long Island. No wells were found to contain syndets. However, in 1957, complaints of frothing and off-taste in well waters started coming into his office. Since that time 171 out of 569 wells tested throughout the country proved to contain syndets. He estimates there are about 100,000 wells in Suffolk County.

Flynn, et al (3) report another case of syndet contamination

originating from a commercial laundry which disposed of their waste water to a leaching pit.

The town of Kearney, Nebraska [10] constructed an experimental lagoon to determine its feasibility of treating their raw sewage. The study had to be discontinued because syndets were appearing in irrigation and house wells in the vicinity.

Six States report the appearance of syndets in wells [11]. Active interest has been indicated by still other States referring to the possibility of syndet contamination of the ground water.

A reconnaissance study by the U.S. Geological Survey [13], including analysis of 135 water samples from six locations found ABS concentrations as follows:

ABS ppm	Number of Samples	Percentage of Total
More than 1.0	6	4
0.3 to 0.9	10	4
0.1 to .2	63	47
0.0	56	41

The report states that about 5% of the samples contained sufficient surfactants to cause tastes, odors, or foaming.

PASSAGE OF SYNDETS THROUGH SOIL

4. Nature of Movement - a) Through soil above ground water. No articles were found in the literature describing this phenomenon.

b) In and with ground water. The case of Kearney, Nebraska [10] reveals syndets appearing in a nearby irrigation well

two months after operation of the lagoon had started. By 14 months, a house well, located about 0.2 mile from the lagoon, was found to contain 7.5 ppm of syndet. At the same time, an irrigation well located about one-half mile from the lagoon, in the same general direction, showed 1.4 ppm of syndet. Syndets were reported only in the immediate vicinity of the lagoon in directions other than those just mentioned.

Neel and Hopkins (10) concluded from laboratory tests that no bacteriological contamination from the lagoon had been carried to any of the wells in which syndets appeared They analyzed the influent sewage for syndets on four days about three and one-half months after starting of the lagoon operation and found 16, 8, 7, and 12 ppm, respectively. Corresponding syndet concentrations in the lagoon on these days were 11, 9, 9, and 10 ppm. Then, at fourteen months after start-up, they made checks on three different days and found 39, 9, and 36 ppm in the influent sewage with corresponding lagoon concentrations of 17, 21, and 20 ppm.

The instance of syndet contamination by a commercial laundry as reported by Flynn (6) revealed syndets, at least two years old, were found 500 feet from their source. Test wells were driven to trace the pollution. The results he obtained indicate the pollution travels as a "slug", with the concentration being greatest at the core and decreasing toward the periphery due to dilution. Flynn concludes from the data that the slug initially travels at the surface and in the direction of the ground water,

but is depressed below the ground water surface by recharge water percolating on top of the slug. He did not state any relation between ground water velocity and syndet velocity.

Flynn, et al [3] concluded that with houses located close together on small lots and provided with individual septic tanks and wells, syndets will inevitably appear in the wells.

5. Removal of Syndets - a) Through soil above ground water. No articles were found in the literature describing this phenomenon.

b) Flynn [6] calculated that on a lot of 20,000 sq. ft., about half an acre, the total recharge water would be 300,000 gallons per year, figuring 20" out of a total of 42" yearly rainfall percolated down to the ground water. Local sales indicate each family uses 104 pounds per year of synthetic detergent as measured from the box or about 26 pounds per year of pure surfactant. If this 26 pounds of syndet were uniformly mixed with the 300,000 gallons of recharge water, a syndet concentration of about 10 ppm would result. The wells Flynn tested have mostly shown lower concentrations than this. The difference may be due to absorption in the soil or removal in septic tanks. However, no articles were found in the literature which reported the amounts of syndet removed by septic tanks nor by the soil particles that the syndet passed through.

The case reported by Neel and Hopkins [10] also shows a reduction in the syndet concentration between the lagoon and contaminated wells.

DETERMINATIONS FROM SURVEY

6. Prediction of Syndet Contamination - a) Present art. Since the contamination cases cited have originated mostly in sewage and in one case in laundry discharges which have been allowed to percolate to the ground water, the possibility of syndet contamination of ground waters is high wherever similar conditions exist.

Flynn, et al [3] concluded that the possibility of a well supply becoming contaminated is enhanced when it is located in line with the direction of ground water flow from the point of contamination. They also expressed the opinion that depth of well and distance from contaminant discharge enter in to the contamination possibility. However, they stated that increased depths of wells and distances from contamination source may delay, but not prevent the appearance of syndets in the well waters.

When individual wells and sewage disposal systems are placed on relatively small lots, Flynn, et al [3] were of the opinion that syndets may be anticipated to appear in the wells. They stated that syndets do not appear to deteriorate and tend to remain concentrated with little dilution. It was their opinion that with continued addition year after year, the amount of syndets would build up in the ground water and the contamination problem would become more acute.

b) Additional information needed. The available literature contains insufficient data on which to predict the probable concentra-

tion of syndet contamination. Additional studies are needed on a number of aspects of the problem as follows:

1. Adsorption characteristics and properties of various soils with regard to syndet removal.
2. Ion exchange properties of various soils relative to the passage or removal of ionizable syndets.
3. Biological activity within soils and ground waters and possible effect upon the removal of syndets.
4. A soil classification which would pertain more definitely to syndet behavior in contact with soils.
5. Syndet concentrations in the effluents from septic tanks and cesspools for observation of simultaneous effects of removals of certain sewage constituents and syndets.
6. Effect of distance travelled by the syndets upon their dilution and persistence in various soils.
7. Correlation between laboratory test results and actual field experiences.

7. Water Criteria Needed - Specific reference to the allowable syndet concentration should be incorporated into the Public Health Drinking Water Standards. Such concentration should preferably not occur in excess of 1.0 ppm.

If any syndet is found, this is quite conclusive evidence that sewage effluent is entering the well. However, results reported in the literature (10) indicate bacteriological contamination does

not necessarily accompany syndet contamination. From this, the conclusion is drawn that unesthetic qualities might govern the limiting concentration. This limit would be less than 1.0 ppm to prevent frothing and off-taste in the water.

In new development areas, such a test for syndets would have little significance, since syndet contamination would be capable of arising only after the development became inhabited.

8. Suggestions for Obtaining Information through Research - a) On predicting contamination. An inventory of different soil types, representative of those soils found throughout the United States, should be compiled from geological maps for this study. Results on synthetic soil compositions would be compared with results on these natural soils from the test column following testing. Likewise, syndets of the types commonly encountered should be gathered for this study.

Freundlich adsorption isotherms should be found for each soil type with the different detergents commonly found in septic tank effluents. This should be done by determining the amount of syndet removed from solution for a given amount of the soil in question with varying concentrations of the particular syndets used.

Experimental lysimeter-type soil columns should be erected to investigate the ion exchange capacity of the soils for syndets or chemicals constituting the syndet builder. Factors affecting regeneration of the ion exchange capacity should be studied. The

concomitant effect of alteration of the syndet by ion exchange would be observed on the other phases of the study.

Biological activity within the soil and ground water should be studied with the Warburg respirometer to determine the rate of activity and its effect upon the syndet with and without the presence of other sewage components. If study on a larger scale than can be accommodated by the Warburg is found necessary, a larger apparatus utilizing the same principles should be built.

The molecular structure, physical properties, and chemical nature of the soils should be studied to determine additional criteria for a new classification of soils which would relate closely to syndet behavior.

Soil beds should have syndet contamination introduced into them and the concentration of the contamination stream would be determined at periodic distances from the source. By this means, the factors of dilution and time could be studied to ascertain their relative importance. The time rate of build-up of syndets in the soil would also be determined if the reactions proved to be irreversible and the syndets did not decay in activity once adsorbed.

Many cases of syndet contamination on Long Island have been found and may provide a worthwhile background to attempt correlation of laboratory and field data. Other suburban areas would also be suitable if septic tanks and private wells are used.

b) On water quality criteria. The methylene blue analytical procedure should be used first and if the results show syndet

concentration less than 1.0 ppm, no additional tests need be run. However, if the results indicate more than 1.0 ppm syndet, a more refined analysis such as described by Fairing and Short [12] should be used to eliminate the many interferences which affect the methylene blue analysis.

9. Summary - The increase in syndet sales has had the concomitant effect of "loading up" domestic sewage with greater concentrations of syndet. The major component of syndets, ABS, is not completely degraded in the sewage treatment facility so that the effluent leaching to the ground water still contains a certain amount of syndet. Passage through the soil and in the ground water has not been effective in completely removing the syndets. Thus, well water supplies have become contaminated when the syndet-containing ground water comes within their withdrawal zone.

Some reduction in concentration of syndet appears to take place between the treatment facility and well discharge, but no articles were found in the literature describing this phenomena.

The contamination travels in the direction of ground water flow, has been reported at distances up to one-half mile from the source, and tends to remain concentrated with little dilution.

The major effect of syndet contamination of the well supply appears to be the unesthetic qualities contributed to the water, such as frothing and off-taste, with the physiological effects, not too well defined, seemingly insignificant in concentrations found thus far.

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APPENDIX E - TOPIC II-2c

GROUND WATER CONTAMINATION

Domestic Sewage Chemical Contaminants

by

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APPENDIX E - Topic II-2c

GROUND WATER CONTAMINATION

Domestic Sewage Chemical Contaminants

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GROUND WATER CONTAMINATION

Topic II-2c Domestic Sewage Chemical Contaminants

INTRODUCTION

Domestic sewage, if allowed to leach into the ground water, will add to the concentration of chemicals initially present in the ground water in addition to presenting a potential for microbiological contamination. Microbiological and viral contaminations are discussed in other Sections. (Topics IV and V)

Over the past several years bacteriological considerations have virtually blocked out chemical considerations in the literature on sewage contamination of water, until recent studies undertaken in California relative to sewage reclamation to replenish ground water supplies, and investigations in New York and elsewhere relative to syndets, brought sewage chemical contaminants back into prominence.

Prior to the extensive use of bacteriological analyses to measure contamination, several chemical determinations were used to determine contamination of water.

In an early (1928) discussion of chemical characteristics of sewage, Buswell[1] wrote "While the most important characteristics of sewage... is its oxygen-consuming power, more data are available... on... nitrogenous compounds... . The composition of nitrogenous compounds (is) as follows:

"Free Ammonia. Free ammonia is perhaps the oldest of the nitrogen methods in sanitary analysis. As an end-product in the bacterial metabolism of nitrogenous compounds, ammonia determinations may signify remote pollution of a water by organic matter."

"Albuminoid Ammonia. The albuminoid ammonia determination was proposed... as a measure of the unhydrolyzed, nitrogenous matter in a water sample."

"Total Nitrogen. The Kjeldahl process for total organic nitrogen requires no discussion. ... It would seem more desirable to determine total nitrogen by the Kjeldahl method and subtract free ammonia from it to give total organic nitrogen... ."

Buswell[1] also published, (pp. 211-213) data showing chemical composition of several sewages which included: Suspended Matter; Chlorine (as chlorides); Ammonia Nitrogen; Organic Nitrogen; Total Nitrogen; Oxygen Consumed ($KMnO_4$); Organic Carbon; Phosphates; and Sulphates.

Mahlie[2] states "Owing to the great diversity of materials entering... the chemist cannot make a test for each kind of material; consequently he tests for certain groups or classes of materials, and from these tests the quality of sewage can be judged."

"Solids-Total, Suspended and Dissolved. ...measure out a certain volume of sewage, evaporate it to dryness in a previously weighed dish, and then weigh the residue."

"Settleable Solids. ...In practice the settleable solids are usually reported on a volume basis. ...a conical shaped test glass is used, known as the Imhoff cone, ..."

"Organic Matter. Organic matter... gives sewage its objectionable properties, and... decomposition of this material... by the action of bacteria that results in the formation of septic sewage. ...to oxidize a source of oxygen is necessary, ...a measure of the amount of oxygen required... would give a measure of the organic matter."

"Oxygen Consumed. The oxygen consumed test... indicates how many parts per million of oxygen are necessary to oxidize the organic matter under certain conditions."

"Dissolved Oxygen. Dissolved oxygen is the free or chemically uncombined oxygen in water or sewage... . Since sewage has an avidity for oxygen,... its presence in raw sewage indicates a very fresh sewage which has not yet undergone any putrefaction."

"Proteins, Carbohydrates and Fats. In a general sense, the organic constituents may be... considered as carbohydrates, proteins, and fats. ..."

"The oxygen consumed test gives a general idea of the amount of carbonaceous material present."

"Nitrogen Compounds. ...the determination of nitrogen in its various forms furnished information regarding the state of either the decomposition or the purification of the sewage."

"Thus, nitrogen as total organic nitrogen is a measure of the proteins and their intermediate decomposition products,... while nitrogen as ammonia indicates the progress of the breaking down of the nitrogenous compounds."

"Nitrites are intermediate oxidation products between ammonia and nitrates. Nitrates are the final or stable forms of oxidized nitrogen."

"Oils, Fats, and Grease. ...are always present to a greater or lesser extent in sewage. ...common usage includes all of them under the name of grease."

"Chlorides. ...represent the amount of salt present... are not affected by sewage treatment and cannot be removed,..."

"Sulphates. ...may break down by bacterial action with resulting formation of hydrogen sulphide gas. Hence, high sulphates are an indication of potential odor formation."

"Hydrogen Sulphide. This is the familiar rotten-egg odor gas that is responsible for most of the odors coming from septic sewage... it is also an active corroding agent... is highly toxic and a number of deaths have been reported from the inhalation of this gas."

"Reaction or pH Value. ...indicates the degree of alkalinity or acidity of a sewage. A pH value of 7.0 is the neutral point, and anything less than 7.0 represents an acid condition, while above 7.0 is alkaline."

"Bio-Chemical Oxygen Demand. The most important test... (abbreviated B.O.D.). This... displacing the oxygen consumed test. ...is the quantity of oxygen required for bio-chemical oxidation in a given time at a given temperature, the determinations usually being five days at 20°C."

Keefer[3] has stated: "...sewage contains mineral, animal and vegetable matter in suspension and solution together with a large number of bacteria. The minerals in suspension consist of paper, pieces of food, grease, fecal matter, match sticks, etc. Fresh sewage has a musty odor, which is not especially offensive. However, within a few hours decomposition begins and objectionable odors are produced."

Hopkins and Schulze[4] stated: "The chemical and physical characteristics of sewage vary widely at different places and depend upon the water consumption, the domestic habits of the people,..."

1. Sources of Sewage Chemical Contaminants. Chemical contaminants from domestic sewage may arise through several different sewage disposal methods. Residential cesspool and septic tank effluents frequently leach into the ground water (5). Municipal sewage treatment plant effluents may be allowed to percolate into the soil and so reach ground water or the sewer system itself may not be tight and thus permit leaking (6). Sewage or sludge lagoons may allow infiltration into ground water to occur. (7)

Potential chemical contamination of ground water also exists where water reclamation of sewage effluents by underground injection is practiced. (8) The potential contamination from reclamation of sewage effluents has been extensively studied, especially by the Water Pollution Control Board of California.

2. Effect on Water Quality - Writing mainly about surface waters, Heukelekian (9) states "The effects of sewage pollution on the quality of the water may be physical, chemical, and biological."

"Physical Effects. The finely divided matter in sewage imparts turbidity and increases the suspended solids content of the water... ."

"Tastes and odors are imparted to the water by sewage either directly or indirectly. Hydrogen sulfide may be produced as a result of biological activity... from the reduction of sulfate or organic sulfur compounds."

"Chemical Effects. The chemical composition of... waters is altered appreciably by the discharge of sewage. The total salt content may be increased. An increase in chloride content is objectionable to domestic water supply; sulphates are objectionable from the standpoint of boiler waters and as a source of hydrogen sulfide production under anaerobic conditions. The ammonia nitrogen contained in sewage tends to increase the concentration of this constituent in the water. Nitrates discharged with oxidized effluents and nitrates produced... from the ammonia nitrogen stimulate the growth of algae in the water causing an indirect increase in tastes and odors and in some cases resulting in actual nuisances as a result of decomposition of large quantities of organic matter accumulated by the growth of these organisms."

"The organic matter contained in sewage modifies the chemical composition of the water directly and indirectly. Directly, an increase in the organic matter of the water causes an increase in the turbidity. The indirect effects of organic matter on biochemical processes are discussed below."

"Bacterial Pollution. Unpolluted... water has low bacterial numbers. Part of the natural bacterial population consists of coliform organisms which are derived from run off from fields and soil and are similar to the coliform organism derived from sewage. The balance of the flora consists of bacteria native to the water and is specially adapted to grow under the environmental conditions prevailing... . It is doubtful whether... native bacteria are actually grown or counted in ordinary culture media. They... grow in a water environment of low food content by attaching themselves to inert surfaces forming

slimy growths and deriving their food by adsorption on biological surfaces."

"Sewage greatly increases the density of pollutional bacteria (coliform) in water. ...In addition there may or may not be present certain pathogenic organisms such as typhoid or dysentery bacteria. Generally, neither the pathogenic nor the pollutional forms of bacteria multiply in the water, although some initial increase in the numbers of coliform organisms has been noted below a point of sewage discharge. It is logical to expect that the numbers of native water bacteria increase greatly in response to the addition of food materials present in sewage. With increasing time of flow the pollutional forms decrease in number, as well as the native population, because of the exhaustion of food."

"Other Biological Forms. As a result of sewage pollution the numbers of protozoa increase in the water. Some of these organisms feed on bacteria and help keep their numbers down and thereby increase their biochemical activities. The numbers of filamentous organisms, such as Sphaerotilus and Leptomitus, increase and attach themselves in long strands to sticks and stones... . Certain forms of filamentous algae such as blue greens and Spirogyra will also be found attached in the same environments as the filamentous bacteria... ."

"A number of higher animals, such as rat-tail maggots, Tubifex (sludge worms) and Chironomous (blood worms) are found in sludge deposits."

Flynn, et al,[5] report impaired taste and odor of well waters containing synthetic detergents originating in the effluent of cesspools and septic tanks. Foaming was also a characteristic of such water when the concentration of synthetic detergent was greater than 1 mg/l. This is discussed more completely under Section II-2a Detergents.

Dappert[6] and Flynn, et al,[5] also report ammonia chlorides and alkalinity of sewage contaminated waters higher than the concentrations in the naturally occurring ground water of the respective areas.

Butler, et al,[8] concluded from the available information that chemical changes in percolating sewage are not great and that many applied chemicals can be expected to reach the ground water along with percolating liquids.

Changes in the form or nitrogen brought about by bacterial action were found by Dappert[6] at a sewage treatment plant with effluent flowing on to natural sand beds for disposal. The concentration of nitrogen forms was: ammonia 12.5 mg/l, nitrates 0.04 mg/l, and organic nitrogen 7.1 mg/l. The underground flow was traced by bore holes and the analysis at a point 1400' from the sand beds was: ammonia 6.0 mg/l, nitrates 10.0 mg/l, and organic nitrogen 1.39 mg/l. Chloride concentration was increased over the natural content of the ground water.

Neel and Hopkins[7] reported that laboratory tests failed to demonstrate bacteriological contamination or pollution, other than detergents, in wells affected by infiltration from a nearby raw sewage lagoon.

3. Reported Permissible Concentrations. The U.S. Public Health Drinking Water Standards[10] specify limits for chemical constituents which might arise from sewage percolation into the ground water as follows:

> "The presence of lead (Pb) in excess of 0.1 p.p.m., of fluoride in excess of 1.5 p.p.m., of arsenic in excess of 0.05 p.p.m., of selenium in excess of 0.05 p.p.m., of hexavalent chronium in excess of 0.05 p.p.m., shall constitute grounds for rejection of the supply.
>
> "Copper (Cu) should not exceed 310 p.p.m.
> Iron (Fe) and manganese (Mn) together should not exceed 0.3 p.p.m.
> Magnesium (Mg) should not exceed 125 p.p.m.
> Zinc (Zn) should not exceed 15 p.p.m.
> Chloride (Cl) should not exceed 250 p.p.m.
> Sulfate (SO_4) should not exceed 250 p.p.m.
> Phenolic compounds should not exceed 0.001 p.p.m. in terms of phenol.
> "Total solids should not exceed 500 p.p.m. for a water of good chemical quality. However, if such water is not available, a total solids content of 1,000 p.p.m. may be permitted."

Flynn, et al[5], found that synthetic detergent concentration must be below 1 mg/l to prevent esthetic impairment of the water, such as taste and foaming.

Aside from the effects of synthetic detergents there appears to be little attention given to domestic sewage chemicals when ground water contamination is considered.

4. Experience to Date. Stiles, et al,[11] conducted (in 1927) experimental studies on chemical pollution of wells via ground water. Uranin was used as the indicator. Experimental wells up to 450' away were found to contain uranin. Uranin remained visible in the ground water for two years and seven months when last examined.

Dappert[6] traced (in 1932) the effluent from an activated sludge plant, which emptied on a natural sand bed and seeped to the ground water. By means of bore holes the flow from the sand bed seepage was traced to a spring about one quarter mile distant.

The Long Island experience reported by Flynn, et al[5] (1958) deals with synthetic detergents appearing in well waters on lots with individual septic tanks or cesspools and wells. Their conclusion was that the only possible origin of the detergents was from the effluent of the septic tanks or cesspools. This is discussed more completely under Topic II-2a.

A similar case of synthetic detergent appearing in wells was described (1956) by Neel and Hopkins[7]. Infiltration from an experimental raw sewage lagoon at Kearney, Nebraska, was found to be the cause. Chloride measurements substantiated detergent results, since greater chloride concentrations were found at sites where detergents were recovered. All analyses indicated concentrations of chemicals were below the accepted chemical standards for potable water.

PASSAGE THROUGH SOILS

5. Nature or Movement.

a) Above Ground Water. Butler, et al[3] stated (1954) that the movement of percolating water and consequently chemicals

in soils is vertical until the ground water is reached before travel ceases. Butler, et al, found that the nature of percolating sewage is little altered by its passage through as much as 13 feet of the soil tested, after initial ion exchange equilibrium had been satisfied, except for those substances that undergo progressive changes through bacterial action.

b) In and With Ground Water. Chemical pollutants, according to Butler, et al[8] will travel farther and faster than bacterial pollutants in ground water. Travel of chemicals has been reported for distances varying from a few feet to several miles, and from two to thirty times as far as coliform bacteria introduced at the same time.

Stiles, et al[11] stated (1927) that chemical pollution travels only in the direction of ground water flow. The chemical pollution appeared to float out in a blanket at or parallel and close to the ground water table. Upon fall of the ground water, the pollution tended to filter out into the capillary fringe and soil, but did not seem always to rise with higher ground water. As chemical pollution traveled, it did not appear to expand laterally with the origin as the apex, but it appeared to contract to a narrower breadth than the width nearer the origin.

Commenting generally (1958) on travel of sewage underground, Salvato[12] stated "Since the character of soil and rock, quantity of rain, rate of ground water flow, amount of pollution, bacteria growth media, and other factors beyond control are very variable, one cannot say with certainty through what thickness or distance sewage must pass to be purified. Pollution travels a short distance through fine sand or clay; but will travel indefinite distances through coarse gravel, fissured rock, dried-out cracked clay, or solution channels in limestone."

Also Salvato[12] has summarized early (1927) public health service experiments by Stiles, Crohurst and Thompson as follows:

"The United States Public Health Service conducted experiments at Fort Caswell, North Carolina, in a sandy soil with ground water moving slowly through it. The sewage organisims - coliform bacteria - traveled 232 ft., and chemical pollution as indicated by uranin dye traveled 450 ft. The pollution moved in the direction of the ground-water flow largely in the upper portion of the ground water and persisted for 2½ years. The pollution band did not fan out but became narrower as it moved away. It should be noted that in these tests there was a small draft on the experimental wells, and that the soil was a sand of 0.14 mm effective size which had a uniformity coefficient of 1.8."

Salvato[12] further stated, relative to more recent California experiments, "Studies of pollution travel were made by the University of California using 23 6-inch observation wells and a 12-inch gravel packed recharge well. Diluted primary sewage was pumped through the 12-inch recharge well into a confined aquifer having an average thickness of 414 feet approximately 95 feet below ground surface. The aquifer was described as pea gravel and sand having a permeability of 1900 gallons per square foot per day. Its average effective size was 0.56 mm and uniformity coefficient 6.9. The median effective size of the aquifer material from 18 wells was 0.36 mm. The maximum distance of pollution travel was 100 feet in the direction of ground water flow, and 63 feet in other directions. It was found that the travel of pollution was not affected by the ground water velocity but by the organic mat which built up and filtered out organisms, thereby preventing them from entering the aquifer. The extent of the pollution then regressed as the organisms died away and as pollution was filtered out."[13]

Again according to Salvato[12] "Butler, Orlob, and McGauhey[8] made a study of the literature and reported the results of field studies to obtain more information about the underground travel of harmful bacteria and toxic chemicals. The work of other investigators indicated that pollution from dry pit privies did not extend more than 1 to 5 feet in dry or slightly moist fine soils. However, when pollution was introduced into the underground water, test organisms were recovered in wells 50, 69, 80, 112, and 232 feet distant. Chemical pollution was observed to travel 300 to 450 feet, although chromate was reported to have traveled 1000 feet in 3 years, and other chemical pollution 3 to 5 miles. Leachings from a garbage dump reached wells 1476 feet away, and a 15 year old dump continued to pollute wells 2000 feet away. Studies in Dutch East Indies report the survival of coliform organisms in soil 2 years after contamination and their extension to a depth of 9 to 13 feet, in decreasing numbers, but increasing again as ground water was approached."

6. Removal of Chemicals from Domestic Sewage.

a) Through Soil Above Ground Water. Ion exchange was found by Butler, et al[8] to alter the chemical constituents of percolating sewage effluent until equilibrium was established between the soil and the applied liquid, when clay was present. Concentration of calcium, magnesium, sodium, and chlorides remained relatively constant in passage through a 13 feet of soil depth observed. Concentrations of sulfates, bicarbonates, and nitrates increased markedly. Phosphates disappeared within the first foot and potassium decreased by approximately 50% below 7 feet depth. Butler, et al,[8] concluded that from available information it was evident that chemical changes in percolating sewage are not great and that many applied chemicals can be expected to reach the ground water along with the percolating sewage liquids.

b) In and With Ground Water. Stiles, et al[11] conducted an early (1927) experiment in sandy soil, slowly moving ground water, which they operated all year round. They found that wet weather was conducive to the extension of pollution and that dry weather with resulting low ground water was inhibitive of the extension of pollution and more conducive to purification of the ground water, probably due to filtering out of the pollution by the capillary fringe and soil with lowering of the ground water, since the pollution was found to remain in the soil near the ground water table.

7. Predicting Chemical Pollution from Domestic Sewage.

a) Present Art. Available literature does not clearly define the movement and removal of chemical pollution. There are limited data which indicate only the general trend of travel of sewage chemicals through subsurface materials.

However, the concentrations of chemicals in domestic sewage, other than detergents, are so low and cause so little trouble compared to the problems of bacterial, viral, and

detergent contaminants that any investigation relative to sewage chemical contaminants should be secondary to the investigations proposed for bacteria, virus, and detergents.

8. Water Quality Criteria Needed.

The U.S. Public Health Drinking Water Standards indicate permissible concentrations in potable water for most chemical constituents of domestic sewage. The Drinking Water Standards should be modified to include a maximum permissible concentration of 1.0 mg/liter for the AES component of detergents to avoid off-tastes and foaming problems.

9. Summary.

Sewage chemical contaminants in ground water involve percolation of sewage effluents through soil into ground water from one or several possible sources of domestic sewage. Normally, the small increment from sewage chemicals compared to the concentration of the various chemicals originally present in the ground water does not produce a significant chemical contaminant, with the exception of synthetic detergents which are discussed under Topic II-2a.

In general, travel of sewage chemicals is vertical down to the ground water table, then sewage chemicals travel in what appears to be along the ground water surface and in the direction of the ground water flow. There are some chemical changes in the sewage chemicals as they percolate through soil depending on type of chemical and soil character. Sewage chemicals may be diluted somewhat in the ground water, but the most significant changes occur when the ground water level falls and the chemical contaminants become stranded in the capillary fringe and soil just below the normal ground water level.

The effect of sewage chemical contaminants is generally insignificant, excepting synthetic detergents, bacterial, and viral contaminants for which proposed researches are outlined in other sections of this report.

Generally, it would be expected that the esthetics of pollution by domestic sewage and the potential bacterial contamination are most important, while actual effects of chemical concentrations added to the ground water are minor. Potential bacterial contamination as discussed in another section, is considered so comparatively important that the 1946 Public Health Service Drinking Water Standards virtually ignores chemical contamination from sewage. These standards should be revised to include syndets and possibly one or more other chemicals to be discussed in another section.

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APPENDIX F - Topic III

GROUND WATER CONTAMINATION

Radiological Contaminants

by

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June 1959

GROUND WATER CONTAMINATION

Topic III - Radiological Contaminants

Larry M. Ogden - Research Assistant

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APPENDIX F

GROUND WATER CONTAMINATION

Topic III - Radiological Contaminants*

INTRODUCTION

Atomic energy industry development and extensive use of radioisotopes for therapeutic, research, and industrial purposes undoubtedly will produce quantities of radioactive wastes which may result in radiological contamination of ground water, since the most economic disposal for radioactive waste materials is underground burial.

Straub (56) states, "Discharge of liquid wastes into the ground may take place through shallow pits located above the ground water table or into shallow wells which penetrate usable potable or industrial ground waters. The probability of contamination from such practice is high, and many instances of chemical contamination are known."

Fortunately, to date the instances of ground water contamination have been small in number and in magnitude. The larger sites for radiological wastes disposal at or near installations of the Atomic Energy Commission have been well isolated and very carefully monitored to ensure against objectional ground water contamination. This may not be always the case, as the use of radioactive materials

*This appendix largely prepared by Larry M. Ogden - 6/15/59

by private enterprise becomes more widespread.

Straub et al.[8] reports: "With the availability of a great variety of radioisotopes at low cost, many applications have been found for their use in medicine, industry, and research. Naturally, this increased demand for radioactive materials has resulted in increased discharge of these materials into the environment."

In December, 1952, Miller et al.[10] sent a questionnaire to 1027 users of radioisotopes. One of the most important survey findings was that about 41% of the users disposed of radioactive wastes by dilution and discharge into sewers. This may not be a hazardous procedure at present, owing to the limited quantities of isotopes currently in use, but the procedure is not wise and should be discouraged.

1. Sources and Disposal of Radioactive Wastes

Kaufman et al.[46], in 1951, stated: "Radioactive wastes... from three general sources: from the atomic energy industry itself, from research laboratories and hospitals employing radioisotopes for tracer and therapeutic purposes, and as a result of the employment weapons."

Straub[31] reports, "There are several sources of radioactive wastes: (a) Nuclear reactors and separation plants, (b) radioisotopes used in research, medicine and industry, (c) nuclear bomb debris (fallout), and (d) power reactors."

In a more detailed consideration of sources of radioactive wastes Ruchhoft[29] reports, "The principle sources of radioactivity

may be listed as follows:

1. "Mining, refining and purifying of radium and uranium ores, i.e., naturally occurring radioisotopes.
2. "Pile reactors: (a) For plutonium production. (b) For power development. (cO For production of radioactive isotopes.
3. "Atomic Weapons.
4. "Radium therapy and radium dial industry.
5. "Ionitrons (static eliminators).
6. "Wastes from hospitals using radioactive isotopes.
7. "Wastes from chemical and biological research laboratories using radioactive isotopes."

Platt(49) reports on the retention of high level radioactive wastes "As originally discharged from nuclear fuel reprocessing plants, most radioisotopes --- concentrations --- permissible concentrations in potable water sources. However, if --- stored in tanks for a period of years --- only the longer-lived fission products are present in hazardous concentrations, at this time, it is economically feasible and attractive to segregate (scavenge) the hazardous isotopes for continued storage, and discharge the remaining wastes to the soil."

Atkins (53) relative to water pollution states, "the growing use of radioactive materials is adding another new contaminant to our already complex pollution problems. The milling of uranium ores is already causing concern for some waters. The first privately-owned nuclear energy power plant is in operation and others will follow. Use of nuclear energy by other segments of industry will increase by leaps and bounds in the immediate years ahead. Water pollution problems resulting from use of radioactive materials will,--- have serious health-related aspects."

Gronquist and Tomlinson[42] report; "American industry is currently (1956) actively engaged in the development of nuclear energy as a source of electrical power. One of the problems associated with this development involves the disposal of the biologically hazardous radiochemical wastes which emerge as a by-product of the fuel cycle."

Ruchhoft[29] reports; "The artificial production of radioactive isotopes for use by industry, research laboratories, and hospitals has grown tremendously in the last few years. The bulk of the isotopes are being under the control and distribution of the Atomic Energy Commission... Finally, application produces wastes containing residual radioactive material, and these wastes present a disposal problem."

Straub[47] states, "Radioisotopes have found wide usage in research, medicine and industry..... In general, small amount (microcurie and millicurie quantities) of single radioisotopes are used in tracer experiments, --- waste volumes --- are small --- concentration of activity is low. Larger quantities, both in volume and activity, may be discharged from hospitals where radioisotopes are used as therapeutic agents."

Saddington and Templeton[58], discussing commercial waste radioactive materials in the United Kingdom States, "With the increasing use of radioisotopes in universities, hospitals and factories there arises the problem of the disposal of relatively small amounts of radioactive waste from a large number of sources, --- in the United Kingdom ... legislation --- will without doubt, eventually take into account the disposal of any waste arising therefrom. Such legislation ---- will rather control the maximum amounts of activity which ---- may be discharged to public drains, sewers or other utilities. ... At the present time ---- most of the sources are totally enclosed or sealed and as such present no disposal problem. ----, a number have such short half-lives that ---- minimizes the danger of spreading radioactive contamination. ---- One possibility which must be prevented is the single discharge of a comparatively large amount of activity, causing a temporary

unacceptably high concentration of activity in the sewage."

Straub (52) reports on disposal in Denmark, "There are no regulations relating to the discharge of low levels of activity from hospitals and other sources using radioisotopes. In general, water dilution is provided and the spent isotopes are discharged to the sewer."

Straub (52) also reports "The Joint Establishment of Nuclear Energy Research (JENER) is located at Lillestrom, some 15 miles east of Oslo (Norway). Here, the JEEP reactor went critical in July 1951. ---- Iodine -131 containing waste from chemical separations is stored and controlled quantities are released to the river."

"----treatment of low level liquid radioactive wastes at Saclay (France) ---- a truck is used to haul the decontaminated liquid to Chatillon ---- discharged into the sewage system for treatment with Paris sewage before releast to Seine River."

"Because of ground water conditions in the Netherlands it is impossible to consider disposal of radioactive wastes into the ground."

"---- Belgian atomic energy facilities are located at Mol. Liquid radioactive wastes ---- are pumped to the River Mol Nethe which has a flow of 50,000 m^3/day."

Germany, "----The extensive use of ground water for water supply purposes precludes utilization of the ground as a means of disposal for liquid radioactive wastes. Furthermore, permission has not been granted by the Ministry of Health to discharge any

radioactive materials into surface waters. These two factors restrict the release of any radioactive materials into the environment."

Glueckauf [3] in 1955 estimated that in the distant future the world consumption of nuclear fuel may eventually reach 1000 tons annually, and states, "If, therefore, we can decide on ways and means to dispose, economically and without danger to ourselves and future generations, of a quantity of fission products of this order, we shall have no need to restrict later on the expansion of nuclear industries on account of the fission product nuisance."

Wolman and Gorman [4] conclude: "the problems in waste disposal for the atomic energy industry are many. The control of waste is currently adequate but expensive. As the industry expands especially in the power field, less expensive methods will be required if atomic energy is to compete favorably in cost with other fuels."

Theis [27] reports, "Disposal of nuclear waste to the ground involves the placement of a complex chemical solution into a complex natural environment ... Geologically, meable formation, (2) permeable cavernous formations, (3) Jointed or otherwise fractured rocks, (4) relatively impermeable shales, or (5) deposits of salines - rock salt and gypsum."

Brown et al [25] states the factors requiring evaluation in considering the feasibility of disposal of radioactive wastes to ground, include:

1. "The chemical and radio-chemical content of the wastes.

2. "The effectiveness of retention of the radiosotopes in the available soil column above the ground water table.

3. "The natural rate and direction of movement of the ground water from the disposal site to public waterways, and possible changes in these characteristics from the overall liquid disposal practices.

4. "The degree of permanence of such retention, as influenced by subsequent diffusion, leaching by natural forces, and additional liquid disposal.

5. "Feasibility of control of access to ground water in the affected region.

6. "Additional retention, if any, on sands and gravels in the expected ground water travel pattern.

7. "Maximum permissible concentrations in public waters of the radioelements concerned."

Morgan (41), in considering burial ground for solid radioactive wastes, reports relative to ground water hydrology, "A factor in consideration of any burial site is its ground-water conditions with particular attention given to shallow aquifers. Exhaustive information should be obtained concerning ground-water movement; natural recharge and discharge with accompanying direction of ground-water movement under normal and other conditions; depth of water table; permeability and transmissibility of the aquifer with velocity of flow. While the area selected should be remote from municipal and industrial centers, effects of large artificial ground-water discharge should be estimated. In addition, the probable underground movement of radioactive substance, particularly liquids ---- should be plotted."

Straub (33) states, "The waste materials from the atomic energy industry are gaseous, liquid, and solid and occur in any phase of the industry from mining of the uranium ore to the ultimate use of a specific radioisotope in industry, research, or medicine. These waste materials differ from those with which we have been concerned in the past in that they are radioactive. As such they may be damaging to human and other tissues."

2. Effect on Water Quality

The only phase of good water quality (Section III) relating to radiological contamination is physiological effects.

Ruchhoft and Setter [22] report: "Briefly, radioactive substances are unstable and are continuously disintegrating through the emission of alpha or beta particles and sometimes electromagnetic (gamma) rays. These are all ionizing radiations and are, consequently, destructive to body tissues, depending upon intensity and duration."

Straub [56] report: "---- maximum permissible concentrations for many of the radionuclides of interest --- are extremely low-levels of related chemical elements. Radioactive materials give off ionizing radiation which is damaging to tissue, and the length of time during which they may be damaging varies with the individual radionuclides. The half-life or decay time --- may vary from a fraction of a second to millions of years. It cannot be changed by any physical, chemical, or biological method; only time being effective for reducing the level of activity."

The permissible concentrations of various radioisotopes have been set up by various authorities.

3. Reported Permissible Concentrations

Recommendations for permissible concentrations of radioactive materials in water were set by the National Committee on Radiation Protection in Handbook 69, "Maximum Permissible Body Burdens and Maximum Permissible concentrations of Radionuclides in Air and in Water for Occupational Exposure", published by National Bureau of Standard, and issued June 5, 1959. This replaced the former "Handbook 52".

On January 8, 1957 the NRCP set forth a preliminary statement of revised (form Handbook 52) philosophy on Maximum Permissible Radiation Exposures to Man (18).

The Atomic Energy Commission also promulgates regulations on permissible concentrations of radioactive material in air and in water which apply to licenses issued by the AEC.

Regulations (1957) of the Atomic Energy Commission [17] states: "The National Committee on Radiation Protection has under review recommendation to limit cumulative exposures over periods of years.

The Commission is giving consideration to appropriate amendments to its regulations to deal with this cumulative exposure problem."

Subcommittee No. 2 reported in 1953 [18]: "From the standpoint of common use and quantity available, I^{131}, P^{32}, Co^{60}, Sr^{90}, C^{14}, S^{35}, Ca^{45}, Au^{198}, Ra^{226}, Pu^{239}, and Uranium present the major problems of irradiation within the body."

Hahn and Straub [12] in 1955 reported: "The most hazardous of all beta-emitting radioisotopes in water is strontium, Sr^{90}, in equilibrium with its daughter product Yttrium, Y^{90}. Other hazardous fission product isotopes are Sr^{89}, Y^{91}, Zr^{95}, Nb^{95}, Ru^{106}—Rh^{106}, I^{131}, Cs^{137}—Ba^{137}, Ba^{140}—La^{140}, and Ce^{144}—Pr^{144}. In addition, P^{32} and P^{32} and Co^{60} may be of interest to water works chemist."

Kenny [15] in a paper (1959) on radioactive discharge to sewers and rivers considered the following radioisotopes in common use, iodine-131, cobalt-60, phosphorus-32, carbon-14, sodium-24, potassium-42, bromine-82, sulphur-35, strontium-89, strontium-90, and tritium.

Setter, et al [35] report (Jan. 1958), "The two most hazardous radionuclides in so far as drinking water is concerned are radium (an alpha emitter) and its daughter products, and strontium-90 (a beta emitter)."

Struxness et al. [28] (in 1956) report, "In generga the critical nuclides include those of maximum abundance, high toxicity and long half-life such as Sr^{90}—Y^{90}, Sr^{89}, Zr^{95}—Nb^{95}, Ce^{137}—Ba^{137}, Ba^{140}—La^{140}, Ce^{144}—Pr^{144}, and Pm^{147}."

Straub et al. [37] (in 1954) reported, "A study of the values in handbook 52 and reactor fission yield data shows the most hazardous radioisotopes in fission products are Sr^{89}, Sr^{90}—Y^{90}, Y^{91}, Zr^{95}—Nb^{94}, Ru^{106}—Rh^{106}, I^{131}, Ce^{131}—Ba^{137}, Ba^{140}—La^{140}, and Ce^{144}—Pr^{144}. These and P^{32} (because of its wide use as a tracer) will be of most interest to the water and sewage works operator."

Subcommittee No. 2 [19] presented (in 1953) Table 3 containing limits in water for continuous exposure for a large number of radioisotopes. The AEC regulations [17] include a tabulation of (1947) permissible concentrations for controlled areas and uncontrolled areas. These AEC concentrations differ considerably from those published by Subcommittee No. 2 (in 1953) [18].

Table I gives a list of the radioisotopes, compiled from various authorities, which are potential ground water contaminants, together with the maximum permissible concentrations in water for uncontrolled areas as contained in the AEC Regulations [17] (1947).

TABLE I

Symbol	Radioactive Element	Maximum Permissible AEC (17) Concentration (microcuries per millilitre of water)	Authority (See Bibliography)
Au^{198}	Gold-198	3×10^{-4}	18
Ba^{140}—La^{140}	Barium-140• Lanthanum-140	2×10^{-4}	12, 28, 37
Br^{82}	Bromine-82	—	15
C^{14}	Carbon-14	3.6×10^{-4}	18, 15
Ca^{45}	Calcium-45	5×10^{-5}	18
Ce^{144}—Pr^{144}	Cerium-144• Praseodymium-144	3.6×10^{-3}	12, 28, 37
Co^{60}	Cobalt-60	1.8×10^{-3}	18, 12, 15
Cs^{137}—Ba^{137}	Cesium-137•Barium-137	1.5×10^{-4}	12, 28, 37
H^{3}	Tritium	1.6×10^{-2}	15
I^{131}	Iodine-131	3×10^{-6}	18, 12, 15, 37
K^{42}	Potassium-42	1.4×10^{-3}	15
Na^{24}	Sodium-24	8×10^{-4}	15
P^{32}	Phosphorus-32	2×10^{-5}	18, 12, 15, 37
Pm^{147}	Promethium-147	1×10^{1}	28
Pu^{239}	Plutonium-239	1.5×10^{-7}	18
Ra^{226} + ½ daughters	Radium-226 + ½ daughters	4×10^{-9}	18, 35
Ru^{106}—Rh^{106}	Ruthenium-106•Rhodium-106	1.3×10^{2}	12, 37
S^{35}	Sulphur-35	5×10^{-4}	18, 15
Sr^{89}	Strontium-89	7×10^{-6}	12, 15, 28, 37
Sr^{90}—Y^{90}	Strontium-90•Yttrium-90	8×10^{-8}	18,12,15,35,28,37
Y^{91}	Yttrium-91	2×10^{-2}	12
Zr^{95}—Nb^{95}	Zirconium-95•Niobium-95	—	12, 28, 37
unidentified Beta or gamma emitters		1×10^{-7}	
unidentified alpha emitters		1×10^{-7}	

4. Experience to Date

The literature contains numerous reports of potential water contamination by natural deposits of radioactive materials and by man-made radioactive products.

New Mexico State Department of Health reports (58) an investigation of waste disposal at the uranium ore milling plant of the Anaconda Company at Bluewater, New Mexico in which it states "Before the Anaconda plant went into operation the New Mexico Department of Public Health recognized the possibility that the wastes might cause radioactive pollution of ground water. In 1953 the Department collected two series of samples from wells in the area before operations started at the Anaconda Plant. These were examined for alpha and beta activity .... A third set of samples was collected on Nov 8, 1955, about two years after the Anaconda plant went into operation. Examination of these samples did not reveal any significant increase in radioactivity at that time."

In a report of radiological surveillance program the Florida State Board of Health stated (54) (Dec. 31, 1958) "Samples obtained from municipal and private wells --- analyzed for radioactivity content contained only minute quantities of radioactivity and are well below maximum permissible level."

Cherubin (5) in 1956 report of relative to potential hazards of laboratory liquid waste if discharged in to Mohawk River, "Certain Knolls Atomic Power Laboratory (KAPL) liquid wastes subjected to evaporation have been analyzed --- studies conducted during the past year have shown that these liquid wastes --- will be so dilute that only small reliance need be placed upon Mohawk River dilution to

reduce deleterious aspects to acceptable safety standards. The release of these laboratory liquid wastes has resulted in no significant effect on the safety of the Mohawk River when used for bathing and fishing in the Niskayuna Basin or as a source of public water supply at Cohees, New York."

Thoma (6) (1956) reported on disposal of low level liquid radioactive wastes into inland waterways; stating "When liquid radioactive wastes are discharged in a river or lake various purification processes may operate to remove them wholly or in part from the water --- the wastes are dispersed and diluted --- in addition --- the stream provides time for the radioactive decay. ---investigations at Harvard University since 1951 have been made to assess the feasibility of disposal of low-level liquid wastes in streams."

Barker and Scott (14) (June 1958) reported on uranium and radium in the ground water of parts of Texas and New Mexico. By means of water samples collected from 47 wells and springs, the determined radiochemical concentrations ranging from 0.9 to 12 parts per billion, and radium concentrations ranging from less than 0.1 to 0.8 micromicrocuries per liter.

Holluta (16) (1958) reported that the radioactivity of water in Lake Constance, near Riet, 40 meters below the surface, had increased tenfold, from 0.02×10^{-10} to 0.22×10^{-10} curies per liter in the period May 1956 to August 1957.

PASSAGE THROUGH SOILS

5. Nature of Movement

The literature includes several discussions on the nature of movement of radioactive materials through the soil.

Anderson and Rohrman (9) in 1956 reported: "---that of the radio elements of greatest concern, ruthenium moves farthest in soil, followed in order by cesium, strontium, and some of the rare earths --- some non-radioactive salts provide ions that are markedly more mobile than are the radioisotopes --- when the nitrate ion is

present in the waste, it will lead all the radioisotopes and other non-radioactive ions in rate of migration. Sufficient nitrate ion is normally present in related waste streams so that nitrate ion monitoring of the underground water provides effective control of ground water contamination."

Brown et al. (43) reported (1956): "The geological and hydrological factors that influence the rate and direction of flow of the Hanford ground waters are described with emphasis on their application toward the ground disposal of liquid radioactive wastes. Experimental and mathematical studies are supplemented by field tests and by observation of the effects of the disposal operations so far permitted microhydrologic procedures and concepts have been adopted to define the probable behavior of the waters and the radioisotopes more adequately than by the use of classical concepts."

Brown et al. (25) reported (1956), "---ruthenium is the most mobile radioactive ion, with cesium of interest because of its long half-life and intermediate mobility. Ions of great biological significance, such as plutonium and strontium are generally retained quantitatively by the soils immediately surrounding the disposal point --- The influence of total salt content of the waste was illustrated by findings at two disposal sites; one which received about 8000 curies of fission products in low salt waste resulting in no detectable ground water contamination; and the second which received about 800 curies of fission products in the same volume of high-salt water, resulting in ground water contamination of 4×10^{-6} uc/cm^3."

Ewing, B. B.(51) (Jan. 1959) reports, "The Sanitary Engineering Research Laboratory of the University of California, Berkeley, has been studying the feasibility of underground disposal of radioactive wastes. As part of this project, a synthesized radioactive waste containing Sr^{89} and Cs^{134} was injected into a confined permeable underground formation and its movement traced by radioassay of samples from monitoring wells distributed at various distances from the injection well. The results were correlated with field-scale hydraulic flow tests and a laboratory investigation of the ion-exchange properties of earth material taken from the same formation. The radioactivity of water pumped from the well during redevelopment was also investigated."

Orcutt et al (48) reports on the movement of radiostrantium through natural porous media, "The porous media studied with both batch and column systems included several connate-water bearing sands, an agricultural soil, and a standard halloysite clay. ---The results indicate the proper application of existing ion exchange theory will greatly reduce the uncertainties in estimating the rate of radiocontaminant travel through natural media ---."

Theis [27] (1956) reported, "Ground water moves through our productive aquifers typically at a rate of the order of magnitude of decimeter or a fraction of a foot per day. In deep-lying consolidated formations the average rate of the deeper formations, probably is typically of the order of a meter or a few feet per year."

Mawson reported [26] (1956), "It is a mistake to assume that when a solution is run into the soil it will soon be diluted by the ground water. This water moves slowly and is not mixed by burbulence and temperature changes in the same way as surface water, so solutions may move a long way without much mizing or despersion. Pollution control depends more upon filtration, adsorption and chemical reaction with the soil than upon dilution in the general body of the water table, but observation of the movement of the ground water is necessary to estimate the speed and direction of travel of solutions put into the ground."

"--- prediction of the time that would be required for the liquid from a pit to move underground to various discharge points depends on --- speed of travel and the flow pattern. Both --- determined in a somewhat complex way by permeability; porosity, and thickness of aquifer and by the natural ground water movement and the spacing of bodies of surface water---."

Orcutt et al [40] (1956) in a consideration of hydraulic and ion-exchange phenomena in the underground movement of radiostrontium, reports, "---required a knowledge of the hydrodynamics and chemistry controlling the movement of exchangeable cations through natural porous media. Darcy's law is not entirely adequate for delineating the velocity distribution of various portions of a liquid moving through a porous medium. Ion exchange is shown to greatly increase the storage capacity of geological formations and to retard the rate of movement of radioisotopes through the ground."

6. Removal of Radioactive Material

Relative to removal of radioactive particles from water; Lacy [1] discussed (1957) ion exchange, surface adsorption and interstitial precipitation as mechanisms of removal of radioactive materials from water by soil, his report; " ---covers an investigation of the radioactive liquid waste adsorption capacity of Conasauga shale, the formation in which ORNL (Oak Ridge National Laboratory) liquid waste pits have been dug." A conclusion, "Leaching by tap water removes very little activity once it is adsorbed in the shale."

Anderson and Rohrman [9] reported (1956): "The removal of cations from the soil is possible and is dependent on the solution composition. Once in equilibrium with a given solution the soil will remain in adsorption equilibrium until the solution composition changes. The degree of cationic saturation can be expected to vary with concentration. Large quantities of leaching solutions are required, however, to effect measurable changes in the soil adsorption. Locations with low rainfall and good ionic characteristics in the soil condensate discharge to ground is stopped."

Carritt and Goodgal [4] (1953) reported of a sorptive properties of silts in natural wasters for radioactive wastes, and the nature and magnitude of the radioisotopes of phosphorous and the interaction of radioisotopes of phosphorus and strontium with several kinds of solids found suspended in natural waters.

Blanchard et al [55], in a laboratory study relative to ground disposal of intermediate-level liquid radioactive wastes at Oak Ridge National Laboratory reported (1958), "Radioactive wastes and ground water solutions --- to determine the sorptive behaviour of the radionuclides. Cesium-137, the major radioactive constituent of the basic waste solution, was adsorbed very effectively with a shale/solution distribution ratio of 500. A small fraction of Ruthenium-106, the only other radionuclide present in relatively large concentration, was adsorbed per unit weight of shale, but this adsorption occurred even when the radionuclide had previously passed through 200 feet of shale."

Hatch et al [24] reported (1956) "--- fission products, with the exception of ruthenium, are largely cationic in aqueous solution, --- some of the natural clays have good capacity for chemical exchange of cations, ---. Montmorillonite clay --- is not known to have any significant capacity for adsorption of

ruthenium. In fact, it has been found that a high percentage, if not all, the ruthenium in certain waste solutions passes readily through the clay columns ---.

Brown et al. [25] in a study of plutonium wastes discharged to ground at Hanford reported (1956), "---the radioisotope Pu^{239} was studied intensively because of its high radiochemical toxicity.

"Laboratory equilibrium adsorption studies showed that plutonium is almost completely adsorbed (in soils representative of the materials underlying the disposal sites at Hanford over a wide pH range.

"The presence of monovalent ions (Na^{+}) or divalent ions (Sr^{++}) in the solution had no apparent effect on the adsorption of plutonium by soil while trivalent ions (such as Al^{+++}) reduced it markedly.

"Ruthenium appears abundantly in most process waste streams because of the large yield in uranium fission.

"A small amount of work with Ce^{144} indicated that adsorption is almost complete from neutral solutions ---.

"Representative soils were equilibrated with chloride solutions of cesium, strontium and yttrium containing Cs^{137}, Sr^{90}, and Y^{90}---. The system, solution-adsorbed cation-soil is not static but dynamic so that the degree of cationic saturation of a soil layer will vary as the solution composition varies.

"The laboratory work showed that removal of adsorbed Ca^{+}, Sr^{++}., and Y^{+++} was brought about with --- Co_2-saturated water --- simulated percolating ground water. The data from the later experiments indicated that if all the normal rainfall in the region percolated through the bed, up to 400 years would be required to reduce the adsorbed Cs^{+} content of the soil by 50% when initially only 0.01 of the soil capacity was cesium saturated. Furthermore, the cesium so removed would enter into exchange with deeper layers of the soil thereby increasing the net time of retention."

Clark and Pohl [38] reported (1956), "Radioactive wastes of low specific activity are being stored in soil columns at the Savannah River Plant. Approximately 130,000 gallons per day of waste liquors is handled in this manner. ---the operation has been quite satisfactory."

McHenry et al [39] (1956) reported relative to chemical and physical interactions of radioactive wastes and soils, "The reactions of radioisotopes in solution with Hanford soils with consideration of the effects of concentration, pH, other ions, total salt concentration, and the type of soil. ---increase in strontium adsorption in the presence of phosphate ion counteract the adverse effect of high salt concentrations. ---experiment and the theoretical considerations illustrate the very low-diffusion rate of Sr-ion in the fixed soil moisture."

Struxness et al. [28] (1956) concluded, "The experience with the disposal of intermediate level liquid wastes in terrestrial, pits at ORNL (Oak Ridge National Laboratory) shows that pits have certain advantages over evaporation and storage in tanks."

Rhodes and Nelson [20] reported: "Laboratory experiments were conducted to estimate the maximum volume of radioactive liquid waste from the Uranium Recovery Plant (Hanford, Washington) that could be discharged to a specific water contamination. The long-lived radioisotopes Cs^{137} and limiting radioisotopes---gallons of liquid waste were discharged to the ground on the basis of criteria obtained from the laboratory experiments. The results of ground water analyses confirmed the validity of the laboratory findings."

Summary Note

The many published reports, based on studies and experience at AEC plants show satisfactory results at specific large area highly controlled AEC plants. Very little information is available relative ground water contamination in residential areas of normal municipalities.

DETERMINED FROM SURVEY

7. Predicting Radiological Contamination

Setter and Goldin [23] (1956) concluded, "The determination of the extent and significance of radioactive water pollution requires a knowledge of the natural radioactive background and current levels of gross alpha and Beta activity as well as some knowledge of the source of contamination (with respect to the kinds of radioisotopes). Methods have been developed and surveys made on both natural background and artificial radioactivity ---. Some of the methods, though involved, have high specificity. Other methods are simple but less specific. The gross Alpha and Beta measurements can be assayed at high over all efficiencies. Such a method for low-level measurements has been described --- sensitive to 10-30 per cent of the maximum permissible concentration for unknown isotopes."

Struxness et al [28] reporting on experience with disposal into earth pits at ORNL stated, " --- before this experience can wastes, more laboratory and field pilot plant data are needed. Some of the factors requiring further evaluation include (1) the effects of interaction between soil and the waste materials, (2) the movements of critical nuclides through various soil formation, (3) the effects of high concentrations of stable salts such as aluminum, nitrates, and various solvents and complexing agents upon the ability underground flow pattern of waste solutsions as compared with ground water."

Goldin et al [32] (1953) reported, "A study of the factors involved in the detection of low level radioactivity in water has been made. --- The statistical lower limits of detectability of alpha and beta radioactivity are shown to be 1.5 and 11 uy C per liter --- respectively, as compared to the general maximum permissible level in drinking water of 100 uy C per liter ---".

Tsivoglov, et al [21] have reported (1957) relative to laboratory techniques, "--- water samples for radio need no preservation, and should in no way be altered during or after collection. Most samples will be assayed for gross alpha and gross beta radioactivity. It is often desirable to analyze further for suspended and dissolved fractions of these gross results. ---Depending upon the particular pollution source it will at times be desirable to analyze for specific components. ---analytical methods for specific radioelements are generally available if need arises."

Setter et al [30] reported (1954), "A method for separately assaying the alpha and beta radioactivity in water and industrial wastes --- suspended solids in a sample are removed by filtration or centrifuging for an assay of insoluble radioactivity. The supernatant or filtrate of a relatively large sample is evaporated in a large counting dish to deposit the dissolved solids in a thin layer so as to minimize self-absorption losses. "The radioactivity is counted in an interval proportional counter, the counting efficiency of which varies from 50 - 52% for alpha activity and from 50 - 75% for beta activity, depending on the amount of back scattered radiation. At low levels of radioactivity, the statistical error of counting has a predominant effect on the accuracy of the assay. At a radioactivity level of 50 uuc. per liter ---, this error is ± 10% for alpha activity and + 20% for beta activity at the 95% confidence level. Lower levels of activity are detected but with less accuracy."

Staub [31] early (1956) reported, "The identification of the radioactive components present (in water) is not too difficult if the number of radionuclides present is small and the concentration, in terms of radioactivity, is high. In the case of low concentrations of radioactivity --- at or near the M.P.C. levels, identification is not simple and becomes increasingly difficult as the number of radionuclides in the mixture increases. Another difficulty stems from the fact that radiochemical procedures for identifying the radionuclides present at these low levels are generally not available. Thus far (1956), procedures for strontium and barium, have been published ---, and those for other isotopes of interest (cesium, yciconium, noibium, cerium, yttrium, iodine, and ruthenium) will be released shortly. By a process of elimination, i.e., by showing that the more critical radionuclides are not present, the quantity of radioactive materials being discharged may be increased by a factor of 100 or more over the presently accepted M.P.C. value of 10^{-7} uc per milliliter for mixed radioisotopes in water.

Kahn et al [34] concluded (1957) with reference to laboratory assays "Precipitation of cesium ammonium phosphomolybdate, co-precipitation of cesium with potassium sodium cobaltinitrate, and concentration by means of an ion exchange resin have been found equally suitable for the analysis of 1-liter samples of water for radioactive cesium---.

"The minimum detectable cesium concentration is established by the counting method, --- it is 7×10^{-9} microcurie per ml. An increase in sensitivity by a factor of 100 can be achieved with the greater geometry of an internal proportional counter and the decreased background made possible by special shielding and anti-coincidence circuits---."

Setter et al [37] have reported (1958) regarding laboratory procedures, "Practical procedures for determing the gross alpha and gross beta radioactivity of water, soil, and biological samples --- consist of separating suspended activity evaporation of filtrates, drying at 103 deg C or ignition at 600 deg C, and deposition of a thin film of sample solids on large (2 in. diameter) dishes for counting in interval, gas flow, proportional counters having a maximum efficiency of about 50% for alpha and 65% for beta activity from one-year-old mixed fission products. The methods used are suitable for measuring nonvolatile radioactivity at levels far below 100 uuc per liter (the maximum permissible concentration of unknown radionuclides in drinking water), are applicable at levels exceeding 100 uuc per liter and may through decay measurements or a knowledge of radionuclide composition, indicate the health significance of observed activity."

Ettinger [36] has reported, "Of all the radioactive materials formed in the production of nuclear power, struntium-90 presents the greatest potential health hazard, the permissible concentration of this isotope in water is about 100 times lower than that for the next most hazardous fission product. Measurement of strontium-90 at very low levels is therefore important in evaluation of radioactive pollution."

Hahn and Straub [12] (1955) gives a procedure for the determination of low concentrations of radioactive strontium (to about 4×10^{-8} uu/ml) and barium to about 10^{-7} uc/ml). "The method was tested on various natural and waste waters. A precision of about 10 per cent was obtained. As the method does not distinguish between the various isotopes of strontium or barium - for example between Sr^{89} and Sr^{90} decay and absorption analyses would be required for this information."

Goldin [2] (1956) reported on a method for determining the Strontium-90 content of water in the presence of large quantities of other fission product isotopes:

"Strontium carbonate is precipitated to concentrate the activity from a large volume (1-20 liters) of water. After removal of most interfering isotopes by precipitation yttrium-90 is allowed to grow in, and is then separated by extraction into a benzene solution of the chelating agent 2-thenoyltrifluoroacetone. This extraction serves to remove the remainder of the interfering isotopes. The yttrium-90 is then back extracted into nitric acid, evaporated on stainless steel and counted. A determination may be completed in twenty-four hours and about six man-hours are required for four samples so processed at the same time."

8. Water Quality Criteria Needed

Existing water criteria relative to radioactive contaminents based largely on the National Bureau of Standards Handbook 69, or AEC Regulations. Further evaluation of the maximum permissible concentrations of radioactive materials in water is needed.

Tsivoglow, et al [21] conclusions (1957) still apply. They stated, "A great deal is still unknown regarding the human uptake of radioactive elements and their direct and indirect physiological effects once ingested. We are especially ignorant of the long-term effects of chronic exposure to radioactive materials in low concentration --- As more is learned regarding the effects of chronic radiation exposure --- it is anticipated that some of the concentrations presently accepted as safe will be revised, either upward or downward."

9. Suggestions for Obtaining Additional Information

It would be desirable to determine more reliably the basic factor which establish the relative location of well water supplies and the sites of users of radioisotopes and possible atomic energy industries with reference to potential radioactive contamination of ground water.

Consideration of the following items is suggested:

1. A review of past experience and previous investigations with particular attention to the adsorption and leeching of radioactive materials through various types of soils, both above ground water and with ground water. This may involve some field surveys to establish soil types.

2. Conducting column type experiments to determine the retention capacity of various types of soils for several commonly used isotopes which occur in dissolved or colloidal states.

3. Conducting of distribution coefficient experiments to determine the adsorption capacity of various soils for several of the commonly used isotopes.

4. Conducting of column type leeching studies with water and various solutions to study the stability of the retention of radioisotopes by retention of radioisotopes by various types of soils.

5. A review of past experience and previous investigation with particular attention to the hydrodynamics of the movement of ionic solutions through natural porous media.

6. Laboratory and field studies to evaluate the factors controlling the movement of radioactive solutions through soils.

7. Development of procedures for obtaining representative samples of suspected ground water.

8. Development of standardized analytical methods to determine gross alpha and gross beta activity as well as analysis for specific radioactive materials.

9. Further evaluation of the reported maximum permissible concentrations to increase the confidence of these figures.

A substantial study by a competent observer has led to general conclusions as follows:

Terrill [45] (1956) reported, "Types of problems which are and will be facing the states immediately include: (1) suitable sanitary engineering techniques for radiation assessment such as equipping and operating laboratories, suitable sampling techniques, analytical methods, and interpretation of results; (2) the application of sanitary engineering criteria in site selection for atomic energy installation, including such factors as evaluation of environmental health hazards from the type of installation proposed and relating these to significant environmental characteristics of proposed sites, determination of waste disposal requirements and water supply requirements, and assessments of radioactivity associated with the site prior and after operations are initiated; and (3) the development of an emergency plan of action to be used in the event of accidents involving spills or other widespread dispersal of radioactive materials."

"Another gap in our sanitary engineering techniques results from the lack of standardized and reliable methods for radiation assessment, some work has been done but in order that official health agencies, at a minimum expense and with optimum utilization of available staff may be guided in radiation assessment for investigative and control purposes, it is planned to increase efforts to develop a choice of standard sanitary engineering techniques

for radiation assessment which are capable of interpretation and reporting in a uniform manner, much the same as the existing standard methods for the Examination of Water and Sewage. This will include the development of sampling methods (number, types, sizes, locations, frequencies) meeting statistical and other requirements for reliability and significance, and developments of standardized analytical methods."

10. Summary

A library search conducted on ground water contamination due to radioactive waste materials, has developed much generalized data.

Several experiences of contamination and potential contamination of water by radioisotopes have been recorded in the literature, but insufficient data are available in many cases, as to sources.

Literature on the nature of movement and the removal of radioactive materials through the soil and in the ground water is indicative of definite possibilities, but more information is needed with special reference to stability of absorbed chemical compounds.

The present art of predicting radiological contamination relates primarily to large installation (AEC). There is little evidence applicable to house lot situation. Much basic research must be done before practical guides can be set up.

11. Topic III - References - See Bibliography Items (1) - 466 to (58) - 523, inclusive (pages 138 to 143, inclusive) using reference numbers in parentheses.

APPENDIX G

GROUND WATER CONTAMINATION

Topic IV - Biological Contaminants - Miscellaneous Data

a - Characteristics and Control of Water - (and Food) Borne Diseases From Salvato - "Environmental Sanitation"

b - (pages b-1 to b-6) Data on Water-Borne Diseases - May 29, 1959 Letter from Herbert H. Rogers, Chief, Environmental Health Training Section - Public Health Service - Department of Health Education, and Welfare

c - (pages C-1-C-21) - Data on Water-Borne Diseases - July 1, 1959 Letter from George W. Burke, Jr., Chief, Water Supply Section - Division of Water Pollution Control, Public Health Service - Department of Health, Education, and Welfare

APPENDIX G

GROUND WATER CONTAMINATION

Topic IV - Biological Contaminants - Miscellaneous Data

INTRODUCTION

Many of the biological contaminants have been known for years and have been discussed in textbooks and treatises. It seems unnecessary to prepare any detailed discussion of these organisms. The summary statements in Part II of the report reviews some aspects of the possibilities of ground water contamination from the various biological agents with reference to ground water contamination.

A number of miscellaneous data appear to have sufficient value and special interest to reproduce herein. These are as follows;

a. Characteristics and Control of Water - (and Food) Borne Diseases

   This tabulation gives information on most water borne diseases in a useful condensed form, which permits a quick summary study of several aspects of the biological contaminants. This tabulation is taken from an appendix in Environmental Sanitation - J. H. Salvato, published by John Wiley & Sons - New York - 1958.

b. (pages b-1 to b-6) Data on Water-Borne Diseases - May 29, 1959 letter from Herbert H. Rogers, Chief, Environmental Health Training Section - Public Health Service - Department of Health Education, and Welfare

c. (pages C-1 to C-21) - Data on Water-Borne Diseases - July 1, 1959 letter from George W. Burke, Jr., Chief, Water Supply Section - Division of Water Pollution Control, Public Health Service - Department of Health, Education, and Welfare.

CHARACTERISTICS AND CONTROL OF WATER- AND FOOD-BORNE DISEASES

	DISEASE	SPECIFIC AGENT	RESERVOIR	COMMON VEHICLE	SYMPTOMS—IN BRIEF	ONSET*	PREVENTION AND CONTROL
BACTERIAL FOODS	Botulism food poisoning	Clostridium botulinum A and C parabotulinum which produce toxin.	Soil, dust, fruits, vegetables, and foods	Improperly processed canned and bottled foods containing the toxin.	Gastrointestinal pain, diarrhea or constipation, prostration, difficulty in swallowing, double vision, difficulty in respiration.	2 hr to 8 days, generally within 24 hr.	Boil home canned nonacid food 5 min; thoroughly cook meats, fish, and dried foods held over. Do not taste suspected food!
	Staphylococcus food poisoning	Staphylococci which produce enterotoxin, Staphylococcus albus, S. aureus (toxin is stable at boiling temperature)	Skin, mucous membranes, pus, dust, air, sputum, and throat.	Contaminated custard pastries, cooked or processed meats, poultry, dairy products, hollandaise sauce, salads, milk.	Acute nausea, vomiting and prostration; diarrhea, abdominal cramps. Usually explosive in nature followed by rapid recovery of those affected.	1 to 6 hr or longer, average of 2½ to 3 hr	Refrigerate prepared food in shallow containers at a temperature below 65°F immediately upon cooling. Reuse leftover food within 6 hr. Avoid handling food. Educate food handlers in personal hygiene and sanitation.
BACTERIA	Salmonellosis (Salmonella infection)	Salmonella typhimurium, S. newport, S. enteritidis, S. montevideo, other.	Hogs, cattle, and other livestock, poultry, pets, eggs, carriers, powered eggs.	Contaminated sliced cooked meat, salads, infected meats, warmed over foods, milk, milk products.	Abdominal pain, diarrhea, chills, fever, vomiting and nausea. Diarrhea usually persists several days.	6 to 72 hr usually 18 hr.	Protected storage of food. Thoroughly cook food. Eliminate rodents, pets, and carriers. Similar measures as in Staphylococcus. Poultry sanitation.
	Typhoid fever	Typhoid bacillus, Salmonella typhosa	Feces and urine of typhoid carrier or patient.	Contaminated water, milk and milk products, shellfish and foods. Fly.	General infection characterized by continued fever, usually rose spots on the trunk, diarrhoeal disturbances.	3 to 38 days, usually 7 to 14 days.	Protect and purify water supply; pasteurize milk and milk products; sanitary sewage disposal; educate food handlers; food, fly, shellfish control; supervise carriers; immunize. Personal hygiene.
	Paratyphoid fever	Salmonella paratyphi A, S. schottmuelleri B, S. hirschfeldii C.	Feces and urine of carrier or patient.	Contaminated water, milk and milk products, shellfish and foods. Fly.	General infection characterized by continued fever, diarrheal disturbances, sometimes rose spots on trunk, other symptoms.	1 to 10 days	Similar preventive and control measures as in typhoid fever and salmonellosis.
	Streptococcus food poisoning	Alpha-streptococci, Beta-hemolytic S., S. faecalis, viridans	Human mouth, nose, throat, respiratory tract	Contaminated meats, milk, croquettes, cheese, dressings.	Nausea, sometimes vomiting, colicky pains, and diarrhea.	2 to 18 hr, average 12 hr.	Similar preventive and control measures as in Staphylococcus. Pasteurize milk and milk products.
	Shigellosis (bacillary dysentery)	Genus Shigella, i.e., Flexner, Sonne, Shiga and others	Bowel discharges of carriers and infected persons.	Contaminated water or foods, milk and milk products. Fly.	Acute onset with diarrhea, fever, tenesmus, and frequent stools containing blood and mucus.	1 to 7 days, usually less than 4 days.	Food, water, sewage sanitation as in typhoid. Pasteurize milk (boil for infants); control flies, supervise carriers.
	Cholera†	Cholera vibrio, Vibrio comma	Bowel discharges, vomitus, carriers.	Contaminated water, raw foods. Fly.	Diarrhea, rice-water stools, vomiting, thirst, pain, coma.	A few hours to 5 days, usually 3 days.	Similar to typhoid. Immunize, quarantine, isolate patients.
	Melioidosis†	Pfeifferella whitmori	Rats, guinea pigs, cats, rabbits, dogs, horses.	Food contaminated with rat excreta possibly.	Acute diarrhea, vomiting, high fever, delirium, coma.	Less than 10 days	Destroy rats, protect food, thoroughly cook food, control biting insects, personal hygiene.
	Brucellosis (undulant fever)	Brucella melitensis goat, Br. abortus cow, Br. suis pig	The tissues, blood, milk, urine infected animal	Raw milk from infected cows or goats, also contact with infected animals	Insidious onset, irregular fever, sweating, chills, pains in joints and muscles	6 to 30 days or longer	Pasteurize all milk, eliminate infected animals. Handle infected carcasses with care.
	Streptococcal sore throat	Hemolytic Streptococci	Nose, throat, mouth secretions	Contaminated milk or milk products	Sore throat and fever, sudden in onset, vomiting	2 to 5 days	Pasteurize all milk. Inspect contacts. Exclude carriers.
	Diphtheria	Corynebacterium diphtheriae	Respiratory tract, patient, carrier	Contact and milk or milk products	Acute febrile infection of tonsils, throat, and nose	2 to 5 days or longer.	Pasteurize milk, disinfect utensils. Inspect contacts, immunize.
	Tuberculosis	Mycobacterium tuberculosis (hominis et bovis)	Respiratory tract of man. Rarely cattle	Contact, also eating and drinking utensils, food and milk	Cough, fever, fatigue, pleurisy.	Variable.	Pasteurize milk, eradicate TB from cattle, X-ray, control infected persons. Selective use of BCG.
	Tularemia	Pasteurella tularensis (Bacterium tularense)	Rodents, rabbits, horse fly, wood tick, dog, fox, hog	Meat of infected rabbit, contaminated water, handling wild animals	Sudden onset with pains and fever, prostration	1 to 10 days, average of 3.	Thorough cooking of meat of wild rabbits. Purify drinking water. Use rubber gloves (care in dressing wild rodents).
	Gastroenteritis	Microorganisms unknown	Probably man and animals	Water, food, including milk, air	Diarrhea, nausea, vomiting, cramps, possibly fever.	Variable, 8 to 12 hr average	Environmental sanitation, education, personal hygiene
RICKETTSIA	Q fever	Coxiella burnetii	Dairy cattle, sheep, goats	Slaughterhouse, dairy employees handling infected cattle, raw cow and goat milk	Heavy perspiration and chills, headache, malaise	2 to 3 weeks	Pasteurization of milk and dairy products, elimination of infected animal reservoir, cleanliness in slaughterhouses and dairies. Pasteurize at 145°F for 30 min or 161°F for 15 sec where illness found.
VIRUSES	Choriomeningitis, lymphocytic	A filterable virus	House mice urine, feces, secretions	Contaminated food	Fever, grippe. Severe headache, stiff neck, vomiting, somnolence	8 to 13 days, 15 to 21 days.	Eliminate or reduce mice. General cleanliness, sanitation.
	Infectious hepatitis	Viruses unknown	Discharges of infected persons	Water, food, milk. Contacts	Fever, nausea, loss of appetite, possibly vomiting, fatigue, headache, jaundice	15 to 35 days, average 25 days	Sanitary sewage disposal, food sanitation, personal hygiene, cook, and filter water supply, + 0.6 ppm free Cl,
PROTOZOA	Amebiasis (amebic dysentery)	Endamoeba histolytica	Bowel discharges, of carriers and infected person, possibly also rat	Cyst contaminated water, foods, raw vegetables and fruits. Fly, cockroaches.	Insidious and undetermined onset, diarrhea or constipation, or neither, loss of appetite, abdominal discomfort, blood, mucus, stool	2 days or longer, average 3 to 4 weeks	Same as Bacillary. Boil water or coag. set filter thru diatomite 5 gr/m/sq ft, Cl_2. Usual Cl_2 and high rate filtration not 100% effective. Slow sand filtration + Cl_2
SPIROCHETES	Vincent's infection (trench mouth)	Fusobacterium plaut, Bacillus vincenti	Oral cavity of man	Contaminated eating or drinking utensils	Lesions in mouth, salivation and fetid odor. Pain on swallowing.	Variable	Oral hygiene, disinfection of eating and drinking utensils. Fresh fruits, veg. and meats in diet.
	Leptospirosis (Weil's disease) (Spirochetosis icterohemorrhagica)	Leptospira icterohaemorrhagiae, L. hebdomadis, L. canicola, other	Urine and feces of rats, swine, ringtail, cats, mice, foxes, sheep	Food, water, soil contaminated with excreta or urine of infected animal. Contact	Fever, rigors, headaches, nausea, muscular pains, vomiting, thirst. Prostration, jaundice.	4 to 19 days, Average 9 to 10 days	Destroy rats, protect food, avoid polluted water; treat abrasion of hands and arms. Disinfect utensils, treat infected dogs.
HELMINTHS	Trichinosis (Trichinosis)	Trichinella spiralis	Pigs, bears, wild boars, rats, fox, wolf.	Infected pork and pork products, bear and wild boar meat	Nausea, vomiting, diarrhea, muscle pain, swelling of face and eyelids, difficulty in swallowing	24 hr, usually 6 to 7 days	Thoroughly cook pork, pork products, bear and wild boar meat, destroy rats. Feed hogs boiled garbage or discontinue feeding. Store meat 20 days at 5°F or 24 hr at −24°F.
	Schistosomosis (Bilharziasis)‡ (blood flukes)	Schistosoma haematobium, S. mansoni, S. japonicum	Venous circulation of man; urine, feces.	Cercariae infected drinking and bathing water.	Dysenteric, pulmonary, and abdominal symptoms. Rigors. Itching on skin, dermatitis.	1 to 3 months or longer.	Avoid infected water, coag. set 1 hr, sand filt. 3 gr/m/sq ft or 5 with diatomite, Cl_2 1 ppm, boil water, 10 ppm $CuSO_4$, and impound water 48 hr, Cl_2. (Also 10 ppm sodium or copper pentachlorophenate.) Slow sand filt. + Cl_2
	Ascariasis (intestinal roundworm)	Ascaris lumbricoides	Small intestine of man, gorilla, ape.	Contaminated food, water, sewage	Worm in stool, abdominal pain, skin rash, protuberant abdomen, nausea, large appetite.	1 to 3 days and 2 to 4 months	Personal hygiene, sanitation. Boil drinking water in endemic areas. Sanitary excreta disposal.
	Echinococcosis (Hydatidosis)	Echinococcus granulosus, dog tapeworm	Dog, sheep, wolf, dingo, swine, horse, monkey.	Contaminated food and drink, hand to mouth, contact with infected dogs.	Cysts in tissues—liver, lung, kidney, pelvis. May give no symptoms. May cause death.	Variable, several years.	Keep dogs out of abattoir and do not feed raw meat. Mass treatment of dogs. Educate children and adults in the dangers of close association with dogs.
	Taeniasis (beef tapeworm) (pork tapeworm)	Taenia solium (pork tapeworm), T. saginata (beef tapeworm)	Man, cattle, pig, buffalo, possibly rat, mouse.	Infected meats eaten raw. Food contaminated with feces of man, rats or mice.	Abdominal pain, diarrhea, convulsions, insomnia, excessive appetite.	1 to 3 months.	Thoroughly cook meat, control flies, properly dispose of excreta, foodhandler hygiene. Use only inspected meat. Store meat 6 days at 15°F.
	Fish Tapeworm (Broad tapeworm)	Diphyllobothrium latum, other.	Carnivorous man, frog, dog, cat.	Infected fresh water fish eaten raw.	Abdominal pain, loss of weight, weakness, anemia.	18 days.	Thoroughly cook fish, roe, (caviar). Proper excreta disposal.
	Paragonimosis (lung fluke)	Paragonimus ringeri, P. westermani, P. kellicotti	Respiratory and intestinal tract of	Infected water, fresh water crabs	Chronic cough, clubbed fingers, dull pains, and diarrhea	Variable	Boil drinking water in endemic areas. Thoroughly cook fresh

WORMS	Fish tapeworm (broad tapeworm)	Diphyllobothrium latum, other	Cyclops, man, frog, dog, cat	Infected fresh water fish eaten raw.	Abdominal pain, loss of weight, weakness, anemia	18 days	Thoroughly cook fish, roe, (caviar). Proper excreta disposal.
	Paragonimus (lung flukes)	Paragonimus ringeri, P. westermani, P. kellicotti.	Respiratory and intes tract of man, cat, dog, pig, rat, wolf.	Infected water, fresh water crabs or crayfish.	Chronic cough, clubbed fingers, dull pains, and diarrhea	Variable	Boil drinking water in endemic areas, thoroughly cook fresh water crabs and crayfish. †
	Clonorchiasis† (liver flukes)	C. sinensis, Opisthorchis felineus	Liver of man, cats, dogs, pigs	Infected fresh water fish.	Chronic diarrhea, night blindness	26 days.	Boil drinking water in endemic areas; thoroughly cook fish †
	Fascioliasis (sheep liver flukes)*	Fasciola hepatica	Liver of sheep	Sheep liver eaten raw	Irregular fever, pain, diarrhea	Several months.	Thoroughly cook sheep liver †
	Trichuriasis† (whipworm)	Trichuris trichiura	Large intestine of man, pig, dog	Contaminated food	No special symptoms, possibly stomach pain	6 to 12 months	Sanitation. Boil water, cook food, properly dispose feces †
	Oxyuriasis (pinworm, threadworm, or enterobiasis)	Oxyuris vermicularis, or Enterobius vermicularis	Large intestine of man	Fingers. Ova-laden dust. Contaminated food, water, saliva	Nasal itching, anal itching, diarrhea	14 days	Wash hands after defecation, keep fingernails short, sleep in cotton drawers. Sanitation.
	Fasciolopsiasis† (intestinal flukes)	Fasciolopsis buski	Small intestine of man and pig	Raw fresh water plants, water, food	Stomach pain, diarrhea, greenish stools, constipation. Edema	1 to 2 mos	Cook or dip in boiling water roots of lotus, bamboo, water chestnut, caltrop
	Dwarf tapeworm	Hymenolepis nana	Man and rodents	Food contaminated with ova, direct contact	Diarrhea or stomach pain, irritation of intestine	1 month	Sanitary excreta disposal, personal hygiene, food sanitation, rodent control, treat cases
POISONOUS PLANTS AND ANIMALS	Ergotism	Ergot, a parasite fungus (Claviceps purpurea)	Fungus of rye and occasionally other grains	Ergot fungus contaminated meal or bread	Gangrene involving extremities, fingers, and toes, or weakness and drowsiness, headache, giddiness, painful cramps in limbs	Gradual, after prolonged use of diseased rye in food.	Do not use discolored or spoiled grain. Fungus grows in the grain, meal is grayish, possibly with violet colored specks
	Rhubarb Poisoning	Probably oxalic acid	Rhubarb	Rhubarb leaves	Intermittent crampish pains, vomiting	2 to 12 hr.	Do not use rhubarb leaves for food
	Mushroom Poisoning	Phalloidine and other alkaloids, also other poisons in mushroom	Mushrooms—Amanita phalloides and other Amanita	Poisonous mushrooms (Amanita phalloides, Amanita muscaria, others)	Severe abdominal pain, intense thirst, retching, vomiting, and profuse watery evacuations	6 to 15 hr or 15 min to 6 hr with muscarine	Do not eat wild mushrooms, warn others. Amanita are very poisonous, both when raw or cooked
	Favism†	Poison from Vicia fava bean, pollen	Plant and bean Vicia fava	The bean when eaten raw, fava pollen.	Acute febrile anemia with jaundice, passage of blood in urine.	1 to 24 hr.	Avoid eating fava, particularly when green, or inhalation of pollen
	Fish poisoning	Poison in fish, arrows and rasps, roe (hard-stable)	Fish. Pike, carp, sturgeon roe in breeding season	Fish—Tetraodon, Molena, Clupea. Pictoral eggs, muscles.	Painful cramps, dyspnoea, cold sweats, dilated pupils, difficulty in swallowing and breathing	30 min to 2 hr or longer	Avoid eating roes during breeding season. Heed local warnings concerning edible fish
	Shellfish poisoning	Possibly plankton (Gonyaulax) food of mussels.	Probably plankton, food of mussels	Mussels	Respiratory paralysis. In milder form, trembling about lips to loss of control of the extremities and neck	5 to 30 min and longer	Obtain shellfish from certified dealers and from approved areas. The toxin appears to be heat-stable
	Snakeroot poisoning	Tremetol in snakeroot (Eupatorium urticaefolium)	White snakeroot, rayny weed	Milk from cows pastured on snake root	Weakness or prostration, vomiting, severe constipation & pain, thirst, temperature normal	Variable. Repeated use of the milk	Prevent cows from pasturing in wooded areas where snakeroot exists
	Potato Poisoning	Solanum tuberosum, other S	Sprouted green potatoes	Possibly green sprouted potatoes	Vomiting, diarrhea, headache, abdominal pains, prostration	Few hours	Do not use sprouts or peel of sprouted green potatoes
	Water-hemlock Poisoning	Cicutoxin or resin from hemlock (Cicuta maculata)	Water hemlock	Leaves and roots of water hemlock	Nausea, vomiting, convulsions, pain in stomach, diarrhea	1 to 2 hr	Do not eat roots, leaves or flowers of water hemlock.
CHEMICAL POISONS	Antimony Poisoning	Antimony	Orby enameled cooking utensils	Foods cooked in cheap enameled pan	Vomiting, paralysis of arms	Few minutes to an hour	Avoid purchase of poor quality gray enameled, or use of chipped enamel, utensils
	Arsenic Poisoning	Arsenic	Arsenic compounds	Arsenic contaminated food or water	Vomiting, diarrhea, painful tenesmus. (A cumulative poison.)	10 min and longer	Keep arsenic sprays, etc. locked, wash fruits, vegetables. >0.05 ppm
	Cadmium Poisoning	Cadmium	Cadmium plated utensils	Acid food prepared in cadmium utensils	Nausea, vomiting, cramps and diarrhea	15 to 30 min	Watch for cadmium plated utensils and destroy. Inform mfr.
	Cyanide Poisoning	Cyanide, sodium	Cyanide silver polish	Cyanide polished silver	Dizziness, giddiness, dyspnea, palpitation and unconsciousness.	Rapid	Select silver polish of known composition. Prohibit sale of poisonous polish
	Fluoride or Sodium Fluoride Poisoning	Fluoride or sodium fluoride	Roach powder	Sodium fluoride taken for baking powder, soda, flour	Acute poisoning, vomiting, abdominal pains, convulsions, pareses of eye, face, finger muscles and lower extremities, diarrhea	A few minutes to 2 hr	Keep roach powder under lock and key, mark "Poison", color the powder, apply with care.
	Lead poisoning	Lead	Lead pipe, sprays, aerdes and utensils. Lead base paints	Lead contaminated food or acid drinks, toys, fumes, paints	Abdominal pain, vomiting and diarrhea. (A cumulative poison.)	30 minutes and longer	Do not use lead pipe if water is acid, Ph. 0.1 ppm. Protect food. Wash fruits. Label paints.
	Mercury poisoning	Mercury	Mercury, bichloride of mercury	Mercury contaminated food	Astringent metallic taste, salivation, great thirst, vomiting, abdominal pain, watery diarrhea	2 to 30 min	Keep mercuric compound under lock and key
	Methyl chloride poisoning	Methyl chloride	Refrigerant, methyl chloride	Food stored in refrigerator having leaking unit	Progressive drowsiness, stupor, weakness, nausea, vomiting, pain in abdomen, convulsions	Variable	Use nontoxic refrigerant, such as "Freon," water, brine, dry ice
	Selenium poisoning	Selenium	Selenium bearing vegetation	Wheat from soil containing selenium	Gastro-intestinal, nervous, and mental disorders, dermatitis in sunlight.	Variable	Analyze soil and selenium bearing soil for growing of wheat, or water with more than 0.05 ppm Se.
	Zinc poisoning	Zinc	Galvanized iron.	Acid food made in galvanized iron pots and utensils	Pain in mouth, throat, and abdomen followed by diarrhea	Variable	Do not use galvanized utensils in preparation of food or drink, or water with >13.0 ppm zinc
	Methemoglobinemia	Nitrate nitrogen	Ground water, shallow dug wells, also drilled wells	Drinking water from private wells	Vomiting, diarrhea, and cyanosis in infants	2 to 3 days	Use water with less than 20 ppm NO_3 for drinking water and in infant formula. Properly develop and locate wells
	Sodium nitrite poisoning	Sodium nitrite	Impure sodium nitrate and nitrite	Sodium nitrite taken for salt	Drowsiness, weakness, stomach cramps, diarrhea, vomiting, blue skin.	5 to 30 min	Use U.S.P. sodium nitrite in curing meat. Nitrite poisonous, keep locked
	Copper poisoning	Copper.	Copper pipe and utensils.	Carbonated beverages and acid foods in prolonged contact with copper	Vomiting, weakness	1 hr or less.	Do not prepare or store acid foods or liquids, or carbonated beverage in copper containers or pipe. Cu should not exceed 0.3 ppm

* Incubation period; † Take some precautions with drinking, culinary, and bathing water as in Schistosomiasis; ‡ Does not originate in the U.S.

More complete characteristics, preventive and control measures, and modes of transmission, other than food and water, have been omitted for brevity as has been the statement "epidemiological study" and "education of the public" opposite each disease under the heading "Prevention and Control." Milk and milk products are considered foods. Under "Specific Agent" and "Common Vehicle" above, only the more common agents are listed.

This table represents a summary of information selected from: 1 Dack, G. M., *Food Poisoning*, 251 pp., The University of Chicago Press, Chicago, 1936. 2 Dolman, C. E., *Bacterial Food Poisoning*, 46 pp., Canad. Pub. Health J. Assoc., 1943. 3 Gething, V. A., "Epidemiologic Aspects of Food-Borne Disease," 75 pp., New Eng. J. Med., 1943. 4 Korff, F. A., "Food Establishment Sanitation in a Municipality," Am. J. Pub. Health, 22, 740 (1932). 5 Morrison Bahr, P., *Synopses of Tropical Medicine*, 224 pp., The Williams & Wilkins Co., Baltimore, 1943. 6 New York State Department of Health Health News. 7. Miscellaneous autopsy and exhibit tests and reports. 8 Strong, R. P., *Stitt's Diagnosis, Prevention and Treatment of Tropical Diseases*, 2 Vols., The Blakiston Co., Philadelphia, 1942. 9 "The Control of Communicable Diseases in Man, 219 pp., The Am. Pub. Health Assoc., New York, 1955. Sept. 1944, Revised May 1945, 1946, Aug. 1952. Copyright, 1945, Joseph A. Salvato, Jr., M.C.E.

A food infection, which is reported more frequently outside the United States, is caused by *Clostridium perfringes (Cl. welchii)*. The organism is a very prevalent one in soil, it is a spore former which is resistant to heat and withstands normal cooking. It is spread by poultry, meats, and meat products. The symptoms include abdominal pains, nausea, some vomiting and diarrhea, the illness is explosive with rapid recovery. The incubation period is 6 to 22 hours with an average of 15 hours. To prevent the illness, cook prepared foods rapidly and refrigerate immediately. Do not allow foods to cool slowly for several hours or overnight.

COPY

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

May 29, 1959

Professor Wm. E. Stanley
Sanitary Engineering - Emer. Project Director
Massachusetts Institute of Technology
Room 1-372
Cambridge 39, Massachusetts

Dear Professor Stanley:

We are enclosing the following material information on water-borne diseases:

1. Diseases of Interest to the Sanitarian (mimeo) -
i listing the major diseases, by categories, that are of concern to the general sanitarian.

2. Diseases of Interest to Environmental Health Training (carbon copy) - Section notes compiled by H. H. Rogers.
i This tabulation is from the APHA Publication, "Control of Communicable Diseases in Man" (old 1950 edition enclosed).

3. 1955, 1956, and 1957 Summary of Disease Outbreaks - Reprints from Public Health Reports. These summaries
x give some detail of the water-borne disease outbreaks during the three-year period.

4. The Communicable Disease Problem in the United States By Theodore J. Bauer, M.D. This article lists and
x discusses the important viral and bacterial diseases.

5. Lecture Outline, Cross-Connections and Backflow Connections by Mr. J. L. Minkin. This publication lists a number of important water-borne disease outbreaks which
x have occurred during the past thirty-five years. The bibliography of this outline will be of considerable value to you on your project. In writing this for use in our training programs, we compiled a rather complete file on published material concerning water-borne diseases. Unfortunately, we have only file copies and working papers.

i - Included herein
x - These omitted herein

COPY

A copy of your request is being forwarded to Mr. Gordon E. McCallum, Chief, Water Supply & Water Pollution Control Branch, DES, PHS, who may be able to supply additional information.

Sincerely yours,

/S/ Herbert H. Rogers

Herbert H. Rogers
Senior Sanitary Engineer
Chief, Environmental Health
Training Section
Training Branch

cc: Dr. Anderson
Mr. Gordon E. McCallum

Room 1-372

May 19, 1959
AIR MAIL

Ref: DSR 7-8110 Ground Water Contamination

Director
Communicable Disease Center
U. S. Public Health Service
Atlanta, Georgia

Dear Sir:

On behalf of FHA, we are making a survey of known knowledge on water contaminants, with special reference to ground water supplies.

Would you kindly advise us along these lines:

1 - Have you any readily available list of references relating to water-borne diseases? May we have a copy?

2 - Have you a list of water-borne diseases due to bacteria? Or could you refer to a recent publication on this?

3 - Have you a list of water-borne viral diseases? Or a reference to a published list?

Your assistance would be helpful and will be appreciated.

Very truly yours,

Wm. E. Stanley
Prof. San. Engng.-Emer.
Project Director

WES:GDR

DEPARTMENT OF
HEALTH, EDUCATION, & WELFARE
Public Health Service, Communicable Disease Center
Southeastern Field Training Station
Atlanta, Georgia

5/55

DISEASES OF INTEREST TO THE SANITARIAN

*Not prevalent in the United States

DISEASE	ETIOLOGIC AGENT	SOURCE OF INFECTION	INCUBATION PERIOD	CONTROL MEASURES
WATER-BORNE				
*Chlorea	Vibre comma	Bowel discharge and vomitus	Few hours to 5 days, usually 3 days	Boil or disinfect all water. Cook all food and disinfect dishes. Control fly breeding.
A. Dysentery	Endamoeba histolymica	Bowel discharges	2 days to 2 months	Sanitary disposal of human feces. Treatment of water supplies.
B. Dysentery	Various sp. of Shigella	Bowel discharges	1 to 7 days	Sanitary disposal of human feces. Treatment of water supplies Pasteurization of milk.
Paratyphoid	Salmonella paratyphi S. Schottmulleri S. Hirshfeldii	Bowel discharges	1 to 10 days	Same as for typhoid
Typhoid	Eberthella typhosa	Bowel discharge. 2 to 5% of patients become carriers	3 to 38 days, usually 7 to 14	Treatment of water supplies. Sanitary disposal of feces. Pasteurization of milk. Aging of cheese not less than 60 days at 35°F.

Enclosure with May 29, 1959 letter from Herbert H. Rogers

DISEASES OF INTEREST TO ENVIRONMENTAL HEALTH TRAINING

Disease	Degree of Interest	Subject Area Affected
Ancylostomiasis	Major	Waste Disposal
Anthrax	Minor	Waste Disposal
Ascariasis	Major	Waste Disposal, Food
Brucellosis	Major	Waste Disposal, Milk,
Chlorea	Minor	Waste Disposal, Water, Milk
Chonorchiosis	Minor	Food
Coccidioidomycosis	Minor	Air, Housing
Common cold	Minor	Air, Housing
Dengve	Minor	Air, Housing
Diarrhea, epidemic	Minor	Air, Housing
Diphtheria	Minor	Housing, Milk
Diphyllobothyriasis	Major	Waste Disposal, Food
Dracontiasis	Major	Water
Dysentery, Amobic	Major	Food, Waste Disposal, Water
Dysentery, Bacillary	Major	Milk, Waste Disposal, Water,Food
Encephalitis	Minor	Housing
Enterobiasis	Minor	Housing, waste disposal
Filariasis	Minor	Housing
Food Poisoning		
Staph	Major	Food
Botulinus	Major	Food
Samonella	Major	Food
Hepatitis, Inf.	Major	Water, Food, Milk
Histoplasmosis	Minor	Air
Impetigo	Minor	Air
Influenza	Minor	Air
Leishmaniasis, cutaneous	Minor	Housing
Leishmaniasis, visceral	Minor	Housing
Leptospirosis	Minor	Water
Lymphocytic choriomeningitis	Minor	Air
Malaria	Minor	Housing
Measles	Minor	Air, Housing
Meningitis	Minor	Housing
Mumps	Minor	Food
Paratyphoid fever	Major	Water, Food, Milk
Pertussis	Minor	Housing
Pneumonia	Minor	Housing
Psittacosis	Minor	Air
Q. Fever	Major	Milk

Rabies	Major	Animal Disease
Rat-Bite Fever (Haverhill Fever)	Minor	Milk
Relapsing Fever (louse-borne)	Minor	Housing
Rheumatic fever	Minor	Air, Food, Milk
Rubella	Minor	Air
Schistosomiosis	Major	Water
Smallpox	Minor	Air, Housing
Scarlet Fever, strep throat	Major	Air, Milk, Food
Strongyloidiasis	Major	Waste Disposal
Taeniasis & Cysticercosis	Major	Waste Disposal, Food
Trichinosis	Major	Food, Garbage Disposal
Trichuriasis	Major	Waste Disposal
Tuberculosis	Major	Air, Housing, Milk
Tularemic	Minor	Water
Typhoid Fever	Major	Water, Food, Milk

Totals

54 Diseases (22 major, 32 minor)

Waste disposal - 13 (10 major, 3 minor)
Water - 10 (7 major, 3 minor)
Milk - 12 (8 major, 4 minor
Food - 16 (13 major, 3 minor)
Housing - 19 (1 major, 18 minor)
Air - 14 (14 minor)
Animal disease - 1 (major)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

PUBLIC HEALTH SERVICE — WASHINGTON 25, D. C.

BUREAU OF STATE SERVICES — Refer to:

July 1, 1959

Professor Wm. E. Stanley
Sanitary Engineering - Emer. Project Director
Massachusetts Institute of Technology
Room 1-372
Cambridge 39, Massachusetts

Dear Professor Stanley:

A copy of your letter, dated May 19, 1959, and a request from Mr. Hebert H. Rogers for additional information has been received by this office.

Enclosed you will find a report on Water-Borne Diseases, Bibliographics on American and Foreign Literature, and a few brief extracts of articles contained in our files. This information is by no means complete but represents only that which we have on hand.

I hope that this material will be of use in your study and we would be most interested to receive the results of your survey when completed.

Sincerely yours,

George W. Burke, Jr.
Chief, Water Supply Section
Division of Water Pollution Control

Encls.

WATER-BORNE DISEASES*

Eight of the most commonly known water-borne diseases are:[1/ 2/ 3/]

1. Amoebic dysentery (amoebiasis)
2. Bacillary dysentery (shigellosis)
3. Cholera
4. Leptospirosis
5. Tularemia
6. Typhoid and paratyphoid
7. Undulent fever (brucellosis)
8. Yellow jaundice (infectious hepatitis)

Before giving specifics concerning some of the more serious of the above diseases, it might be well to note their incidence in the United States within the past few years. Table I on the following page has been composed from figures released by the National Office of Vital Statistics Public Health Service. [4/] These figures have been compiled from data supplied in the annual reports of State and Territorial departments of health. It is important to realize that these figures do not reflect the total number of cases occurring in any given year, since the figures include only those cases reported to the Public Health Service. Also, the specific vehicle of infection (water, air, food, etc.) for each of the seven diseases tabulated has not been determined; therefore, those cases definitely attributable to water-borne sources cannot be ascertained.

As to epidemics, Table II reflects those disease outbreaks from 1948-1957 which have been specifically water-borne. Again, these figures represent only those outbreaks reported and not the total number of water-borne epidemics actually occurring.

*Enclosure with July 1, 1959 letter from George W. Burke, Jr., Chief, Water Supply Section, Division of Water Pollution Control Public Health Service - Department of Health, Education, and Welfare.

Amoebic Dysentery (amoebiasis) is an intestinal disease usually causing diarrhea and sometimes leading to liver abscess, constipation, or stimulation of chronic appendicitis. Susceptibility to infection of this organism is general and there is no known artificial immunity. In North America, amoebic dysentery is not common but with other manifestations is being recognized with increasing frequency. It is estimated that almost 10 percent of the population are carriers presenting no symptoms. Chlorination of water supplies as generally employed is inadequate for destruction of cysts; however, boiling of drinking water is a positive method of disinfection.

Bacillary dysentery (shigellosis) is also an intestinal infection--causing acute diarrhea, fever, and frequent defecation often with blood and mucous. Susceptibility is general, but the disease is more common and more sever in children than in adults. Its prevalence is endemic, epidemic, and sporadic. As other intestinal infections, shigellosis incidence is markedly reduced wherever water supplies are rendered safe, sewage is disposed of in a sanitary manner, milk is pasteurized, and infant hygiene is of a good order. It is most common in the summer months and institutional outbreaks are frequent.

Cholera, in the typical case, is identified by the sudden onset of nausea, vomiting, watery diarrhea, rapid dehydration and frequent passage into collapse. A fatality usually occurs in about 50 percent of cases unless adequate medical treatment is instituted at an early stage. The sources of infections are feces and vomitus of patients, feces of persons with apparent infection and carriers. Its mode of transmission is by direct or indirect fecal contamination of water or of foods by soiled hands, utensils, or flies. Susceptibility is general although natural resistance to infection varies. The epidemic center of this disease is India and certain adjacent areas of southeast Asia. From these centers, it spreads along lines of human communication, from time to time reaching more remote countries and causing widespread epidemics. It is usually absent from the Western hemisphere. Preventive measures for control are sanitary disposal of human feces and protection of water supplies against human fecal contamination.

Leptospirosis, in its typical form, begins abruptly with fever, rigors, headache, muscle pains, vomiting and infection of the conjunctivae. In about 50-60 percent of the cases, jaundice appears in about the sixth or seventh day with marked tenderness of the liver. Convalescence occurs about the third week and relapses occur in about 20 percent of all cases, with the same proportion being fatal. A majority of human infections result from contact of skin or mucous membrane with polluted water which contains the urine of infected rats. Thus the disease shows selection for such trades as fish dealers, abattoir workers, poultry dressers, sewer workers, agricultural workers, miners, and veterinaries. Also, it has been reported 8/ that leptospirosis was transmitted to a person swimming in water infected with rat urine. Accordingly, it is largely a disease of male adults and susceptibility to the disease is general. The organism is present in rats

over the entire world and often carried by dogs with only sporadic human cases having been reported throughout the United States. Preventive control measures are rat control by ratproofing trapping, poisoning and reducing their food supply, protection of workers exposed to infection by preventing organisms from entering through the skin, and by other measures to limit the entrance of the infectious agent through the mouth.

Tularemia is characterized at the onset by sudden chills and fever with the patient usually being prostrate and confined to bed. About 5 percent of all cases are fatal. All ages of persons are susceptible with permanent immunity following recovery of an attack. The disease is not communicable from man to man. Tularemia prevails throughout North America, in many parts of continental Europe and in Japan. In the United States, it occurs every month of the year but especially during rabbit hunting season. Disinfection by simple chlorination will kill this organism.

A tularemia epizootic in the mountain vole (member of the rodent family) in central and eastern Oregon, northeastern California, and other parts of the Great Basin was investigated by State and Federal public health authorities. Water samples taken from wells, streams, and ditches were tested for the tularemia organism and 23.3 percent were found to contain the organism. The population of these mountain vole during March 1958 was believed to be the largest and most extensive on record in North America.

Typhoid and paratyphoid fevers are very similar in characteristics in that the infection is systemic and characterized by continued fever, involvement of lymphoid tissues, enlargement of spleen, usually rose spots on the trunk, diarrheal disturbances and a variety of constitutional disturbances. The sources of infection are feces and urine of infected individuals and carriers. The microorganism is carried from these feces through direct and indirect contact with patient or carrier. Principal vehicles for indirect spread are contaminated water, food, milk, shellfish, and under some conditions, flies. Susceptibility is general and permanent immunity follows recovery. The disease is widespread throughout the world. Formerly endemic and epidemic in most large cities and in many rural areas of North America, it now commonly occurs as sporadic cases and as small contact and carrier epidemics. Typhoid is steadily declining in incidence particularly in urban areas supplied with safe water and pasteurized milk and where human feces are disposed of without contaminating water supplies, food, milk, or surface of the soil. Preventive control measures are protection and purification of public water supplies, and construction of safe private water supplies.

Undulent fever (brucellosis) is usually identified by a general infection with gradual or insidious onset and characterized by irregular fever of uncertain and prolonged duration, profuse sweating, chills, and pains in joints and muscles. Sources of infection are the tissues, blood, milk, dairy products and urine of infected animals---especially goats, cattle, and swine. It is not communicable from man to man although the infecting microorganism may persist in the urine and other body discharges

for long periods. The disease occurs more often in males than in females and is found throughout the United States and Canada, affecting persons of all races usually as sporadic cases but occasionally as small epidemics. The months of May through October are the most critical. Latent or missing cases far outnumber reported cases.

Yellow jaundice (infectious hepatitis) is an acute infection characterized by constitutional manifestations followed by a phase in which jaundice may develop and symptoms are attributable to liver damage. The symptoms usually include fever, nausea with or without vomiting, fatigue, headache and abdominal discomfort. After a few days, the fever subsides, bile may be detected in the urine and clinically recognizable jaundice usually appears. The second phase is of variable duration and occasionally leads to chronic impairment of the liver function. Convalescence may be prolonged. The sources of infection are discharges from the nose, mouth, and alimentary trace of infected persons. The usual mode of transmission is not known. Several epidemics have been caused by contaminated water, food or milk and by direct personal contact. Susceptibility of this disease is general. It prevails sporadically and in epidemics--the latter are most commonly reported from institutions and rural areas. Infectious hepatitis is most common among children and young adults with the incidence highest in the autumn and early winter in the temperate zone. Preventive control measures are good community sanitation and personal hygiene with particular emphasis on sanitary disposal of respiratory discharges and feces, and adequate disinfection of water supplies.

It may be interesting to note that the number of cases reported for hepatitis reached a peak during 1954 (see table).

There has been some question among experts as to whether or not conventional water purification followed by simple chlorination will protect a public water supply from contamination by the infectious hepatitis virus. For instance, 5/ in New Delhi, India, during December 1955 and January 1956 an epidemic occurred with an estimated 40,000 cases resulting. Cause of this epidemic was reported to have been traced back to an infectious virus which entered the New Delhi water supply source--the Jamuna River. The virus was traced to human fecal contamination which entered upstream from the water intake. Even though conventional filtration and low-level chlorination was utilized at their water purification plant, the virus was apparently not removed.

Two papers published in a Swedish medical journal concerning an outbreak of hepatitis attributed to oysters were translated by personnel of the National Institutes of Health, Public Health Service. In all 629 primary cases of the disease were eventually reported. The oyster storage area was apparently contaminated by fresh sewage, and the papers did seem to establish the fact that the hepatitis virus will survive in water for at least a short period of time and also that oysters can serve as a vehicle for the transmission of the disease. Specifically, one of the papers

stated: "....The most common mechanism for the infection of oysters is their cultivation and preservation in polluted water. The diseases which oysters can thus carry and transmit are therefore principally the well-known water-borne diseases, such as cholorea, dysentery, typhoid fever, hepatitis, and perhaps also polio."

Poliomyelitis has often been suspected of being a water-borne disease. However, this has never been conclusively proven either true or false by the Public Health Service.

In Canada, a polio epidemic was believed to have been water-borne. From the Canadian Journal of Public Health 6/ "...An Explosive exacerbation of a poliomyelitis epidemic in Edmonton occurred at a time when the preceding epidemic curve and the lateness of the season gave reason to believe the epidemic was subsiding.

"The cases of this late episode were distributed uniformly amongst the population. This distribution, in such a brief space of time, did not conform to our conception of the usual spread from contact infection.

"A possible reservoir of infection was present in a town upstream from which inadequately treated sewage had access to our water supply. The virus of poliomyelitis has been demonstrated in sewage in the presence of this disease. Ordinary chlorination of water is a doubtful protection against the virus.

"Epidemiologically, this series of events suggests that Edmonton has suffered a water-borne outbreak of poliomyelitis. It provides, of course, only circumstantial evidence, but is recorded in the hope that cumulative evidence may help in time to complete and clarify the picture of this frustrating disease."

Also in England, there has been a feeling that polio could be a water-borne disease, as brought out in a New York Times article 7/: "...The current hypothesis is that polio virus, as well as typhoid bacilli may be transmitted to bathers from the untreated filth of towns that pours from rivers into the sea...."

Table I

REPORTED MORBIDITY AND MORTALITY OF SPECIFIED NOTIFIABLE DISEASES
Years 1952 to 1957

	1957		1956		1955	
	Cases	Deaths	Cases	Deaths	Cases	Deaths
Amebic dysentery (amebiasis)	5,031	95	3,689	130	3,348	106
Bacillary dysentery (shigellosis)	9,822	156	10,306	156	13,912	187
Leptospirosis	47	—	44	—	24	—
Tularemia	601	3	522	4	584	9
Typhoid and paratyphoid	1,231	34	1,700	54	1,704	34
Undulent fever (brucellosis)	983	8	1,300	9	1,444	10
Yellow jaundice (infectious hepatitis)	14,922	897	19,234	806	31,961	841
TOTALS	32,637	1,193	36,795	1,159	52,977	1,187

	1954		1953		1952	
	Cases	Deaths	Cases	Deaths	Cases	Deaths
Amebic dysentery (amebiasis)	3,523	131	4,444	129	4,280	136
Bacillary dysentery (shigellosis)	13,846	243	16,533	337	23,197	334
Leptospirosis	48	—	42	—	62	—
Tularemia	681	4	601	7	668	8
Typhoid and paratyphoid	2,169	45	2,252	52	2,341	78
Undulent fever (brucellosis)	1,823	15	2,032	18	2,537	23
Yellow jaundice (infectious hepatitis)	50,093	821	33,700	821	17,428	794
TOTALS	72,183	1,259	59,604	1,364	50,513	1,373

TABLE II

WATERBORNE DISEASE OUTBREAKS

REPORTED IN THE U. S. 1948-1957

Year	No. of Outbreaks	No. of Cases
1948	21	619
1949	25	1,570
1950	15	1,299
1951	7	3,960
1952	14	530
1953	11	719
1954	7	452
1955	2	22
1956	9	1,719
1957	4	131

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1/ Maxcy, Dr. Kenneth F., Rosenau Preventive Medicine and Hygiene. Seventh Edition; New York: Appleton - Century - Crofts, Inc., 1951. 1., 447 pp.

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Abstract

Western Gulf and Colorado Basins
USPHS
Dallas, Texas
October 1952

In 1952 the New Mexico State Department of Public Health in cooperation with the U.S. Public Health Service, Divsion of Water Pollution Control, started a study of the water pollution of the water courses in the Southwestern United States.

Preliminary tests showed that the rivers and irrigation waters were heavily polluted with enteric pathogens and the study group selected salmonella as an index of pollution.

A more detailed study was conducted in and around the area of Albuquerque, New Mexico, which is located on the Rio Grande River.

Tests below the city showed a contamination of one salmonella colony per 20 ml of sample. The sources of this contamination were located and found to be several small industrial waste effluents (slaughter houses) and the effluent from the Albuquerque sewage treatment plant. Here the tests showed salmonella colonies present in 1 ml. samples and one pour plate showed 40 colonies in a .1 ml. sample.

Compared with other locations in the United States and other countries this is an extremely high concentration of salmonella. In the Berlin treatment plant there were only 3 salmonella colonies found in 1952 samples of the effluent, and in the East Lansing, Michigan influent as tested by Mallman showed only one colony in 672 cultures made from concentrated raw sewage.

The water courses in the Southwest are unique in that they diminish in quantity as they flow from source to the mouth. This is due largely to the climate and the soil conditions. There is one section of the Rio Grande 675 miles long which receives no perennial tributary contributions, and yet, the largest cities of the upper basin, Santa Fe, Albuquerque, Socorro, Las Cruces, El Paso, and Juarez are located on its banks in this area. Also in this section there are four main divisions of the river into irrigation canals which leaves the main river bed practically dry up to a point where the irrigation waters begin to find their way back again. These irrigation waters, being the only water in the area available are used for recreation, fishing and swimming.

Thus, the large potential health can be realized due to the lack of dilution of the contaminated water courses, the recreational use of these waters and the use of it to condition farm vegetables between harvesting and delivery to the consumers.

The sewage treatment plant of Albuquerque was admittedly overloaded and designs were being completed for amplification.

The study shows the reported incidence of enteric diseases in five countries in Arizona for five years with a mean high of 693 cases and a low of 102 cases per 100,000 persons while the mean for the entire United States was only 19 in 1950.

Abstract

ENTERIC DISEASE OUTBREAK IN LOUISIANA

August 1956 - Shreveport, Louisiana

72 cases of enteritis were reported in 27 families.

A man had an underground lawn sprinkling system hooked up to a pump with its intake in a bayou behind his home.

Later he applied for and received a metered connection to the city main and intended to use the city water for his front lawn only. The city plumbing code did not require a backflow or vacuum breaker on such installations at that time.

In 1954, the man installed a larger pump and by use of a time clock device thought he could water his entire lawn with the bayou water without a cross connection, so he joined the front and rear systems together. He did not realize that there was 65 lbs. pressure in the sprinkling system and only a maximum of 58 in the city main.

The bayou water was relatively clear until August 7, 1956 when a broken sewer line drained into the bayou 1/2 mile from the pump intake. The line was repaired the following day but reports were received that the city water looked green. Three days later outbreaks of enteritis were reported in the area and within two hours sanitarians had located the cross connection in the sprinkling system.

Abstract

OUTBREAK OF WATER BORNE DYSENTERY
JAPHA - January 1959, Vol. 49, No. 1, Page 82

An article written by Lt. Col. Louis N. Altshuler and Captain Donald J. Hernandez relates an epidemiological study of an outbreak of water-borne dysentery in U.S. Army personnel and dependents living in and around Boeblingen Germany. The epidemic occurred from April 23 until May 1, 1958 with a total of 905 cases reported.

An investigation revealed that the community was served by an infiltration gallery collection system using a manually controlled chlorinator with a maximum possible dosage of 3.5 ppm.

A trench, which was being excavated for a new water line running from the infiltration gallery, intersected an overflow pipe from the gallery, three sections were removed, and proceeded to a sewage contaminated stream. Water from the stream backed up in the trench past the overflow pipe and could be seen dripping into the infiltration gallery around the closed valve. It was also possible that contaminated water was following along the outside of the overflow because the ground was saturated with rain water during the period.

Since there were no chlorine records kept and subsequent experiences showed that the chlorine demand could exceed the maximum possible dosage it was concluded that the drinking water was the source of the epidemic. Laboratory analysis confirmed this conclusion and all personnel were advised to boil their water or carry canteens and use water-purification tablets.

The source of water was changed by the German authorities until the pipe line could be completed and the trench filled.

Abstract

OUTBREAK OF GASTROENTERITIS IN OHIO 1941

A town of 1703 persons had 115 cases of gastroenteritis. They had a water supply from 5 wells close to a riverand an old canal but repeated tests proved the wells to be safe. Distribution of the cases or certain streets inducated contamination at a point close to the elevated storage tank. The installation of a chlorinator and use of a chlorine residual now acts as a safeguard for the water supply.

Abstract

WATERBORNE OUTBREAK OF INFECTIOUS HEPATITIS

U. S. ARMY REPORT 1955*

83 persons went on an Army-sponsored ski trip to the resort town of Badastein where they stayed in two hotels for three days. Fifteen of these persons were later placed under medical care having shown clinical symptons of infectious hepatitis. A 16th case was later diagnosed and it was found that the patient had stayed in the same hotel a week later. All of the patients had used the hotel water for drinking purposes.

A thorough epidemiological study uncovered an old stone water reservoir and cast iron pipe laid in 1909 that was used to supply the hotel with utility water from a mountain spring. This reservoir was located underground 122 feet downhill from a septic tank used by another hotel. This septic tank discharged effluent through a cast iron pipe into a cesspool located a short distance downhill but still above the reservoir. The sewage effluent line crossed over the water line at almost right angles. The water table in the area was high and the ground formation was found to be fissured limestone overlain with layers of humus with fine and medium gravel. The water in the reservoir proved to be contaminated.

Through chemical and bacteriological examinations of the hotel's water it was shown that a cross connection existed between the contaminated utility water supply and the treated city water supplied for drinking purposes.

An investigation of the records of the second hotel disclosed that during the same period as the ski trip a guest had become ill and had been treated by a local doctor for infectious hepatitis and had remained in bed in the hotel for over a week.

Thus it seems that water was the transporting agent for the infectious hepatitis virus.

Abstract

A WATER-BORNE EPIDEMIC OF HEPATITIS

By

Christiansen, O.

In 1956 a summer camp in Denmark was occupied by 135 persons, chiefly boys between the ages of 10 and 12. Shortly after their return home, 41 developed hepatitis. The camp was divided into 4 teams, and while the fourth tem had no case of hepatitis, each of the teams 1, 2, and 3, coming from 3 different towns had a high percentage of cases. Confinement to bed lasted from 2 to 75 days, with an average of 24. There were no deaths, but 24 of the patients were confined to bed for 3 weeks or more, and 21 were admitted to hospital. In some cases, a few days after the presumptive time of infection, there was a history of transitory gastro-intestinal disturbances, followed 3 or 4 weeks later by signs of hepatitis. Connected with thit out-break were altogether 18 secondary cases, the patients having been in direct contact with one or more of the primary cases. In the neighborhood of the camp there had been some cases of hepatitis during the summer of 1956, but no contact infection was demonstrable. The meat and milk supplies could be exonerated. Bathing came under suspicion, but none of team 1 went in for bathing, and it was remarkable that team 4 which had gone in for it never had a case of hepatitis. Ultimately the source of infection was traced to a well on a farm where the daughter of the house suffered from hepatitis from the middle of June to the middle of July. The immunity enjoyed by team 4 may be traced to its water supply having come from another source. Team 3 drew water from this source during only one day, and if this well were responsible for the whole outbreak, it is possible to put the incubation period at a mean of 34 days.

Claude Lillingston

Excerpt from Bureau of Hygiene and Tropical Diseases - August, 1957
Bulletin of Hygiene - Vol. 32, No.8

Abstract

HEPATITIS EPIDEMIC CONVEYED BY OYSTERS

An infectious hepatitis epidemic which occurred in Göteberg, Sweden was traced by an epidemiological study to oysters which were caught in the bay around the small town of Havstenssunds.

These oysters were caught and sold to a distributor who, when he had an excess, held the oysters in a live well located close to the boat harbor in the bay. The same area was found to receive pollution from the town of Havstenssund even though the water was clear and appeared to be safe. A worker for the distributor came down with hepatitis and was placed in bed at home, but he was most probably emitting viruses before his confinement and the water closet in the distributor's plant emptied into the bay below the harvor. It is thought that more sub-clinical cases must have also been emitting viruses at the same time to produce such a heavy contamination.

A total of 119 cases of hepatitis occured in Göteberg and 629 in the entire country were reported. Some of these cases were secondary cases contributed to personal contact.

In several cases there were dinner parties where the Havstenssund oysters were served and the entire number of guests contracted the disease with some eating only one or two oysters. This seems to indicate that the concentration of contaminant in the oyster was very high.

APPENDIX H

GROUND WATER CONTAMINATION

Topic V - Viral Contaminants

by

Elizabeth C. Maclean

Department of Biology

December 1959

APPENDIX H

GROUND WATER CONTAMINATION

Topic V - Viral Contaminants

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APPENDIX H

GROUND WATER CONTAMINATION

Topic V - Viral Contaminants
by Elizabeth C. Maclean

There has been increasing concern that waterborne virus infections may become frequent. Since the nature of viruses has in general been poorly understood, the following introductory paragraphs have been included to present an elementary outline of some of the properties of viruses and to indicate the present inadequate state of our knowledge of the role of viruses in ground water contamination.

INTRODUCTION

a - The nature of viruses - Viruses are specific disease-producing agents which are distinguished from other pathogens by two properties:

1. They multiply only within the cells of a susceptible host. Extracellularly, they behave as purely chemical agents.
2. Due to their extremely small size, they pass through filers which would retain bacteria.

These properties have been described in many discussions which appear in the literature. For example, Rhodes & van Rooyen(35) (1958) explain:

> "The common characteristic of viral agents...is dependence on the intracellular environment, for the viruses proliferate in the interior of cells and not extracellularly...A suspension of virus particles freed of tissue cells shows no evidence of respiration or biochemical activity and in vitro manifests none of the usual characteristics of living matter. Yet, when such a preparation is innoculated into a susceptible host, the virus particles invade cells, and multiplication takes place in the intracellular position. All the experimental evidence suggests that viruses are obligate intracellular parasites and do not multiply extracellularly."

The Water and Sewage Control Engineering Glossary(92) (1949) defines 'virus' as follows:

> "A term now generally used to denote a living organism which passes through filters which strain out bacteria

physically and is invisible by ordinary microscopic methods. Technically described as a collective designation covering disease stimuli whose biological nature is not well known"

The tendency to ascribe communicable diseases to 'viruses' in the absence of other definite information is deplorable, since viruses are in fact specific entities which give rise to definite symptoms, and which have been rather rigorously studied in the laboratory in recent years.

b - Definition of Viral Contamination - No explicit definition of the term 'viral contamination' appears to have been made in the literature. In this report, viral contamination is considered to consist of the presence of viral particles in water supplies in such concentration that persons using the water, whether on a single occasion or over a prolonged period, develop clinical symptoms of which a virus is the causative agent.

c - The Problem of Water-Borne Virus Disease - Major outbreaks of water-borne disease have occurred only infrequently in the United States. For example, in 1956, a total of only 9 outbreaks (both bacterial and viral) were reported to the Public Health Service. 1,719 persons were involved; this number was the largest in some years. (Dauer & Sylvester[100] 1957). However, some authorities, such as Borts[5] (1949) have expressed the opinion that reported outbreaks "represent but a small portion of the actual occurrence of disease from private water supplies." Possibly, many cases of water-borne infections have not been recognized as such.

The widespread nature of virus infections in general has been emphasized by Horsfall[99] (1957) who states;

"In this country, (viruses) tend to produce between 4 and 6 episodes of illness per person per year. On the average, in the United States, man is afflicted by one or another virus disease about 10 percent of his life. Over a span of 70 years, man suffers for 7 years with virus diseases. To put it another way, in this country, about 5 billion man-days are lost each year through virus diseases. No other category of disease approaches this total in terms of human disability."

Two lines of argument lead to the conclusion that the problem of water-borne virus disease deserves serious consideration:

(1) Although such outbreaks of virus diseases may be rare, they can be extremely serious when they do occur.

(2) The United States is now in the midst of a period of rapid population growth. Thus, problems related to the disposal of toxic agents, including viruses, can be expected to increase in seriousness during the coming years.

d - Potential Water Borne Virus Diseases - This question can be best discussed according to virus groups rather than specific diseases, since laboratory study has tended to define certain serologically related groups of agents, whereas symptoms of a particular type of disease (e.g., meningitis) may be associated with a variety of agents.

Berg(40) (1958) states:

> "The viruses with which we are concerned primarily are those which are regularly excreted in large quantities in the feces of infected individuals. These are:
> 1. Infectious hepatitis virus(es)
> 2. The Enteroviruses
> (1) Polioviruses (3 types)
> (2) Coxsackie A viruses (25 types)
> (3) Coxsackie B viruses (5 types)
> (4) ECHO viruses (24 types)
> 3. The Adenoviruses* (19 types associated with man)."

The viruses listed are classified according to their immunological behavior, and by the effects which they produce in tissue culture.

Brown(3) (1949) considered the same topic in an earlier review, and listed "inclusion conjunctivitis", "infectious hepatitis", "poliomyelitis", and "pretibial fever" as water-borne infections of probably viral etiology.

*N.B. The description "regularly excreted in large quantities in the faeces of infected individuals" does not apply to most of the adenoviruses, which commonly occur in the respiratory tract.

I. Infectious Hepatitis - This disease is described as follows by the Public Health Service (Burke(98) (1959)):

> "Yellow jaundice (infectious hepatitis) is an acute infection characterized by constitutional manifestations followed by a phase in which jaundice may develop, and symptons are attributable to liver damage. The symptoms usually include fever, nausea with or without vomiting, fatigue, headache and abdominal discomfort. After a few days, the fever subsides, bile may be detected in the urine and clinically recognizable jaundice usually appears. The second phase is of variable duration and occasionally leads to chronic impairment of the liver function. Convalescence may be prolonged. The sources of infection are discharges from the nose, mouth and alimentary tract of infected persons. The usual mode of transmission is not known. Several epidemics have been caused by contaminated water, food or milk, and by direct personal contact. Susceptibility of this disease is general. It prevails sporadically and in epidemics - the latter are most commonly reported from institutions and rural areas. Infectious hepatitis is most common among children and young adults with the incidence highest in the autumn and early winter in the temperature zone. Preventive control measures are good community sanitation and personal hygiene with particular emphasis on sanitary disposal of respiratory discharges and feces, and adequate disinfection of water supplies."

Scarcely any laboratory studies of the infectious hepatitis agent have been carried out, since there is no satisfactory method of assay for this virus. Among 30-odd species tested, man is the only susceptible animal. Moreover despite "strenuous efforts" to that end it has not yet been possible to grow the agent in tissue culture. The situation has been discussed by Rhodes & van Rooyen(35) (1958). A few experimental studies have been made with the use of human volunteers.

Infectious hepatitis has been a reportable disease in the United States since 1952. During the period 1952-1957, 167,338 cases and 4,989 deaths were reported (Burke(98) (1959). During recent months, the incidence of this disease has increased sharply 7,305 cases having been reported during the first two and one half months of 1960. Newsweek Magazine(155) (1960)). However, only a small minority of these cases were due to water-borne infection.

II. Poliomyelitis - This disease has received a great deal of study. The affinity of poliovirus for

nervous tissue and the paralytic form of the disease are generally known. Less frequently recognized is the fact that paralysis occurs only in a small proportion of cases: As Rhodes & van Rooyen[35] (1958) point out;

> "Infection with the virus of poliomyelities may be manifested in various ways. Some infected persons apparently do not become sick at all, although they excrete the virus... The commonest manifestation of infection with poliomyelitis is... minor illness ... characterized by fever, headache, drowsiness, vomiting, constipation and muscle pain. The illness seldom lasts for more than a few days... Poliomyelitis is (also) one of the many causes of meningitis."

Method of assay of the reponsible agent have also received much study. Ideally, virus assays should give a direct and complete count of the number of infectious particles present. Methods which achieve this goal have only begun to be worked out in recent years. Previously, titres were expressed as LD50, i.e., the dilution of a virus-containing fluid required to kill 50% of susceptible test animals. Such methods indicate the relative number of particles present but give no information concerning the absolute concentration of virus particles.

Until recent years, all assaying of poliovirus was carried out by innocculation in rhesus or cynomolgus monkeys, or, occasionally, cotton rats. Rhodes & van Rooyen[35] (1958) state, "it was customary to recover poliomyelitis virus from the stools of 90 per cent of paralyzed cases by the use of these methods."

New tissue culture methods have vastly improved conditions for quantitative study of poliovirus. In 1954, Dulbecco and Vogt[112] developed a method whereby individual infectious units could be counted after they had formed 'plaques' in susceptible cell monolayers. A variety of host cells may be used, but Rhodes and van Rooyen consider human embryo and amnion cells the most sensitive. Schaffer and Schwerdt[108] in a current review express the opinion that ideal conditions for polio virus assay may not yet have been formulated, since, at best, only one in thirty virus particles

succeeds in forming a plaque. However, they feel that the reproducibility of current infectivity determinations is high.

In any study one should remember that techniques used in any laboratory study of poliovirus before 1954 were considerably less sensitive than those available at present.

The incidence of poliomyelitis has dropped sharply since the introduction of the Salk Vaccine. During the current summer (1959) case rates among children under 5 (the most susceptible age group) were 6/100,000 in the absence of vaccination and 0.5/100,000 among those who had received vaccine.(114)

III. Coxsackie Virus Diseases - These viruses were first isolated in 1947 and are characterized by their pathogenicity for suckling mice. Two groups, A and B, are distinguished by the nature of their effect on the test animals. According to Rhodes & van Rooyen(35)(1958);

> "Strains of both groups have been recovered all over the world, and it is evident that Coxsackie viruses are very widely prevalent. Group A viruses have been clearly established as the causal agents of herpangina, an acute ulcerative condition of the throat. Group B viruses cause epidemic myalgia (epidemic pleurodynia or Bornholm disease), asceptic meningitis, and infantile myocarditis."

Both groups may be assayed by determination of LD 50 in suckling mice. In addition, group B strains may readily be grown in monkey kidney cell cultures..

Reports indicate that the occurrence of Coxsackie virus diseases is common, but no statistics are available. available.

IV. ECHO Virus Disease ---- the ECHO (enteric cryptopathogenic human orphan) virus group was first discovered in tissue cultures, where they were distinguished serologically from all known virus types. Subsequent studies have shown that these viruses occur in apparently normal individuals, but also are found to be significantly associated with asceptic

meningitis (for example, by Lehan et al[70] (1957), and with 'summer diarrhea' in children under 4 years of age. (Ramos-Alvarez[38] (1956)).

The distinct nature of the Polio, Coxsackie and ECHO virus groups is not well established. According to Hammon et al[52] (1958):

> "It is concluded...that certain ECHO and Coxsackie viruses not only overlap with polioviruses in their pathological effects on the central nervous system...but also they bear antigenic relationships to polioviruses. Thus, these three groups of agents become less distinct and become progressively more difficult to define and justify as members of separate generic-like classifications."

The National Foundation, recognizing the relationships of polio, Coxsackie and ECHO viruses considers them jointly under the designation 'Enteroviruses'. (Committee on the Enteroviruses[61] (1957)).

The ECHO viruses are assayed in human cell tissue cultures. As with Coxsackie viruses, ECHO infections appear to be widespread but since these agents are only occasionally identified, statistics on the incidence of ECHO diseases are unavailable.

V. Adenovirus Diseases - The adenoviruses were originally isolated from tissues culture and are defined according to their serological properties by Rowe et al[36] (1956) and[37] (1955)). According to the Committee on Enteroviruses[61] (1957):

> "The adenoviruses, although predominantly inhabitants of the respiratory tract may occasionally be found in the intestinal tract. However, their properties are such that they are easily distinguished from the true enteroviruses."

Pharyngoconjunctival fever is an adenovirus disease characterized by Bell et al[69] (1955), which is believed to be spread through the use of swimming pools. Recently, Kjellen et al[54] (1957) isolated adenovirus, type 3 from the stools of patients with a disease "with symptons typical of pharyngoconjunctival fever."

VI. Other Viral Diseases - 'Pretibal Fever', described by Daniels & Grennan[6] in 1943, was at first suspected of being spread by a water-borne virus. Later, Gochenour et al[119] (1952) showed that the causative agent was Leptospira autumnalis.

The isolation of measles virus from the feces of patients has been reported once by Fraenkel. The observation was not confirmed by a second group of workers. (Black et al[111] 1959).

1. Sources of Viral Contamination - Many small water supplies are subject to surface contamination from various sources. Horts[5] (1959) criticized a majority of farm wells in Iowa which he considered,

> "Subject to pollution via defective platforms and casings, from rains and by fowl and animals permitted to run at large in the yard where the wells are located."

The common excretion of viruses by farm animals is indicated by such work as that of Beran et al[104] (1958) who found a hitherto unrecognized virus in the feces of young pigs.

Pollution of water stored in open reservoirs has more bearing on municipal water supplies, but may be of some interest here. Smith & Ongerth[101] (1957) have considered this question, and state;

> "The viruses present another challenge to water safety. Filtration is much less effective in removing viruses than in removing bacteria or parasites... Like the typhoid bacillus, Coxsackie viruses have been shown to survive longer in unpolluted than in polluted water.* They have survived as long as 47 days in river water. While chlorine will inactivate these viruses, from 7 to 46 times more chlorine is required for killing Coxsackie viruses than for killing Escherichia coli ... Admittedly, poliomyelitis, Coxsackie, and ECHO viruses have never been proved to have produced water borne epidemics and thus may only be theoretical hazards in water supplies."

Some viruses, such as that producing pharyngoconjunctival fever, might pass into the ground water from water used for swimming. Such a possibility seems rather remote, but should not be ruled out without investigation.

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*However, Gilcreas & Kelly[28] (1955) report just the opposite.

See quotation on p. 45.

Generally, sewage is the one important source of viral contamination in ground water. Numerous studies have shown that polio and other viruses sometimes occur in urban sewage in substantial concentrations, and it is quite possible that these viruses may leach through the soil under appropriate conditions.

Paul et al[22] (1939) first isolated poliovirus from sewage in Charleston, S.C., during an epidemic. They estimated from the severity of the disease thus produced in monkeys that a rather high concentration of the virus was present.

Paul & Trask[21](1942) conducted a 15 month study of New York City sewage and found poliovirus present on one occasion, also during an epidemic.

A similar study in Stockholm by Kling et al[49](1942) revealed the presence of poliovirus in sewage during, and three months following, an epidemic. After 9 months, the virus could no longer be detected.

Paul and Trask[19](1942) discussed the presence of poliovirus in sewage, noting;

> "During epidemics, the dissemination of poliomyelitis virus throughout the community is great, particularly when one considers how much virus may be present in a single human stool (for somewhere between 1,000 and 10,000 doses infective for the monkey have been demonstrated in a 50 g. stool). Most of the dissemination occurs through carriers, which are usually unrecognized ... The more common, abortive cases harbor the virus as well if not better than the paralytic cases."

Melnick[11](1947) studied poliovirus in New York and Chicago sewage. Virus was found there only during late summer and fall months of some years. The virus was found to survive 8-10 hours in a sewage treatment plant, appearing in the effluent.

Kelly et al[41](1957) "frequently" found polio virus in New York State sewage during the summer and fall. They report;

> "No correlation was noted between poliomyelitis virus in sewage, reported paralytic cases, andsocioeconomic status of the community."

Work done up to 1949 on poliovirus in sewage was discussed by Maxcey[27] who notes that

> "while the virus may occasionally be demonstrated in raw sewage... and may survive in sufficient quantities to permit detection during some stages of the treatment processes - and even in the effluent - it has not been traced beyond this point in the external environment."

Coxsackie virus has also been found in sewage. Clark et al[50](1951) recovered a group A virus in a residential area of Toronto. Kelly[42](1953) and Kelly et al[43](1955) report a seasonal incidence of Coxsackie viruses in sewage of the Albany area. The viruses were reported to be,

> "present continously between June and November, and only sporadically during the remainder of the year."

Mack et al[107](1958) isolated polio, Coxsackie, & ECHO viruses from sewage 88 times during a 23 month study. Virus was isolated twice in a study of 26 samples of sewage treatment plant effluent. They state,

> "In the light of the results of this work it is recommended that we make a critical review of our sewage disposal systems."

A single report of the recovery of adenovirus, type 3, from sewage was made by Kjellen et al[54](1957). The presence of the virus was associated with an epidemic in two Swedish communities of a disease resembling pharyngoconjunctival fever.

The studies mentioned here have shown that pathogenic viruses can often be demonstrated to exist in sewage. The infective agents can occur there in high concentrations, thus constituting at least a potential threat to ground water supplies.

2. Effect of Viruses on Water Quality - Obviously, viral contamination, as defined for the purposes of this study, renders water totally unsafe for drinking or culinary use and probably for other uses. It should be pointed out that the presence of non-pathogenic viruses, such as the bacteriophages, would be quite innocuous.

The failure of viruses to produce any effect on palatability is illustrated by the experience of Gauld[2] (1946) who traced an epidemic of infectious hepatitis among troops in Italy to the drinking of water from a contaminated well:

> "Halazone tablets were provided for the treatment of the water. Many of the men interviewed stated that they did not always use these since the water was quite clear and palatable."

3. Permissible Concentrations of Viruses in Water - Very limited exposure to contaminated water may be sufficient to produce infection. An example is the observation of Harrison[34] (1947) of infectious hepatitis with jaundice among men who had drunk no more than two canteens of water containing the virus.

An opposing consideration is the suggestion - little more than a suspicion at the present - that low concentrations of virus, possibly in attenuated form, may be active in producing immunity, without resulting in desease. Neefe & Stokes[15] (1946) found that ingestion of water contaminated by the infectious hepatitis agent, but stored for a long period, produced liver dysfunction, but no overt jaundice. The subjects of this experiment were subsequently immune to the disease.

Similar conclusions appear in the work of Olin & Wesslen[94] (1957) who compared the incidence of poliomyelitis, and of antibodies to poliomyelitis in Stockholm and Gothenburg. They state;

> "In Gothenburg a comparatively high incidence of antibodies was demonstrated at earlier ages than in Stockholm. This is in agreement with the facts that the total incidence of paralytic cases is low in Gothenburg and that the proportion of paralytic cases occurring at earlier ages is higher in Gothenburg than in Stockholm."

The two communities were considered to be generally similar, except that the water supply of Gothenburg was more subject to fecal pollution. Accordingly, the authors felt that the water supply might possibly be responsible for the larger proportion of protective antibodies found in Gothenburg.

Apart from these rather general considerations it seems that nothing is known, in a quantitative way, about the permissible concentrations of pathogenic viruses in water. Gilcreas & Kelly[28] (1955) have emphasized the need for work on this point. They remark:

> "Epidemiological studies are...necessary for determining infective densities of viruses in water as compared with coliform microorganisms. It is possible that although enteric pathogenic viruses are not completely destroyed by present day water supply treatment, they may be so reduced in numbers that they would not be infective to consumers."

4. Experiences with Viral Contamination

In the following sections, epidemiological, laboratory and statistical experiences obtained with potentially water-borne virus diseases are summarized, and illustrate the problems involved in such studies. The evidence for infection via water has been only circumstantial in most of the cases cited, but nevertheless, has been extremely convincing on occasion. Positive proof for water-borne viral infection would consist of a laboratory demonstration of the presence of the virus in the suspected water supply; this has only once been achieved (Neefe et al[15] (1945).

I. Infectious Hepatitis - It is well established that infectious hepatitis can be a water-borne disease. Symons[25] (1956) remarks:

> "Epidemic jaundice or infectious hepatitis is caused by a virus that may be carried in water. The disease which is quite severe, was practically unknown (or at least unrecognized as water-borne) in the United States until after World War II."

Gauld[2] (1946) believes that some, or perhaps all, explosive outbreaks of infectious hepatitis are spread by water. Nevertheless he states:

> "Mass infections are not the rule and most epidemiological evidence indicates that the usual route of infection is some form of person-to-person contact."

a. Epidemiological Experiences - Infectious Hepatitis: During the past thirty years a number of epidemics of infectious hepatitis have been described in the literature which were believed to have been water borne. These were associated with a number of different types of water supplies.

Surface contamination of wells was held responsible for outbreaks involving 173 cases among university students in Canada (Fraser[32] (1931) and 86 cases among U.S. troops in Italy during World War II. (Gauld[2] 1946; Harrison[34] (1947).

Polluted wells were also mentioned in connection with two epidemics for which sufficient information is not available to determine whether contamination occurred from the surface or through the ground. (Lundgren[48](1930); Christiansen[56] (1957).

Infection due to the use of polluted creek water for showering was suspected by Trussell[12](1946).

The drinking of polluted raw river water has been responsible for several outbreaks of infectious hepatitis. An outbreak resulting in 147 cases was described by Hallgren[47] (1942) and another by the same author[87] in 1943. An observation of interest in connection with the second of these outbreaks was the fact that the virus had apparently travelled several miles down river from an area where 52 cases had occurred in the preceding months. Polluted river water was also held responsible for 13 cases in Alaska by Davis[58](1957), and for 11 cases in Australia by Wallace[53](1958).

Pollution of a water supply drawn from a partially frozen lake, in Sweden, accounted for an epidemic described by Olin[33](1947) in which there were at least 40 cases.

Spread of infectious hepatitis has not been limited to untreated water supplies. Hallgren[47](1942) described an outbreak of 187 cases in Sweden which ceased abruptly after chlorination was included in the treatment of a supply which otherwise was purified only by gravel filtration.

Much more disturbing was the recent epidemic in Delhi, India, where an estimated 35,000 cases occurred despite coagulation, filtration and chlorination of the city water supply. The treatment was evidently insufficient to inactivate the large amounts of virus in the influent to the city's water treatment plant, which for a time experienced an unusually heavy contamination with sewage. (Sanyal[44] 1956; Editor, Public Works,[31](1956).

Details concerning the type of water supply are not available for two other epidemics believed to have been

water borne. These outbreaks were described by Laurell & Lofstrom[79](1948), and by Brown[3](1949), and involved 56 and 41 cases repectively.

Most relevant to the present study are the histories of several outbreaks in which it seems evident that the infectious hepatitis agent has penetrated a water supply after traveling through the soil. An outbreak in a Swedish TB sanatorium, which was studied by Hallgren[47](1942), came to an end 34 days (corresponding to the incubation period of the disease) after the exclusion from the water supply of a well found to be polluted with coliform organisms. Subsequent investigations revealed a leaking sewer in the neighborhood of the well. There were a total of 187 cases of infectious hepatitis among both patients and staff.

One of the most thorough studies of an epidemic of infectious hepatitis was that carried out by Neefe et al[15] in 1945. Experimental observations were made with the aid of human volunteers. The epidemic occurred at a summer camp in the Pocono mountains, and 350 of the 573 campers and camp personnel became infected with the disease. Epidemiological studies pointed to one well from the girls' area as the source of infection.

Four of five volunteers who ingested this water, after several months storage, developed symptoms of liver dysfunction after a prolonged incubation period, although overt jaundice did not appear. On the other hand, volunteers who ingested the agent excreted in the feces of camp patients developed typical jaundice.

The authors after carefully reviewing the evidence, stated,

> "it is logical to assume that the 'water agents' and the 'feces agents' were the same."

Thus, in this single instance, experimental evidence was obtained for the passage of infectious hepatitis virus in water. The well was believed to have become contaminated by seepage from nearby cesspools, although the exact point of entry of the virus was not obvious.

Farquhar et al[6](1952) investigated a small outbreak of infectious hepatitis in an isolated mountainous area of Pennsylvania. Three households were involved, each with its own well and cesspool. One well was found to contain coliform organisms, and was believed to be the source of the virus, which presumably had traveled from a nearby cesspool. Pollution ceased after the family installed a new cesspool at a greater distance from the well.

Tucker et al[46](1954) studied an outbreak in which 102 of 291 campers contracted infectious hepatitis at a children's camp in Tennessee. The cases were preceded by an explosive outbreak of gastroenteritis, and were distributed throughout the camp population. Some visitors who drank water from the camp supply also became infected. The spring used as source of supply was shown to be polluted by coliform organisms, and experiments with sodium flourescein dye showed that pollution occurred via seepage through the terra cotta drains of an adjacent cottage.

Mosley & Smither[17](1957) investigated an outbreak of infectious hepatitis in a small town in Kentucky, where nine cases occurred among the 23 members of adjacent households. An additional nine cases occurred among visitors and other contacts. Evidence for contamination of the wells used by these families was drawn from studies of coliform count, nitrate, nitrite and ammonia analysis, and appearance in all wells of fluorescein dye discharged in the toilet at the house of the original case.

The general relationship of infectious hepatitis incidence to housing conditions is brought out in a recent study made by Goldstein and Wehrle[63](1959) in Syracuse, N. Y., who note,

> "A striking correlation was observed between socioeconomic areas in the community ... and the frequency ... of cases. It is suggested that the prevalence of this infection may be favored by factors such as crowding and the poor hygiene and sanitation often found in the lower socioeconomic groups."

b - Experimental Experiences - Since it is impossible, as yet, to propagate the infectious hepatitis virus in any laboratory animal or tissue culture system, laboratory studies of the agent have been carried out only on a few occasions when human volunteers were available.

Havens[72](1945) found that the infectious hepatitis virus passed through a filter which withheld Salmonella cholera suis, and withstood 30 minutes of heating at 56°C.

Neefe and co-workers[16](1946); [18](1947) made a series of studies using material obtained in their investigation of the Pocono camp epidemic described above. Their findings are summarized in the following table.

Chlorine residual after 30 minutes contact	Other Treatment	Result
1 p.p.m.	none	no inactivation or attenuation of the virus
15 p.p.m.	none	definite attenuation
No chlorination	sodium carbonate, aluminum sulfate, or activated carbon	partial inactivation or attenuation
1.1 or 0.4 p.p.m.	coagulation and filtration	inactivation

c. Opinion & Comments - An editor of Public Works in commenting on the 1956 Delhi epidemic of infectious hepatitis, expresses the following views on water purification:

> "Based on his own observations of experiments carried on during the war under his general direction, the editor believes (1) That when water has been very well clarified, as by passage through a diatomite filter, a free chlorine residual of 0.5 p.p.m. or a little more will inactivate the virus. (2) That lacking good clarification the required chlorine dosage will be very much higher - perhaps 10 or 15 p.p.m. There is no proof for these beliefs; more work needs to be done to establish safe methods of treatment."

II. Poliomyelitis - To prove conclusively that a disease is water borne it is necessary to demonstrate unequivocally in the laboratory, that the agent producing the disease is present in water suspected of having spread the infection. This has not been accomplished in the case of poliomyelitis. Nevertheless, a thorough study of the literature strongly indicates that poliomyelitis may be water borne, although this route of transmission is only implicated on rare occasions. There seems to have been no epidemic as yet, in which poliomyelitis was believed to have been spread by water, and in which laboratory investigations were carried out with the use of the nodern sensitive techniques for virus assay. Consequently, previous failures to demonstrate the presence of poliovirus in suspected water supplies must be regarded as tentative rather than conclusive.

a. Epidemiological Experience with Poliomyelitis - The most cogent evidence that poliomyelitis has been spread by drinking water are the careful descriptions of a number of epidemics which have occurred during the past 15 years.

Kling (91) described (in 1947) the 1944 epidemic in Katrineholm, Sweden, where part of the water supply was derived from a heavily contaminated source, and was purified only by sand filtration. At an early stage in the epidemic, five cases were reported within five days among persons who had no contact with each other, or with the one previous case. The epidemic ceased abruptly after chlorination of the town water supply was instituted, although cases continued to be reported for several months in adjacent rural areas where chlorination could not be carried out.

In the same paper, an epidemic in Halmstad, Sweden, is described in which there was a case rate of 20.4/100,000 in an area of the city supplied by wells found to be subject to pollution by sewage. The case rate was 9.3/100,000 in the adjacent area served by a separate water supply. It was shown that all cases in the low-incidence area had visited the area of polluted water during the three week period prior to their illness.

Hargreaves[89](1950) reported on an epidemic of poliomyelitis in Cornwall, England, during 1949, in which 27 cases were in the Truro area. He notes;

> "Owing to exceptionally dry weather, the normal source of the city water supply had proved inadequate, and the local company had been compelled to draw from a heavily polluted stream, the River Allen. At the pumping station the water is passed through precipitation tanks (aluminum hydroxide) and thence to pressure sand filters. Finally it is chlorinated and allowed to stand in a small service reservoir, but during peak periods the water passes direct to the mains after chlorination. Two samples taken from taps in the town showed serious pollution. The chlorination plant in use at the time was abandoned and superchlorination with an electric injector instituted ... Within five days of superchlorination, the epidemic ceased...
>
> "The outbreak in Truro presents certain interesting features (1) The high age group attacked (2) A history of direct or indirect contact with previous cases was remarkable for its absence. (3) The cases were evenly distributed over the town. (4) The explosive nature of the outbreak and abrupt cessation after superchlorination of the city's water supply ... It is likely that many carriers existed in the neighborhood, and contamination of the city's emergency water supply, the intake for which was located in meadows used by children as an unofficial playground, was therefore probable. Unfortunately, it was not possible to prove the presence of virus in the water by animal passage."

Little[83](1954) describes an epidemic of poliomyelitis in Edmonton, Alberta, which he believes to have been water borne. In November 1953, at a season when poliomyelitis incidence normally falls off, cases of the disease increased in an explosive manner. Milk supplies could not be incriminated. Water supplies were believed to be responsible for the epidemic, the North Saskatchewan River, from which Edmonton draws its water, being polluted by sewage from the town of Devon, 20 miles upriver. Five clinical and 30 suspect cases of poliomyelitis had been reported in Devon during Oct.-Nov. 1953, and at the time of the Edmonton epidemic, chlorination of sewage in Devon had failed temporarily. This theory seemed substantiated by the fact that, previously, cases of typhoid had occurred among persons drinking raw river

water in Edmonton at a time when unchlorinated sewage in Devon was shown to be contaminated by excreta of a typhoid carrier. Apparently, chlorination of the Edmonton water supply was adequate to inactivate the typhoid organisms, but not poliovirus. Little concluded,

> "Epidemiologically, this series of events suggest that Edmonton has suffered a water-borne outbreak of poliomyelitis. It provides, of course, only circumstantial evidence, but is recorded in the hope that cumulative evidence may help in time to complete and clarify the picture of this frustrating disease."

Bancroft et al[57](1957) describe an epidemic which occurred during 1952 in Huskerville, a University of Nebraska student housing area. Sixteen paralytic cases occurred among 347 children in two and one half rows of the development, with only one paralytic case among 256 children in the other one and one half rows. The probability of such a distribution on the basis of chance alone was calculated to be only one in 5,000. After careful study, the authors concluded;

> "A variety of evidence pointed to proximate fecal pollution of the water supply as the sole factor to which significance could be attributed in explaining the distribution of clinical poliomyelitis within the community. The evidence indicating probable fecal pollution of water in the area was indirect but substantial."

Evidence included the fact that the water supply of the development was subject at the time to periods of negative pressure, a situation which was favored in the high poliomyelitis area by the slope of the land. Twelve toilets in this area lacked vacuum breakers. Efficiency of chlorination of the water supply was also suspect. Since the investigation was carried out some considerable time after the epidemic, no laboratory examination could be made of the suspected water.

In addition to the five poliomyelitis epidemics just described, in which, it seems, only a water borne infection could explain the details observed, a number of others are on record in which the spread of infection by water seemed to be a possible factor.

The report of Caverly[41](1895) who described 123 cases of poliomyelitis in Vermont, seems to have been the first to suggest a connection between infection and water supply. He simply noted that virtually all the cases studied lived near a sluggish stream which, because of drought conditions, was at a particularly low level at the time of the epidemic.

In 1940, Paul & Trask[66] studied 17 cases in Connecticut, and noted that the first 3 appeared in the town of Waterbury, while the subsequent cases lived further down a river receiving sewage from that town.

Cleret[81](1944) described an epidemic in France which was believed to be water borne. Details are not available.

Toomey et al[51](1945) isolated what was probably a strain of poliovirus from creek water during an epidemic in Perrysburg, Ohio, but felt that the presence of virus in the water was probably of little importance in the spread of the epidemic.

Casey[85](1945) studied in detail an epidemic of poliomyelitis in Alabama in 1941, where 121 cases occurred in rural Walker county. Eighty per cent of the cases were traced to contact infection, but he concluded;

> "There was the possibility that sewage-polluted waters concentrated by a severe drought explained many sporadic cases, many cases of the disease in adults, and, perhaps, the original case from which the epidemic started ... Significantly, most of the older children or young adults who had not given any history of contact with an infected person had nevertheless been bathing in one of the sewage pollution streams."

The inital case was a child who had bathed several times, before contracting the disease, in a stagnant river which could have been polluted by drainage from an adjacent area where poliomyelitis had occurred earlier in the year.

Wenner & Branson[84](1950) studied a poliomyelitis epidemic which occurred in Iowa in 1948. The area studied bordered on the Missouri River, with adjacent 'bottom lands'

traversed by many drainage ditches, creeks, small ponds and back water areas. The low ground extended 5-8 miles from the river. The standard of sanitation was generally poor, and creeks and drainage ditches were exposed to pollution.

The first cases occurred in the 'bottom lands' area, the epidemic then slowly spreading eastward and away from the river. The authors state;

> "Onset of poliomyelitis in respective members of certain households occurred almost simultaneously, suggesting exposure of members at a common source."

Six tests were made for the presence of virus in water. Positive results were obtained from a sewer outlet, and from a creek in an area where several cases had occurred. Virus was absent from the other samples, including one from a creek which passed four yards from the home of one poliomyelitis case.

In many other instances, evidence for infection by water has been searched for but not found. For example, Gear & Measrock[30] (1948) found no concentration of cases near sewage works or along water courses during a careful investigation in South Africa. Sigurjonsson[80] (1950) studied the disease in Iceland over a 25 year period, and found an unusually high incidence, but no evidence for spread by water.

A systematic search for the virus in water supplies during epidemics has been undertaken on at least two occasions. Kling[93] (1940) tested 27 such samples in Sweden and obtained 26 negative results. In the remaining case, the innoculated monkey developed what seemed to be a mild form of the disease, which was transmittable in serial passage. The results of Francis et al[67] (1948) who tested nine specimens from epidemic areas in this country, were entirely negative.

Statistical studies of poliomyelitis incidence in relation to water supply have yielded rather ambiguous results. Casey & Aymond[8] (1940) in Louisiana found a significant preponderance of cases in communities with water

supplies but no sewers. On the other hand, Bayley[97](1952) in Argentina found that case rates were lower in communities with piped water supplies, and were unaffected by the presence or absence of sewerage systems.

Dempster[4](1948) found a higher case rate in American cities with deep wells than in those with surface water supplies - the reverse of what might be expected if water were of importance in the transmission of the disease.

Heinertz and Valhne[76](1952) drew the opposite conclusion from a survey made in Sweden. Cases of the disease were more numerous among very young children in communities where the water supply was subject to fecal pollution, whereas immunity seemed to have been conferred upon older persons.

The study of incidence of immunity carried out in Stockholm and Gothenburg by Olin and Weslen[94](1957) (referred to above in section 3) followed a similar pattern. In France, Lepine[77](1952) found no difference in case rates between areas of chlorinated and non-chlorinated water supply.

Infection through the exposed pulp of decayed teeth was demonstrated by Aisenburg and Grubb, as reported by Shay[1](1947). Shay accordingly undertook a comparison of average fluorine concentration in drinking water, and poliomyelitis case rates in the counties of Pennsylvania. His reports are presented in the following table:

Fluorine p.p.m.	Number of Counties	Total Population	Cases/100,000
0.0	10	334,974	15.43
0.1	28	5,135,308	7.25
0.2	17	1,344,082	5.92
0.3	5	791,712	3.05
0.4	3	1,553,087	3.00
0.5	2	383,265	2.08
0.6	1	201,000	1.21
3.4	1	156,754	1.26

These results seem to indicate a significant correlation between water conditions favoring dental health and the incidence of poliomyelitis. It is curious that no further reference to this line of research seems to have appeared in the literature.

Two reports, from Sweden, tend to implicate water in poliomyelitis infection. Gard[65](1938) notes a case of an adult who developed the disease a few days after drinking water from a ditch.

Spaak[88](1945) investigated a number of cases of poliomyelitis which occurred in Kunsara parish of central Sweden in 1939. In addition, studies were made of previous cases of the disease in the same area during the period 1911-1939. In one area, all cases were shown to have used the same water supply at the time of infection. In another, 2 cases had used the same water supply continuously, while 3 more had probably used it occasionally. Concentrated water samples from both sources produced symptoms of poliomyelitis when injected into monkeys. Spaak concludes;

> "The most remarkable epidemiological feature in the cases of poliomyelitis described is the tendency to the development of endemic centers ... The cases dealt with here appear to indicate that the cause of such a formation of centers may perhaps be found in the pollution of water supplies by poliomyelitis virus."

It is difficult to know whether to take a report of this sort seriously. On the one hand, survival of the virus in water has certainly been suggested as a means whereby the disease may be carried over between epidemic seasons (Rhodes et al[82](1950). Yet here only a handful of cases were involved over a period of almost 30 years, and the suspected wells must have supplied many persons in the same district who remained healthy.

This case may well be included in the opinion of Gear[64](1952) who says;

"Although many attempts have been made to isolate the virus from water from various natural sources, only rarely have they been successful. Even these successful isolations are not convincing."

In summarizing epidemiological observations with poliomyelitis in relation to water supplies, it would seem that water cannot play a major role in the spread of this disease.

Certain findings, however, can only be explained at present by the spread of poliovirus in water, even though laboratory findings have not succeeded in proving that the water contained the virus. So long as any cases of poliomyelitis are attributable to infected drinking water it is necessary to consider the disease as potentially water borne, and to guard against the possibility of infection by this route.

b. Experimental Experiences - Considerable experimental work has been done or is in progress.

1. Route of Infection - The work of Kling et al[96](1929) showed that infection with poliovirus could occur through the digestive tract, as well as through the respiratory track, as previously recognized.

2. Survival in Water - Kling et al[96](1929) also showed by monkey assay that polio virus in artificially polluted tap water retains its infectivity for at least 31 days in the light and 114 days in the dark at room temperature.

Similarly, Carlson et al[7](1942) reported survival for as long as 100 days when the virus was stored in tap water in a refrigerator. Aeration of tap water containing the virus appeared to be without effect.

Rhodes et al[82](1950) showed that the virus remained infective when stored in river water for 188 days at 4°C, as determined by monkey assay.

3. Chlorination - Experimental work on poliovirus has, understandably, centered around studies of the effectiveness of common water purification procedures, particularly chlorination, in removing the virus.

Most of this work was done before 1949, and was reviewed by Maxcey[27] in that year, who stated;

> "While further carefully controlled studies are desirable, on the basis of experimental results now available, it appears to the author that the application of chlorine under conditions which will insure the maintenance of 0.2 - 0.3 p.p.m. free available chlorine residuals after one half hour of contact may be sufficient to inactivate the quantities of poliomyelitis virus that might be present in a potable water."

Experimental studies [Kempf et al[20](1942); Paul & Trask[19](1942); Carlson et al[7](1942); Ridenour & Ingols[71](1946); and Lensen et al [60](1947)] had at first indicated that prolonged contact with 1 p.p.m. or more of chlorine was required to inactivate the virus.

The later work, in terms of free residual chlorine concentration, indicated a greater effectiveness of chlorine as an inactivating agent.[71] Doubtless, the degree of pollution introduced in many of these experimental studies was greatly in excess of that likely to occur under practical conditions.

4. Other Water Treatment Procedures - A variety of studies have been reported and are summarized in the following table;

Treatment	Result	Reference
Aluminum hydroxide sedimentation & filtration which removes 99.4% of *E. coli*	Poliovirus not removed	Kempf et al[20] (1942)
Aluminum hydroxide sediment of 1.50 ml/liter	Removal	"
Standard coagulation & filtration procedures	Slight reduction	Carlson et al[7] (1942)
Activated charcoal (10-50 p.p.m.)	Partial removal	"
Sand filtration	No removal	"
Slow passage through sand filter blocked with aluminum floc.	Extensive removal	"
Activated sludge-1,100 p.p.m. with 6 hrs aeration	Extensive removal	Carlson et al[73] (1943)

Kempf[20](1942) noted;

> "samples from three of four water purification plants selected at random did not contain a sufficiently high concentration of aluminum hydroxide to sediment the poliovirus."

Maxcey[27](1949) in summarizing this work points out that whereas coagulation and sedimentation, sand filtration, absorbtion on activated charcoal, storage or aeration, fail individually to completely remove poliovirus from water, a combination of these procedures is generally employed in practice

5. Other properties of poliovirus - Poliovirus is inactivated by heating for 30 minutes at 45° - 50° C (Paul & Trask[19] (1942). It survives treatment with 15% ether or low dilutions of phenol.[19] It is inactivated by short exposure to ultra-violet light[19](Carlson et al[7](1942) It withstands pHs in the range 3.5 - 8.0[7].

6. Miscellaneous Experiments - Zichis & Piszczek[74](1948) studied the contamination of drinking water by back siphonage using "A plumbing system representing that found in a two story residence building." The experiments showed that the whole system could become contaminated with polio and other neurotropic viurses by a simple form of back-siphonage, and that the viruses remained active in the plumbing system (which contained chlorinated tap water) for several days.

The possibility of indirect infection with neurotropic viruses from water was investigated by Murphy & Syverton[68] (1955) who grew pea, tomato and potato plants hydroponically in water contaminated with mouse encephalomyelitis virus. It was stated,

> "virus attained concentrations of 10^3 in plant roots but titers exceeding 10^1 were not obtained in the leaves of plants. Evidence was obtained which indicated that the intermittent recovery of virus from the leaves of plants resulted from the irregular translocation of virus from plant roots."

A study by Chapman & Vinsel[102] (1957) showed that home dish washing machines operated at 150°F or above were much more effective than careful handwashing in removing viruses of various types (including poliovirus) from excessively contaminated dishes. Removal was aided by the liberal use of detergents.

c. Opinion and Comment - The recognition of the widespread occurrence of poliovirus in sewage, its relative resistance to destruction by means of chlorination, and its ability to survive in water for long periods led to considerable alarm that poliomyelitis might be widely disseminated in public water supplies.

A number of attempts to assess this danger appeared in the literature during the years ending in the early 1950's, but they found little evidence for the actual spread of the disease by water. More recently, some have suspected that poliovirus infection may be spread by water, but on a smaller scale than was at first feared.

At the moment, therefore, the question is still considered to be an open one. Pertinent sections of comments available are quoted below; they should be considered in the light of the evidence available at the time each was written.

In 1941, Paul and Trask[66] remarked;

> "It would seem unwise at present to make general statements about (the finding of the virus in sewage) so far as the epidemiology of poliomyelitis is concerned ... That watercourses, and particularly watercourses polluted with sewage, may be related to one of these channels (of infection) is suspected. The virus of poliomyelitis has never been isolated from 'running water' but the tests herein reported show that it has been repeatedly isolated from 'running' sewage. It is not evident from this last finding whether its presence in sewage is a direct or even an indirect link in the chains which lead this potentially infectious agent from one patient to another in this disease. Our observations merely call attention to the fact that the virus is there during epidemics."

Casey[85] (1945) in discussing his study of a poliomyelitis epidemic in Walker County, Alabama, notes;

> "nearly every large epidemic of poliomyelitis has occurred after a severe drought in the affected area, and the 1941 epidemic in Walker county was no exception. The drought was the worst in more than fifty years ... Studies done in Louisiana revealed that the epidemic disease was three times as concentrated in towns with a water supply but no sewage disposal system as it was in rural areas or in towns with both water supply and adequate sewage disposal systems. Details in Walker County in 1941 showed the same condition. The epidemic was much more severe in... primitive communities than it was in (one) which has both a municipal water supply and a sewage disposal system. The same contrast was observable in communities outside Walker County where the epidemic raged ... The connection between water and epidemic poliomyelitis cannot be escaped."

Maxcey[27] (1949) in discussing attempts to isolate poliovirus from drinking water supplies states;

> "Up to the present ... attempts to demonstrate the virus of poliomyelitis by laboratory methods in water used for community drinking purposes have not been productive. The studies are comparatively few in number, however, and represent a very limited experience...
>
> "(Investigators) of outbreaks of poliomyelitis in recent years have invariably come to the conclusion that the manner in which cases were distributed, the progressive radial spread from foci of infection, the buildup and decline of the epidemic curve, and other features were not consistent with the hypothesis of dissemination by a common water supply ... There is on record not a single explosive outbreak of this disease which has been conclusively shown to be due to the simultaneous exposure of a group of people to a common water supply ...
>
> "The occasional finding of the virus of poliomyelitis in domestic sewage during a period of high prevalence is without significance in the transmission of the disease, unless or until it can be shown through what channels the virus from this source may reach the alimentary tract of human beings. So far the virus has not been traced beyond the effluent from sewage treatment works. That it may occasionally survive the conditions which effect natural purification in rivers and lakes, and reach the intake of a water system is a theoretical possibility only. Up to the present, attempts to demonstrate the virus in suspected drinking water are questionable or negative."

In England, Mackenzie[26](1950) considered the possible danger of contamination of public water supplies by poliovirus, and stated his opinion;

> "There is no evidence whatever that the virus of poliomyelitis has ever been distributed in a public water supply in sufficient quantity to cause infection, or that it is capable of surviving in such quantity, if at all, the purification processes which have ... been applied to the (Metropolitan London Water) Board's water."

One would assume that Mackenzie must have been unaware of the epidemic described by Hargreaves (also in England) in the same year (see section a above) which provided circumstantial, although not conclusive evidence for the distribution of infective quantities of poliovirus in a public water supply.

Rhodes et al[82](1950) state;

> "Poliomyelitis is discharged in considerable quantity in the feces of patients and there are obvious opportunities for the contamination of water supplies. Kling, from observations in Sweden and other European countries, has supported the concept of poliomyelitis as a water-borne disease. The majority of workers, however, would agree with Maxcey (quoted above) ... Nevertheless it is probable that under certain conditions in country districts sporadic cases of the disease may be contracted from polluted water used for drinking, washing, or swimming. It is also possible that prolonged survival of the virus in infected water may have some bearing on the carry-over of infection from one season to another despite the apparent absence of human cases."

Gear[64](1952) remarks;

> "The study of the fate of the poliomyelitis virus excreted from human beings has clearly indicated that water may readily be contaminated with the virus of poliomyelitis... Although many attempts have been made to isolate the virus from water from various natural sources, only rarely have they been successful. Even these successful isolations are not convincing... The workers in Sweden have been particularly impressed by the role of water in spreading infection... The evidence in Scandinavia is perhaps more convincing than in many other countries. Scandinavia is a well-watered country with many fair-sized rivers. In contrast, South Africa has few large rivers and many parts are arid with no rivers or even streams to spread infection. Indeed in the South African epidemics of 1945 and 1948 there was no suggestion that the infection was waterborne."

Bayley[97] (1952 considered that under conditions prevailing in Argentia potable drinking water was consumed, but that sewage might cause infection via the overflowing of blocked cesspools, or by the use of non-potable water for bathing or washing. Small sewage contaminated creeks were used for washing clothes in several villages where epidemics occurred.

Rhodes & van Rooyen[35] (1958) expressed the opinion:

> "There is little evidence to incriminate piped water supplies in urban communities...The situation is different in rural areas and it is quite possible that excreta contaminated streams may spread the infection. Although sewage contaminated water may not be much used for drinking purposes, it is commonly used in such areas for bathing, ablution, and washing dishes. It is possible that infection can be acquired by swimming in lakes and streams into which untreated excreta are discharged and even pools where the water is chlorinated."

The U.S. Public Health Service (Burke[98] (1959) states:

> "Poliomyelitis has often been suspected of being a water-borne disease. However, this has never been conclusively proved either true or false by the Public Health Service."

III. Coxsackie and ECHO Virus Diseases -

a. Epidemiologic Experiences - Epidemiologic studies of these organisms have only begun to appear in the literature during recent years. For the most part, studies have been confined to the determination of the etiologic agent responsible for the epidemic and have rarely extended even to a consideration of the mode of spread. What little evidence there is to date does not indicate that these infections are water-borne. However, it is pertinent to consider them here because:

1) Their presence in sewage makes a water-borne route of infection at least theoretically possible.

2) Continuing studies may well reveal that water-borne epidemics of Coxsackie and ECHO virus

diseases do occur. In this connection it is noteworthy that although infectious hepatitis is well established as a water borne disease, nevertheless, only occasionally are epidemics traced unequivocally to water supply.

Cole et al[39] (1951) identified a Coxsackie "A" virus in an epidemic of Herpangina, and presented evidence for spread of the disease by person-to-person contact. The authors summarized three previous papers on the epidemiology of Coxsackie "A" infection; the mode of spread evidently had not been considered in any of the papers.

O'Connor & Morris[23] (1955) reported infection of wild cottontail rabbits in a wildlife reserve in Maryland by "Texas-1" Coxsackie virus. Norway and house mice, grey squirrels, and opossums were found to be free of the infection. The rabbits were shown to have acquired the infection by feeding in low ground contaminated by a septic tank.

Leehan et al[70] (1957) investigated an outbreak of disease in Iowa which was attributed to ECHO virus, type "4". Neither water nor milk supplies could be implicated in the spread of the epidemic. The authors stated:

> "The source of this epidemic and its mode of spread were not clearly defined by this study."

Rubin et al[59] (1958) made an epidemiological study of a Coxsackie B epidemic of asceptic meningitis in Iowa. Their conclusions regarding mode of spread are as follows:

> "A common source of dissemination is unlikely. There was no evidence incriminating the milk or water supply ... The epidemic curve did not show the explosive onset followed by a slow fall in the incidence of cases usually associated with a common-source outbreak ... (but is) characteristic of an infectious disease that spreads through a susceptible population until the 'chain of infection' is broken by a marked dimunition in the number of susceptible persons ... The most likely mode of transmission was thought to be person-to-person contact."

b. Experimental Experiences with Coxsackie and ECHO viruses - The Coxsackie viruses constitute a group which can be studied

in the laboratory with relative ease. Even before the introduction of tissue culture methods, the use of suckling mice, rather than monkeys (as in the case of poliovirus) made assay of Coxsackie viruses a much less expensive and more convenient procedure. Also, of course, the diseases caused by certain Coxsackie strains are quite mild, and thus the additional difficulties of working with a dangerous pathogen may be avoided.

Gilcreas & Kelly[29](1954) compared the relative rates of survival of E. coli, E. coli B bacteriophage, and intestinal viruses Coxsackie and Theiler (the latter is an enteric pathogen of mice) under various conditions. They found generally comparable rates of survival of these agents. They also note,

> "It is apparent that viruses as well as coliform bacteria are destroyed (by chlorination procedures) and consequently that chlorination in amounts sufficient to reduce coliform bacteria to insignificant densities would be accompanied by parallel destruction of intestinal viruses ... Apparently the intestinal viruses studied are more susceptible to ultraviolet light than are coliform bacteria."

An extension of this study by the same authors[28](1955) showed that at 8° to 10°C, the viruses survived much longer (10 months or more) than E. coli, of which 99% were destroyed during three weeks of storage in water. At room temperature, results were complicated by the reproduction of E. coli, but in general the survival rates of bacteria and viruses were more nearly equal than at lower temperatures. Survival of viruses was more prolonged in sewage than in water, and was also increased by the presence of phosphate. The authors suggest,

> "Salts other than phosphate may exert a similar protective effect on animal viruses in storage. The experiments presented here offer the practical implication that virus survival may be increased in natural waters that are high in phosphate."

In the same paper, the effect of water treatment procedures on E. coli, bacteriophage, Thieler, and Coxsackie viruses was also reported. The chlorine dose required for

inactivation of the viruses was twice (0.2 p.p.m.) that required to remove E. coli.

Slow sand filtration resulted in extensive purification, but rapid sand filtration was not effective even in removing bacteria. Flocculation removed the agents partially, although it did not inactivate them.

This work was later criticized by Chang et al[105] (1958) who stated;

> "since no quantitative data were given on the turbidity of the water, the nature and amounts of viral and bacterial innocula, the buffer used, the pH of the treated water, or the amount of floc formed and turbidity removed, it is difficult to judge the removal efficiency of the flocculation process, or to apply the results in practice."

With regard to chlorination, Kelly and Sanderson[45] (1958) later reported;

> "Complete inactivation of enteric viruses was not achieved by the bacterial disinfection of water supplies, with free residual chlorine concentrations of 0.2 p.p.m. for 10 minute contact periods at pH 7. Concentration of free residual chlorine of from 0.2 to 0.3 p.p.m. inactivated viruses after contact periods of 30 minutes. Contact periods of at least four hours were necessary for inactivation by combined residual chlorine concentrations of 0.7 p.p.m."

Chang et al reported the effect of flocculation procedures on the virus population of water of known composition[105] (1958) and of raw river water[106] (1958). Effects of rate of stirring, bicarbonate or phosphate buffer, amount of alum or ferric chloride floc, and pH are reported in detail. The study attempted;

> "to ascertain (1) how certain pathogenic viruses differ from bacterial viurses in their behavior in the flocculation process, and (2) how efficiently current water works practices remove viruses and bacteria from natural surface waters."

It was found that removal of Coxsackie viruses was somewhat less efficient than that of bacterial viruses. The authors suspected;

"---removal estimates based on bacterial virus will slightly over-estimate the efficiency of the process for the removal of Coxsackie virus."

Flocculation was inhibited by low concentrations of gum arabic, which was believed to interfere with the formation of coagulant-cation-virus complexes.

In general, it would appear that the properties of Coxsackie and polioviruses are similar. Both appear seasonally in sewage in high concentrations, survive in water for long periods, and are more resistant than bacteria to chlorination and other water treatment procedures.

Apparently, studies of this sort have not been carried out with the ECHO viruses, but one would expect these, also, to possess similar properties.

IV. Other Viral Diseases - A number of reports have suggested viral etiology and spread by water for certain other diseases.

a. Epidemiological Experiences - The experience of Kjellen et al(54) (1957) in which adenovirus type 3, was found in feces of patients and in sewage during an epidemic of a disease resembling pharyngoconjunctival fever has been mentioned above (section 1). Other experiences with pharyngoconjunctival fever have generally been related to swimming pools.

Gorbatow(77) (1951), as summarized by Biological Abstracts, described 36 cases of diarrhea in a rural community of 3,000. Bacteriologically, the water was of poor quality, but no definite connection could be established between water consumption and the incidence of the disease. In view of the association of ECHO viruses with diarrhea, it seems that this may have been a viral epidemic.

b. Experimental Experiences - Thygeson & Stone(86) (1945) studied the epidemiology of Inclusion Conjunctivitis. This disease was associated with the use of non-chlorinated water

in swimming pools and considered to be due to a viral agent. It seems possible that this disease may be related to the more recently defined entity, pharyngoconjunctival fever. Material containing the virus was stored in tap water at room temperature and tested for infectivity in baboons. The virus survived for more than 6 hours, but less than 18 hours.

Clark et al[24](1956) studied pure Type 3 adenovirus, and found that it was readily inactivated by chlorine in a manner dependent upon chlorine concentration, pH and temperature. The authors concluded;

> "The wide difference in the susceptibility of animal viruses to chlorine is a new observation. Previous studies on the resistance of poliomyelitis virus, Coxsackie virus, and the virus of infectious hepatitis to chlorine have indicated that these agents are considerably more resistant than are bacterial cells. Type 3 adenovirus, however, has about the same sensitivity to chlorine as does E. coli or S. typhosa. The results obtained in this study seem to indicate therefore, that transmission of Type 3 adenovirus through swimming pool water that is properly chlorinated is highly unlikely."

Since this adenovirus is much more easily inactivated than the enteroviruses, it seems improbable that it could withstand passage through soils.

PASSAGE OF VIRUSES THROUGH THE SOIL

Consideration related to the size of an infectious organism is an important factor determining its ability to pass through soil. In recent years, the electron microscope has been used for direct measurements of the size of many viruses. In 1954, Williams[109] reported;

> "Some of the animal viruses appear to be essentially uniform in size and to exhibit, consequently, a two-dimensional packing when prepared for electron microscopy from concentrated suspensions. The smallest sizes reported for one of the uniform-sized viruses is that of mouse encephalomyelitis, strain FA, which has a diameter of only 27 mu in close-packed array. The newly identified Lansing poliomyelitis virus appears to be entirely monodisperse with essentially the same diameter, estimated to be 28 mu in packed arrays. The reported size of two

Coxsackie, Group A viruses is larger, 37 mu but this diameter was determined for individual particles. Since the individual poliomyelitis virus particles are also 37 mu across when measured individually, it appears that they and the Coxsackie viruses studied are essentially the same size."

Artifacts in preparation of electron microscope specimens can be expected to add at least 5 mu to the apparent diameter of small particles.

In a current current review Schaffer & Schwerdt(108) (1959) reported:

"Very recently, electron micrographs of replicas of the internal structure of crystals of Mahoney strain (polio) virus yielded measurements of 27.3 ± 1,4 mu for the diameter of particles in close-packed array...no significant difference in size among representative strains of the three immunological types has been observed by electron microscopy."

Thus, 300 Å may be taken as a reasonable estimate of the diameter of viruses of the enterovirus group. The size of the infectious hepatitis agent is unknown, but is probably not less than this, since no animal viruses are known which are significantly less in diameter than 300 Å, while many are much larger. The report by Smith(110) (1959) of an insect virus 120 A in diameter is the only case of a significantly smaller viral agent." By comparison the dimensions of bacterium E. coli are of the order of 2 u (i.e., 20,000 Å).

a. Passage Through Soil - Studies of the passage of chemicals or bacteria through soil may give an indication of the behavior to be expected from viruses, since the viruses are intermediate in size between large organic molecules and the bacteria. The behavior of viruses in soil might, however, differ greatly from that predicted on the basis of size alone since their adsorbtion properties will also be of importance.

b. Movement of viruses above and with ground water - experimental work - Some experimental work has been done on travel of viruses in ground water, but much more extensive studies have been carried out with bacteria and chemicals.

I. Studies with Bacteria and Chemicals: In studying contamination of ground water a technique used by a number of

H - Viral

workers has been the establishment of a source of identifiable contaminants in an earthen pit. Wells are then dug at various radii from the source of contaminants, and samples of water from a large number of such wells are analyzed at regular intervals.

This type of experiment is valuable in that it gives data concerning the spread of contaminants under natural conditions whereas laboratory experiments are always subject to artificial limitations, and thus are sometimes difficult to interpret in practical terms.

However, experiments of this sort only yield useful information over a period of years, and in any case, only give information pertinent to the particular site selected. Soil characteristics and conditions of ground water flow may vary widely from site to site. With these limitations in mind one may obtain useful information from such experiments.

Stiles et al[75] (1927) carried out an experiemt using an area of sandy soil at Fort Caswell, N. C. A trench was dosed with human excreta plus the dye, uranin. E. coli and uranin in the ground water were measured over a period of two and one half years.

E. coli travelled up to 232 ft. from the source of contamination, while uranin travelled 450 ft. under the same conditions. Stiles noted that the rate of ground water flow, soil pH, geological formation, bacterial competition, and weather conditions all influenced the rate of spread of contamination. Wells located directly in the path of down hill ground water flow were most heavily contaminated, the concentration of contaminants falling off steadily in adjacent radii.

Fournelle et al[103] (1957) made a similar study at Anchorage, Alaska, where subarctic conditions prevail. The soil was of a "sandy gravel texture" and the ground water table lay 5-6 feet below the surface of the ground. Uranin and

Streptococcus zymogenes were used as indicators of contamination. Survival of the test organism was indicated by maintaining a culture in a dialysis sac at the source of contamination, thus distinguishing between die-off of the organism and removal by filtering action of the soil.

The authors found;

> "It was possible to trace (S. zymogenes) for 50 feet. The width of the path of travel varied between 1½ and 4 feet ... The organism described a definite path of flow with sharp and clear cut boundaries."

Relative to the chemical, uranin, Fournelle et al[103] state;

> "Uranin was found to be very satifactory for determining direction of flow of ground water. The dye was traced 100 feet from the point of dosing and was detected two years and 10 months later. The path of the dye varied from an initially narrow channel, 1½ to 4 feet in width, to a wedge-shaped expansion measuring 40 feet at the distal end after several years ... (the original channel had) well defined negative borders. This channel was apparent for approximately 2 to 5 weeks. The rate of movement of the dye through the ground water was about 2 feet per day."

These two studies, carried out under widely differing climatic conditions, showed uranin to travel about twice as far through the soil as bacteria. This result is consistant with the relative size of the particles concerned. On this basis, freedom of a well from E. coli or other bacteria would not ensure freedom from viral contamination, since viruses might be expected to travel about one and one half as far as E. coli.

On the other hand, the surface to volume ratio of viruses is much greater than that of bacteria, so that adsorbtion phenomena would be of greater importance. Thus, the distance travelled by bacteria and viruses might be very nearly the same.

II. Studies directly with viruses - The only experimental study of the effect of soil percolation on viruses which has appeared in the literature to date is the work of Gilcreas and Kelly[28] (1955) who state;

> "Seepage of water through soil has a dual role as far as pollution problems are concerned. In the drainage of surface

> waters, seepage through soil may provide purification. Seepage may also, however, serve as a channel from a highly polluted source (such as a privy or cesspool) to an unpolluted one ... The comparative behavior of enteric viruses and bacteria during seepage of water through soil is of importance in determining the validity of the use of the coliform index under such conditions. To compare the penetration of viruses and bacteria through soil, suspensions of Coxsackie virus and E. coli in water were allowed to percolate through garden soil (moisture content, 4%) contained in glass tubes 36 mm. in diameter. A mixture of the agents in 300 ml. of spring water was added to 6, 18, and 36 inch columns of soil and the percolates were collected. Percolation through at least 3 feet of soil was necessary for the reduction of either viruses or coliform organisms, and even that distance of travel, however, was insufficient to remove them completely."

A histogram given by Gilcreas and Kelly shows about 50% recovery of Coxsackie virus, 30% recovery of E. coli, and 75% recovery of bacteriophage following percolation through 3 feet of soil.

Thus, 50% reduction of Coxsackie virus titre was demonstarted after percolation through soil of 4% moisture content. Neither the percolation distance required for effective removal of the virus, the effect of rate of flow, nor the effect of different types of soil were investigated.

A study expected to be made at the R. A. Taft Sanitary Engineering Center of the U.S.P.H.S. will investigate the effects of column flow on virus concentrations (Walton (117) (1959). The columns to be used are those which have been employed for an unpublished study of the effect of slow filtration through sandy soil of E. coli, detergent, and chlorides. These columns are 6" in diameter with a 10' soil column. Liquid flows in the upward direction at a rate of about 1 liter per day. The usefulness of data to be obtained from this study is considered to be limited by the relatively small size of the columns used, and a more extensive system is recommended for really significant studies of virus travel.

The work proposed to be undertaken by Walton and coworkers will indicate the nature of virus travel with the ground water. That of Gilcreas and Kelly seems to concern

the movement of viruses in seepage above the ground water. Quite different results might be expected from these two types of experiment, but both of the systems described are, in any case, to be considered as of preliminary usefulness only.

C. The ability of infectious hepatitis virus to pass through soils - epidemiological studies: - Hallgren[47](1942) investigated the water supply of a Swedish sanatorium where an epidemic of infectious hepatitis occurred. The water supply from a concrete tank was clearly incriminated. The tank was "Sunk through the morain gravel right down to the underlying primaeval rock" and lay 12 feet, slightly downhill, from the main sewer of the sanatorium. Subsequent investigation revealed a break in the sewer near this point. The ground was frozen at the time of the contamination of the water in the tank.

Neefe and Stokes[15](1946) investigated sanitary facilities at a summer camp in the Pocono mountains where numerous cases of infectious hepatitis had been traced to contamination of well water. Back flow from toilets, direct leaks, and surface contamination were ruled out, and it was surmised that the well had become contaminated by seepage from adjacent cesspools, several of which lay within 200 feet of the well.

The authors reported;

> "These cesspools were 6 to 8 feet in depth and had open bottoms, stone walls, and cement tops... None of the cesspools had overflowed prior to the start of the epidemic. In fact, although in use for a number of years, drainage of the cesspools had never been necessary, indicating that the contents had diffused into the ground. The ground layer of the area, varying in depths from a few inches to approximately 4 or 6 feet, consisted of ordinary top soil overlying a layer of 'hardpan'. The exact nature of the underlying rock was not determined but it was said to consist of red shale and limestone. In certain places where the rock layer protruded through the soil and could be inspected, many cracks and fissures could be detected."

Farquhar et al[9](1952) incriminated well water in a small outbreak of infectious hepatitis in Pennsylvania. The

water appeared to have become contaminated from a cesspool which lay in slightly higher ground at a distance of not more than 50 feet. In the area, creviced shale was overlaid by a thin layer of top soil. Evidently the passage of the virus was facilitated by extremely wet soil in a season of heavy rain.

Tucker et al[46](1954) in describing conditions prevailing at a camp where 102 cases of hepatitis were contracted stated;

> "The camp ... is located in a narrow valley on the western side of the Highland Rim section of the State. This section is typical of a great part of middle Tennessee in that the top soil is underlaid with limestone with frequent outcroppings ... It was discovered that although the main sewer line was constructed of metal sewer pipe with lead sealed joints, the sewer lines extending from the cottages to the main sewer were laid with terra cotta pipe."

Sodium fluorescein dye was placed in the toilet of the cottage nearest to the spring which supplied water to the camp. The dye appeared in the spring water after 40 minutes. This cottage was located about 50 feet from the spring.

Peczenik et al[62](1956) traced an epidemic of infectious hepatitis in an Austrian hotel to contamination of water from the septic tank of an adjacent hotel where there had been one case of the disease. The septic tank was approximately 20 feet above and 122 feet distant from the water reservoir. The area was described as having a fairly steep gradient and an abundance of ground water. The terrain was composed of fissured limestone overlain with a layer of humus and fine and medium gravel.

Mosley & Smither[17](1957) investigated an epidemic of infectious hepatitis in Utica, Kentucky. Half of the cases were believed to have become infected via contamination from private wells. The authors state;

> "Of the 6 households in which cases occurred in members or visitors, all derived their water from drilled wells located on their property or at an adjacent house. The depth of the wells varied from 80 to 212 feet. No reliable

information concerning depths of casing, type of casing used or adequacy of sealing could be obtained."

The only well which gave consistently positive coliform cultures was located 30 feet from the laterals of a septic tank. Information concerning geologic formation was available from the record kept during the digging of another well, about 750 feet from the contaminated wells. The log is given as follows:

"Depth, ft. Type of Rock

0-15	Yellow clay
15-19	Sandy Soil
19-28	Light gray shale, solid
28-43	Dark, shale, soft
43-45	Coal
45-50	Hard lime
50-54	Fire clay
54-75	Water sand
75-85	Sandy shale
85-100	Solid shale
100-103	Coal
103-120	Shale and lime shells
120-127	Lime
127-130	Fire clay
130-151	Shale
151-153	Hard lime
153-170	Sandy shale
170-180	Shaley sand
180-201	Water sand"

The authors state

"It is believed that the strata in this area should provide adequate protection from surface water, provided no leak should occur as would be possible through a geologic fault or an abandoned well, or about an inadequately sealed casing. From the information available it is not possible to state where such a leak may have occurred to permit dye to enter wells varying from 80 to 212 feet in depth. A geologic fault extending through this depth is

considered very unlikely. There are several abandoned wells in the area, 2 of which are located within 100 feet of the laterals of (one of) the septic tanks. Although these are believed to be no more than 125 feet deep, it is possible that they contributed to the underground distribution of material from the septic tank through the subsurface strata."

In the experiences described here, infectious hepatitis virus appears to have travelled through the soil for distances of 12 to 200 feet. In most cases however, the findings seem to indicate that direct channeling through fissured substrata is what had occurred, rather than seepage through the soil itself.

Fournelle et al[103](1957) as noted above found that uranin dye travelled in the ground water at a rate of about 2 feet per day. This slow rate of travel is certainly not consistant with the rapid spread of infection noted in some of the above epidemics.

d. Survival of viruses in water:

The passage of viruses through the soil will be determined not only by the action of the soil as filter or adsorbent, but also by the time during which the virus is able to survive in the ground water. The results of studies of the survival time of viruses in various waters are therefore presented in this section. Survival times vary greatly - from a few hours in the case of inclusion conjunctivitis to many months for some of the enteroviruses

I. Infectious hepatitis virus - Survival in water - The studies of Neefe et al[15](1946) showed that the infectious hepatitis agent survived 4 months storage in well water kept at air temperature, despite exposure to light. However, the concentration and/or virulence of the virus was lessened by this treatment.

An opportunity to determine the behavior of the virus in flowing water was provided by the infectious hepatitis epidemic described by Olin[33](1947), which occurred in Sweden.

Sewage from a hotel passed through a small grease trap into a two-chambered septic tank. Overflow from the septic tank ran into a slowly flowing brook and finally into a lake which was about 450 meters from the tanks. In deep water, 60 meters from the edge of the lake and an equal distance from the drain outlet, lay the inlet for the water supply of the hotel. The water inlet lay above the sewer outlet with respect to the normal direction of flow of water in the lake, backflow of sewage being also prevented by a wooden rampart. However, at the time of the epidemic this rampart was found to be damaged, and the quantity and flow of liquid water in the lake had been greatly reduced by persistent freezing temperatures. Thus, significant quantities of infectious hepatitis virus survived a rather circuitous passage through 550 yards distance of water near freezing temperature.

II. Poliovirus - Survival in water - Kling[96](1929) diluted an emulsion of brain and cerebrospinal fluid from a monkey killed by poliomyelitis with sterilized tap water. They showed that the virus retained its virulence for at least 114 days in the dark and 31 days in the light at room temperature.

Carlson et al[7](1942) reported that poliovirus remained viable for at least 100 days when stored in the refrigerator in tap water.

Rhodes et al[82](1950) showed that poliovirus from human patients remained active for 188 days in river water at 4°C.

All these studies made use of monkey assays. It is possible that more sensitive tissue culture assay techniques would demonstrate even more prolonged survival of poliovirus.

III. Coxsackie and Theiler viruses - Survival in Water - Gilcreas & Kelly[29](1954) compared the relative survival in various waters of E. Coli, E. Coli B bacteriophage, and Coxsackie and Theiler viruses. They concluded;

> "At temperatures which roughly approximate seasonal variation in water storage temperatures the coliform bacteria

at times survived forlonger periods and at other times the intestinal viruses had the greater survival ... it may be concluded that the two rates of survival are comparable ... A comparison of survival rates of coliform bacteria in eight water types examined (showed that) survival of phage was greater and persistence longer than that of coliform bacteria. This was true regardless of water type."

In an extension of this work, Gilcreas & Kelly[28] (1955) stored the same agents in "Screw-capped test tubes at 20°-30°C and 8-10° C for a period of 40 weeks." They reported:

"In both water and sewage, viruses survived for a longer period of time and to a greater extent than did E. coli when stored in the cold. By the third week of cold storage, the coliform bacteria had dropped to 1% of their original number, while virus survival continued unchanged for at least 4 months. Even after 10 months in the cold, there was little destruction of virus. It made no difference in the rate of destruction of the agents stored in the cold whether they were in water or sewage.

"Survival of viruses at room temperature was much briefer than in the cold: Coxsackie virus was partially destroyed by the third week and Theiler virus by the sixteenth week... When the agents were stored in sewage rather than in water, coliform organisms reproduced at a greater rate and bacteriophage was destroyed at a slower rate... Unpurified virus suspensions were stored for several weeks at room temperature to which were added (various) amounts of disodium phosphate... Survival of virus in water with the added phosphate was greater than that of virus in water with no added phosphate.. Salts other than phosphate may exert a similar protective effect on animal viruses in storage. The experiments presented here offer the practical implication that virus survival may be increased in natural waters that are high in phosphate."

IV. Inclusion Conjunctivitis - Survival in Water - The experiments of Thygeson & Stone[86] (1945) showed that the inclusion conjunctivitis virus survived in water for 6 hours, but was inactivated within 18 hours, as determined by assay in baboons.

6. REMOVAL OF VIRUSES - Little is known concerning the removal of virus from waters under natural conditions. Experimental work, largely concerned with water-purification processes, has tended to show that in any given set of circumstances, the resistance of viruses to inactivation is either equal to or

much greater than that of bacteria such as Escherichia coli. These circumstances are described for each virus group in sections 4b, 5b, and 5d.

a. Above ground water:- The removal of viruses above the ground water will be determined by the filtering and adsorbing properties of the soil and also by purification of surface water prior to seepage through the soil.

I. Filtration - This will depend on the size of the viruses, which are known to pass through much smaller pore diameters than bacteria. Chemicals have been shown to penetrate through the soil about twice as far as bacteria. (Stiles et al[75] 1927; Fournelle et al[103] 1957). On the basis of size, viruses should travel an intermediate distance. Specific experimental tests have not been made, but preliminary work (Gilcreas & Kelly[28] 1955) is in agreement with this hypothesis.

Earlier studies by Carlson et al[7] (1942) showed that sand filtration did not remove polio virus from water unless the filter were blocked with large amounts of aluminum floc, producing a very low flow rate. Evidently virus was removed under conditions favoring adsorption rather than filtration, as might be expected.

II. Adsorption - One would expect that adsorption of an agent by the soil would be dependent upon surface area, and on chemical nature. The small size of enteric virus particles (about 300 Å) should favor their adsorption by the soil. However, direct studies of virus adsorption by soil have not yet been made.

A number of experiments have been carried out with both polio and Coxsackie viruses using the alum floc technique of coagulation and sedimentation commonly employed in water purification. (Carlson et al[7] 1942; Kempf et al[20] 1942; Change et al[106] 1958). All of these studies showed that viruses were less effectively removed by this treatment than were bacteria. Evidently, those viruses which were removed remained active while adsorbed to the floc.[7]

During floc formation, at least, the expectation of strong adsorbtion of viruses is not fulfilled; nevertheless their behavior in the soil may be quite different.

III. Surface Inactivation - It is possible that exposure to light at the surface may remove viruses from water before they can enter the soil. Both polio and Coxsackie viruses have been shown to be inactivated by ultraviolet light with relative ease. (Paul & Trask[19] 1942; Carlson et al[7] 1942; Gilcreas & Kelly[29] 1954). The significantly longer survival of poliovirus stored in the dark, rather than in sunlight, found by Kling[96] (1929), is another example of this effect.

b. In and With the Ground Water - Removal of viruses in and with the ground water will be dependent in part upon adsorbtion and filtration by the soil. An additional factor of importance is the survival time of the agent. By definition, viruses do not metabolize; availability of oxygen should therefore be unimportant except in so far as it affects chemical inactivation processes. In the absence of suitable hosts viruses will not reproduce; thus, temperatures normally encountered in the ground water should not greatly affect the survival of viruses. Destruction of viruses will be somewhat accelerated at temperatures which would permit the multiplication of bacteria.

Studies of the survival of viruses in water show that both polio and Coxsackie viruses may be expected to remain active in water for periods of many months. (Rhodes et al[82] 1950; Gilcrease & Kelly[28] 1955). Studies on the persistance of viruses in water have been carried out with distilled water, tap water, and river water. Gilcreas & Kelly also showed that the presence of phosphates prolonged the survival of Coxsackie viruses. It is quite possible that other salts which might be present in soils - perhaps occasionally in rather high concentrations - could exert either a protective or a destructive effect on the viruses. This point has not been investigated to date.

It is well known that synthetic detergents are present in sewage and occasionally in contaminated ground water. Detergent solutions under certain conditions may be used in the laboratory to disrupt viruses into their constituent macromolecules (for example, Rushizky & Knight[116] 1959). While these chemical effects are generally observed with rather high concentrations of detergents, it is possible that some inactivation of viruses may be caused by the detergents present in sewage, and possibly even in contaminated ground water.

In summary, it would seem that removal of viruses by die-off in the ground water will only take place at a rather low rate.

7. PREDICTING POTENTIAL GROUND WATER CONTAMINATION BY VIRUSES -

a. Present Art - Accurate prediction of viral contamination of ground water on the basis of experimental knowledge may become possible in future years; at present, our knowledge of how far viruses will travel through the soil, and how long they will survive under natural conditions is fragmentary.

On the basis of the available information outlined in this report, the following suggestions are made: Wells should be dug more than 200 feet from cesspools or septic tanks, and should be at a higher level with respect to the direction of ground water flow. Separation of wells and cesspools is particularly important in areas where soil substrata are extensively fissured or where geological faults are suspected. Sewer lines passing close to wells or water supply reservoirs should be constructed of metal with sealed joints.

Freedom of wells from coliform organisms tentatively, but not conclusively, indicates freedom of the water from viruses.

The following items of information are considered to substantiate the foregoing suggestions:

1. Experience with outbreaks of infectious hepatitis shows that the agent has, by whatever manner of travel, passed into water supplies after passage through up to 200 feet of soil. (Among other, Neefe & Stokes(15) 1946).

2. Experimental studies of the spread of bacterial and chemical pollution from pits indicates that the spread of these agents is rather closely confined to the direction of ground water flow; i.e., in general, downhill. (Stiles(75) 1927; Fournell et al(103) 1957.)

3. Spread of the infectious hepatitis virus through the ground for any appreciable distance has in all cases occurred in areas where direct channeling through fissures is at least a possible means of spread.

4. Tucker et al(46) (1954) described an epidemic of infectious hepatitis which apparently was caused by passage of the agent through the walls of a terra cotta sewer pipe and thence into a water supply.

5. Well waters suspected, on epidemiological grounds, of containing the infectious hapatitis agent have been shown to contain coliform organisms also.

6. Experimentally, Gilcreas & Kelly[29](1954) have found generally comparable survival rates of E. coli, and for viruses. However, under some circumstances, E. coli is much more readily inactivated than are the viruses.

b. Additional Information Required - It would be of interest to know what concentrations of viruses are required for infection of humans or domestic animals. Essentially, such information would constitute a quantitative definition of viral contamination. In the absence of this information, we must assume that virus concentrations must be reduced to a level too low to be detected by any known method of assay.

The ability of viruses to survive in the ground water should be further studied. Such knowledge should be related to a wide variety of waters - i.e. encompassing a range of pH, mineral content, detergent and other chemical content, and other characteristics.

The interactions of viruses with the soil should be studied. In particular, information concerning the adsorption of viruses to soil particles under natural conditions would be of great value.

The relative importance of virus passage through channels and seepage through the soil should be evaluated.

Outbreaks of virus disease which might be water borne should be investigated thoroughly in all cases, since such episodes provide practical information for future guidance.

8. WATER CRITERIA NEEDED - Recent epidemiologic and experimental experiences with virus diseases have made it evident that the validity of the coliform index for the determination of potability of water with respect to biological agents should be carefully reviewed.

In the case of infectious hepatitis, the conclusions of Neefe et al[18](1947) were;

> "The available evidence concerning the properties of (hepatic viruses) indicates that they are resistant to certain procedures which eliminate or destroy bacteria and suggests that certain methods of water disinfection known to be adequate for bacterial intestinal pathogens may not be adequate for the more resistant viruses ... initial studies suggested that the hepatic viruses might be more resistant to chlorine than the pathogenic bacteria commonly encountered in water."

The 1955 epidemic of infectious hepatitis in New Delhi, India, has entirely borne out this opinion.

A similar situation exists with regard to poliovirus. Bancroft et al[57] (1957) stated;

> "It appears that in some instances ... drinking water judged to be safe by ordinary good standards of treatment and surveillance may be a significant source of clinical poliomyelitis. The boiling of drinking water during epidemic periods constitutes a simple technique immediately available and capable of wide application in communities in which the possibility of infection from this source cannot be ruled out."

The adequacy of the coliform index as a criterion of water quality has been reviewed by Gilcreas & Kelly[28] (1955) in the light of experiments carried out by these authors. They question whether:

> "a satisfactory coliform index actually indicates freedom of the supply from viruses. In satisfying this question, the problem has been to determine: (1) whether viruses can be detected in water; (2) how their survival under different supply treatment procedure compares with the survival of coliform bacteria; and (3) whether the presence or absence of members of the coliform group can be used without reservation to indicate the biologic quality of water."

They find;

> "It is clear that the coliform index is not an adequate measure of pollution by viruses in sewage, as fluctuations in virus content were not marked by comparable changes in coliform content."

However, these authors conclude;

> "results suggest that the coliform index is, in general, a valid measure of pollution both bacterial and viral, and that it is also a reliable indication of the efficiency of treatment processes when the limitations of marginal treatment in the removal of pollution -

> particularly by enteric viruses - are understood. The coliform index should be interpreted with discretion and regard for the information available concerning the relative survival rates of the agents in question under conditions of water treatment. The experiments indicate that effective and complete treatment of water is necessary to insure safety from potential pollutions by enteric viruses. Marginal treatments are not sufficient, even though they may reduce the density of the coliform group to conform closely with established water quality standards. Much further investigative work on the problem is needed to determine the fundamental significance of the coliform group - compared with viruses and other pathogenic agents - as an indicator of pollution ... Pending further investigation of the problem, it seems safe to state that the coliform index is still a reliable indicator of standard water supply treatment."

The coliform index is in general an adequate water quality standard, yet must interpreted "with discretion." Apparently, freedom from coliform organisms indicates freedom from pathogenic viruses under normal conditions, but is inadequate for providing definite assurance of the absence of viruses. Theoretically, therefore, it would be desirable to include assay for some common enterovirus in the standard water testing procedures. However, practical consideretions do not favor the adoption of such a standard. Assay of pathogenic viruses requires the use of tissue culture methods and thus inconvenience, time required for determinations, and expense are all greatly increased relative to coliform tests. Considering the matter of expense alone, the only practical medium for large scale tissue culture of enteroviruses is monkey kidney; monkeys now cost initially about $50 or more each, and much expense is involved in maintaining an animal colony.

Clearly, it would be impractical for every water-testing laboratory to run virus assays on a routine bases. The Coxsackie viruses may also be assayed in suckling mice. Assays of this sort would be much less expensive than tissue culture methods, although also much less precise, and still much more expensive than the methods required for bacterial assays. However, mouse assays of Coxsackie virus might be the most feasible method for routine examination of waters for the presence of viruses.

The phages seem to offer a possible alternative to pathogenic virus assays. The assay of phages is comparable in expense and time to that of bacteria, and they occur regularly in sewage. However, coliphages, like E. coli itself, may differ considerably in their removal properties from the pathogenic enteroviruses. The dimensions of common bacteriophages are of the order of 0.1 μ - somewhat larger than the enteroviruses, although of a similar order of magnitude.

Experimental studies by Gilcreas & Kelly[29](1954); [28](1955) and by Chang et al[105][106](1958) indicate that the behavior of the coliphages is more like that of the enteroviruses than that of bacteria, but that in some cases they are more readily removed from water than are the enteroviruses. In short, adoption of coliphage content as a standard of water quality would perhaps be somewhat of an improvement over the coliform index, but would still be open to the criticism that results must be interpreted "with discretion."

An entirely practical and theoretically satisfactory solution to the problem of water quality standards is not evident at the present time. We know, however, that water supplies which are initially heavily contaminated, or those which are subjected only to single step or marginal treatment are those most likely to be contaminated by viruses.

Among well waters, those dug in relatively heavily populated areas - as in some suburbs where many houses have their own cess pools - would seem to be suspect. It would seem logical, therefore, to require that any water which meets only minimal standards of coliform pollution, should be subjected to additional tests for viruses. As indicated above, mouse assay for Coxsackie viruses would probably constitute the most satisfactory screening procedure.

2. SUGGESTIONS FOR RESEARCH WORK - Experimental studies of water-borne virus disease are at present faced with an unfortunate situation. As pointed out by Clarke and Chang[113]

(1959) infectious hepatitis is the only virus disease in the transmission of which at the present time water is known to play an important role. Yet this agent is the only one of the viruses concerned which cannot be studied in the laboratory. The agent does not infect any known laboratory animal and fails to multiply in any known tissue culture system. At the present time, many laboratories are engaged in attempts to find a culture system for the infectious hepatitis agent, but without notable success.

In the absence of a method for quantitative studies with the infectious hepatitis virus, experimental studies should be carried out with one of the enterovirus group.

Experiments designed to predict contamination of water by enteroviruses could be ambitious in varying degrees. A simple method of approach would be to compare the die-off time of each of the agents with rates of ground water flow. A maximal possible distance of travel with the ground water could then be estimated. Some data on survival time of viruses are already available but further experiments should be carried out to account for a number of factors not considered in the earlier studies, such as:

1. Low assay efficiencies in early studies of virus survival where LD 50s for animals were determined. Plaque counting methods would be expected to indicate longer survival times.

2. Effect of salts and other materials commonly or possibly present in ground waters.

3. The concentrations of virus which would be present under practical conditions. Results with concentrated virus suspensions which could contain 10^{12} or more particles per ml would provide an upper limit for survival time; the highest concentrations of viruses occurring in sewage would be much lower than this.

Another approach to the problem would be a study of interaction of viruses with soils. The extent of adsorption

of viruses to soil particles could be determined in the laboratory by batch studies in which virus suspensions could be shaken with representative types of soils.

Such studies would be simple single-step operations. Very possibly, the percentage absorbtion of virus on shaking with a given quantity of soil might be correlated closely with percentage removal of virus on passing through a given distance of the same soil, in case removal of viruses by filtration should prove to be small or negligible. Should this be true, it might be feasible to predict viral contamination of a well by testing the ability of adjacent soil layers to adsorb viruses, at least in areas where soil composition is reasonably homogeneous.

Determination of the possibility of viruses passing through soil for given distances might be carried out in a number of ways. Soil columns could be set up in the laboratory, possibly the most simple method, but these would represent only a single direction of flow and might be subject to channeling effects at the edges.

Walton[117](1959) has suggested the use of a tiltable tank for this type of study. Such a tiltable tank should contain at least several inches depth of water-saturated soil and should be sufficiently broad and long to permit a study of the movement of viruses in two dimensions. It should be tilted just sufficiently to produce a rate of flow approximating that of ground water.

Such an arrangement would have the advantage that the total volume of water flowing through could be much larger than in most column experiments and samples could be easily withdrawn from a number of points in the tank. A preliminary study should be made to determine if this scheme might be subject to surface oxidation or other objectionable effects.

Earthen pit studies could incorporate all the features required to study virus movement through the soil However,

the time and expense involved might not be justified by the additional information they would supply.

Any study of the adsorbtion of viruses by soil or their removal on passing through the soil should include a dialyzing culture maintained at the point of virus origin, as recommended for bacterial studies by Fournelle et al[105](1957). This would provide a simultaneous check on the survival of the virus under conditions of prolonged contact.

Studies, as suggested above, could be carried out also either with phage or with one of the pathogenic enteroviruses. As indicated above, results with phage would provide only an indication of the behavior to be expected from the virus pathogens.

The relative simplicity of phage assays would make more detailed studies feasible from the point of view of both time and expense; which perhaps might compensate for the limited applicability of results. Recently a coliphage comparable in size to the enteroviruses has been described. (Sinsheimer[118](1959) The survival behavior of this coliphage may be expected to be more similar to that of the enteroviruses than that of the larger well-known T-coliphages and it is possible that this coliphage may provide a very desirable test organism for soil studies.

However, final results should be obtained eventually directly with the virus pathogens. It is essential that studies of this type be carried out in conjunction with a laboratory well-equipped for tissue culture work and by personnel who have experience with these laboratory techniques.

The adjustment of water quality standards to provide protection against contamination by viruses might be based on studies in which the coliform index or other similar biological tests could be related to the results of virus assays for water of various compositions or history. Conditions must be determined under which a satisfactory coliform index would probably indicate freedom from viruses. Also conditions should be determined which might require an additional direct test for the presence of viruses.

Examination of water quality criteria in relation to viruses has progressed much further at the present time than has work on the prediction of contamination of ground waters. At least two laboratory groups are actively investigating this problem - at the New York State Department of Health, Albany, N.Y., and at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

A number of publications by these two groups have appeared in which the validity of the coliform index has been considered or in which the effects of various water treatment processes on viruses were discussed. Gilcreas & Kelly[28](1955): Gilcreas & Kelly[29](1954): Kelly & Sanderson[45](1958): Chang et al[105][106](1958). Further work on viruses in water is being continued by these workers and others with the objective of making definite revisions of the present water quality standards.

10. SUMMARY - Infectious hepatitis is a well-known potentially water borne virus disease. Available evidence indicates that poliomyelitis may occasionally be carried by water, although conclusive proof has never been obtained for a water-borne poliomyelitis infection.

The other viruses of the enterovirus group (Coxsackie & ECHO viruses) like poliovirus, can commonly be demonstrated to be present in sewage and thus at least theoretically may be spread to susceptible individuals through sewage contaminated water. The spread of these enterovirus infections by water has never been demonstrated, possibly due to the fact that the etiologic agents have rarely been identified in Coxsackie and ECHO virus epidemics.

Laboratory work with the viruses has shown that in general they can survive for many months when stored in water and are probably more resistant than bacteria to chlorination and other water purification procedures. The validity of the coliform index as a measure of biological pollution of water is consequently under review.

Evidently infectious hepatitis virus and presumably other enteroviruses can travel 200 feet or more through the soil, possibly by some mechanism of channeling. Their small size (about 30 mu) permits viruses to pass through the walls of porous vessels which would act as a filter for larger biological pathogenic agents, such as bacteria. The nature of the interaction of viruses with soil is virtually unknown.

Outbreaks of water borne virus disease are quite rare, but could become more frequent in future years if precautions are not taken. Both poliomyelitis and infectious hepatitis are sufficiently serious diseases that extreme efforts should be made to avoid outbreaks of any sort.

Accordingly, there are many aspects of potential viral contamination which it would be valuable to study in any program which considers the prevention of ground water contamination.

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APPENDIX I

GROUND WATER CONTAMINATION

DEFINITION OF TERMS

December 1959

APPENDIX I

GROUND-WATER CONTAMINATION

DEFINITION OF TERMS

Some confusion has been found in the literature search in the use of the words "contamination" and "pollution". Two illustrative sets of definitions for the two words seem to be worth recording.

I. The American Public Health Association, et al, Glossary: Water and Sewage Control Engineering(1) (1949), gives definitions as follows:

a) "CONTAMINATION - A general term signifying the introduction into water of microorganisms, chemicals, wastes or sewage, which renders the water unfit for its intended use."

b) "POLLUTION - The addition of sewage, industrial wastes, or other harmful or objectionable material to water."

II. Fair and Geyer, Water Supply and Waste-Water Disposal(2) (1954), with the "Glossary..." definitions before them prepared the following definitions:

a) "Contamination of water is the introduction or release into it of potentially pathogenic organisms or of toxic substances that render the water hazardous and, therefore, unfit for human consumption or domestic use."

b) "Pollution of a body of water is the introduction into it of substances of such character and in such quantity that its natural quality is so altered as to impair its usefulness or render it offensive to the senses of sight, taste, or smell. Contamination may accompany pollution."

Both sets of definitions are based on the premise that something is introduced into or added to water. In this report, the word "contamination" is considered to include also the situations where water naturally has in it minerals or organic compounds hazardous to health or offensive to the senses of sight, taste, or smell.

Examples: iron, manganese, nitrates, and fluorides, in concentrations above a maximum permissible.

Accordingly, the definitions of "contamination" proposed for this investigation and report is The American Public Health Association, et al. definition modified as follows:

Ground Water Contamination - A general term signifying the introduction of substances into ground water; or ground water with a natural objectionable content of microorganisms, minerals, chemicals or other substances which renders the water unfit for a domestic water supply.

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(2) Fair, Gordon Maskew and Geyer, John Charles, Water Supply and Waste-Water Disposal, New York, John Wiley & Sons, Inc., (1954), page 2.

APPENDIX J

GROUND WATER CONTAMINATION

REPORT ON PRIORITIES FOR RESEARCH PROJECTS

October 20, 1960

APPENDIX J

GROUND WATER CONTAMINATION

PRIORITIES FOR RESEARCH PROJECTS

INTRODUCTION

Complying with instructions, a review has been made of the library information and tentative priorities proposed for the several general groups of research activities suggested to develop additional information needed to set-up water quality criteria and procedures for controlling potential ground water contamination in the development of residential projects.

A number of factors will control the priorities to be assigned to the several research programs which should be developed to provide the needed information suggested in the reports on the several actual or potential ground water contaminants in order that properly supported water quality criteria and contamination control procedures might be promulgated.

Certain factors, or aspects of the total ground water contamination problems, which may control assignment of priorities include the following,

a - The probable importance of the several contaminants relative to health hazards.

b - The character of the presently available knowledge of contaminants. Some are well known to be dangerous as health hazards.

c - The complexity of initial preparatory research involved. Some important contamination items, such as viral contaminants, may require considerable ancillary research before the major studies relative to ground water contamination can be effectively carried on.

d - Personnel, facilities, and funds available to develop various research programs.

It may be desirable to initiate some exploratory investigations or experimental work on some of the projects, in advance of the suggested priority location, to take advantage of certain available facilities or to better delineate the scope of the main research program.

PROPOSED PRIORITIES

The following relative priorities are suggested based on published information from library searches. More recent unpublished experience data could readily justify modifications, therefore, the proposed priorities should be reviewed periodically, particularly when the proposed project (Priority 1) of assembling data from the files of various agencies is completed.

The proposed priorities are listed in Table A and briefly explained, as follows;

Priority 1 - Experience Data - An investigation of unpublished experience data, expected to be available in the files of public health and other public agencies. It is expected these exploratory studies would uncover data which would indicate more accurately the relative importance of various ground water contaminants and also develop some experience in the application of control measures.

Priority 2 - Synthetic Detergents - Sewage Chemicals - Investigation of synthetic detergents and sewage chemicals may be important from two angles (a) because contamination by detergents has resulted in objectional water characteristics and (b) the appearance of detergents in ground water indicates sewage is reaching the ground water supply. The topic of sewage chemicals has been included, along with detergents, chiefly because similar chemistry is involved in both cases, and since contamination by detergents quite generally indicates sewage contamination. Biological agents are not included as they require different techniques, altho a determination of coliform organisms might well be included for its value as a long used index of sewage contamination.

Priority 3 - Biological contaminants - Early study has been proposed, for the topic of bacterial contaminants, on the basis that sewage contamination is becoming so extensive it is past time when more complete knowledge should be available on the travel through soil of biological agents and the resulting effect on their capacity for producing diseases. Also these studies should be concurrent with the chemical studies proposed as Priority 2. Viral contaminants are given a later priority primarily because of the lack of any approved practical techniques for study of viruses by sanitarians.

Priority 4 - Chlorides - The spoilage of ground water sources is becoming so extensive that investigation of chlorides should be given high priority, particularly with reference to the permissible maximum chloride concentration and factors which determine it.

Priority 5 - The number of writings on nitrates indicate a substantial problem. Again much of the problem may be related to sewage and insanitary conditions in rural areas. Accordingly, early studies should be undertaken to determine the scope of the problem and the sanitation procedures which may reduce or control the problem.

Priority 6 - Insecticides, Larvacides, Pesticides, Herbicides - The rapid increase in the use of toxic chemicals for the control of insects, larva, pests, and undesirable plants and the considerable numbers of fish kills in recent years attributed to these toxic chemicals seems to warrant early studies of the potential contamination of ground water supplies for residential projects.

Priority 7 - Petroleum Oil Wastes - The extensive pollution of water supplies by petroleum oil operations - both oil production and oil products distribution - together with the increasing need for water conservation warrants early attention to a review of control measures relative to petroleum oil wastes, both in the oil fields and also around the huge numbers of commercial operations involving petroleum oil products.

Priority 8 - Radiological Contaminants - The potentialities of increased use of radioactive materials and problems of waste disposal, together with the need for ground water conservation warrants studies on behalf of the ground water users. The possibilities of using radioactive particles as tracers warrant investigation of the travel of radioactive chemicals through various soils - again from the point of view of the water user. The division of effort between FHA and other governmental agencies interested in disposal of radioactive waste materials will be a continual administrative problem.

Priority 9 - Chemicals included in PHS Drinking Water - Standards, 1946 - These chemical items are given priority above other chemicals because the PHS Standards should be supplemented, as promptly as feasible, with some authoritative manual to guide the isolated residential ground water users, on the extreme concentrations of chemicals, probably higher than the PHS Drinking Water Standard allowances, beyond which the questionable ground water supply must be abandoned. Chromium or chromates might be a separate study project because of the uncertainty of the relative toxicity of trivalent vs the hexavalent forms. The trivalent form is not included in the PHS Standards.

Priority 10 - Viral Contaminants - The increasing contamination of ground waters by sewage and potential viral contamination justify some exploratory investigations of viral contaminants even before standard methods are available for identifying viral contaminants. This would acquaint the ground water users with the possibilities of viral contaminants and also should encourage biological and medical agencies in the development of bio-assay procedures which might be applicable to viruses in ground water, by sanitary research personnel.

Priority 11 - Potential Inorganic Contaminants - These potential chemical contaminants include many compounds proven to be toxic to fishes. Some of them, such as barium and cadium, have been proposed for inclusion in a revision of the PHS Drinking Water Standards.

Priority 12 - Metal Finishing Wastes - The dispersal of metal fabricating industries into rural areas are likely to develop problems of contamination of ground waters due to sub-surface disposal or lagooning of waste waters from the treatment of metals.

Priority 13 - Animal and Vegetable Process Wastes - Many of the industrial plants producing those wastes are in rural areas and the disposal of waste waters is becoming a problem. As population densities increase, the potential contamination of ground waters may become acute. An important aspect should be the determination of the concentration of the wastes or the effluent from liquid waste treatment plants which may safely percolate into ground water.

Priority 14 - Gas Plant Wastes - These include some serious items, such as cyanides, but the numbers of plants likely to be located in rural areas may be small.

Priority 15 - Coal Tar Products - The group of chemicals from coal tar waste waters have caused considerable trouble, but only in a few areas. Some chemicals such as phenol may be more troublesome items.

Priority 16 - Dye Wastes - Many stream pollution problems arise from dye waste disposal. However, the instances of disposal of dye wastes into underground waters have been few.

Priority 17 - Explosive - Waste waters from explosive plants have been discharged into streams and in some cases into lagoons or underground leaching lines. However, the numbers of plants close to residential areas are few.

Priority 18 - Petrochemical Industries - The development of these industries has been rapid. The magnitude of the probable impact on ground water quality is still uncertain. However, any program of research on ground water contamination must include consideration of the possibilities of waste waters disposal from petro-chemical industries.

Priority 19 - Disinfectants - The potential contamination of ground waters by chemicals used essentially as disinfectants in industries with resulting disposal of liquid wastes, in suburban or rural areas, warrants consideration. Presently the most commonly used disinfectant being chlorine, there appears less urgency to initiate research programs.

Priority 20 - Physical Contaminants - The physical qualities of turbidity, tastes, odor, color, and temperature will be frequently encountered in connection with many ground water contaminants. Also these quality characteristics are well known. Accordingly, study of these items as specific contaminants has been placed last in the priority list.

Obviously, any suggested program of priorities involv judgment factors. Also any listing of priorities should revised in the light of new information and new needs for

These suggested priorities should provide an initial general planning of research programs, with revisions to as new information and facilities may indicate.

Respectfully submitted,

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