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Deployable Waste Management System

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This project identified local environmental regulations for an 1,100-person Bare Base at three potential mission sites, determined the effect of mission type and location on waste quantities and composition, and provided a set of preliminary guidelines for waste control technologies based on the regulations and characterization data. Environmental regulations were determined for plasma-arc vitrification and gasification of wastes. Incineration requirements were also included to provide a basis for comparison. Waste sources included troops, biological/chemical warfare activities, medical services, and aircraft and vehicle operation and maintenance. Environmental standards were obtained for specific countries. Current environmental control requirements are minimal and do not vary significantly from site to site. It is anticipated that the new regulations to be issued in 1999 will be more demanding and will expand the number of species requiring monitoring and control. An 1,100-person Bare Base was estimated to generate more than 196,000 lb/day of solid and liquid wastes and wastewater. The load on a plasma or gasification system would total nearly 16,000 lb and 108 million Btu/day of waste solids, sludges, oils, and fuels.

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ABSTRACT

This project identified local environmental regulations for an 1,100-person Bare Base at three potential mission sites, determined the effect of mission type and location on waste quantities and composition, and provided a set of preliminary guidelines for waste control technologies based on the regulations and characterization data. Environmental regulations/standards were determined for plasma-arc vitrification and gasification of wastes. Incineration requirements were also included to provide a basis for comparison. Waste sources included troops, biological/chemical warfare activities, medical services, and aircraft and vehicle operation and maintenance. Environmental standards were obtained from the Overseas Environmental Baseline Guidance Document (OEBGD) and Final Governing Standards for specific countries. Waste volume and characteristic data were obtained from surveys, literature review, and consultation with Air Force staff. Current environmental control requirements are minimal and do not vary significantly from site to site. A revised OEBGD is expected in 1999, and it is anticipated that the new guidance will be more demanding and will expand the number of species requiring monitoring and control. An 1,100-person Bare Base was estimated to generate more than 196,000 lb/day of solid and liquid wastes and wastewater. The load on a plasma or gasification system would total nearly 16,000 lb and 108 million Btu/day of waste solids, sludges, oils, and fuels.

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PREFACE

This Draft Report presents the results of work done by Battelle in Columbus, Ohio on the "Deployable Waste Management System," Contract No. F08637-95-D6004, Delivery Order 5505, 14 August 1998 through 30 June 1999, Major Paul B. DeVane, Air Force Research Laboratory (AFRL/MLQE) Project Manager, Tyndall AFB, Florida and Jill A. Ritter, AFRL/HERS Project Coordinator, Wright Patterson AFB, Ohio.

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This report covers the period of performance from September 1998 to February 1999, focusing on the overseas environmental regulations pertinent to Bare Bases deployments and the characterization of wastes generated at Bare Bases. We would like to express our appreciation to the following:

Site	Organization	Contributors
Eglin AFB	AAC/WMO	Byron (Chip) Wolf (current Bare Base waste control technology)
	Sverdrup Technologies, Inc.	Scott A. Matheson (plasma technologies) James Andel (medical wastes)
	Eco Waste Solutions	Bob Vandenburg (incineration)
Shaw AFB	CENTAF/A1-CEXV	Lt. Eric S. Fajardo (Bare Base waste surveys)
Tyndall AFB	AFCESA/CEXR	MSgt Dan Red Cloud, (Bare Base operational data background)
	Applied Research Associates, Inc.	Mike McDonald Lixion Li (catalytic hydrothermal conversion)
	TRW	Dick Woodworth (Air Force contacts)
Wright-Patterson AFB		Major Lana Harvey (biological/chemical warfare waste information)

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DEPLOYABLE WASTE MANAGEMENT SYSTEM Draft Final Report

1. Summary

The Air Force needs a deployable waste management system, made up of one or more modules, to be used in the field to control the release of Bare Base wastes. In order to minimize waste processing logistics, site cleanup, and force vulnerability, the Air Base Systems Office (WMO*) at Eglin AFB is preparing a solicitation for contractors to build near-term deployable waste management systems. These advanced systems can eliminate the need for landfills to dispose of Bare Base wastes. The Air Force Research Laboratory Logistics Support and Air Base Technology Branch (AFRL/HESR and AFRL/MLQC, respectively) are jointly initiating a project to develop the next generation of integrated deployable waste disposal system(s). The AFRL identified plasma arc vitrification and gasification as attractive mid-term solutions that could meet future environmental requirements while efficiently disposing of the Bare Base wastes. Information on incineration requirements and regulations was included in this report to provide a basis for comparison.

In order to specify plasma or gasification systems, information on environmental regulations in force at potential oversea Bare Base sites was needed. Current overseas environmental regulatory requirements for fixed Air Force Bases are based on US environmental law. The requirements are consistent and do not vary significantly from site to site. The requirements document was last updated in 1992; new guidance is expected in 1999. It is anticipated that the new fixed-base regulations will be much more stringent, significantly lowering emission limits. However, these regulations may not apply to contingency deployments such as Bare Base operations. Air Force policy is to employ practices that minimize impacts to personnel and surrounding resources. In the absences of specific Bare Base environmental requirements, the fixed-base regulations were used as a conservative guide for assessing control requirements.

Waste quantity and composition data were also needed to specify plasma or gasification systems. Air Force, Army, Navy, Environmental Protection Agency (EPA) and industrial data were used to estimate the quantity of wastes that will be generated from personal, biological and chemical warfare, medical, and aircraft and vehicle sources at a Bare Base.

* Note: a list of abbreviations and acronyms are provided on the final page of this document.

The anticipated environmental requirements and waste projections formed the basis for plasma and gasification system guidelines.

1.1 Impact of Location and Environmental Regulations on System Design

Three overseas deployment locations were selected to quantify the impact of location on Bare Base waste-treatment equipment. A combination of three climates, three mission types and three levels of environmental restrictions were desired. It was also decided that the threat from biological and chemical warfare agents should be included. The specifics of the three locations selected are noted in Table 1.

Analysis of fixed-base environmental regulations at these different potential overseas deployment locations indicates that most restrictions are identical to those outlined in the Overseas Environmental Baseline Guidance Document (OEBGD) and therefore are not site specific.

Table 1. Sites Selected for Analysis

Location (Region)	Climate	Mission		Environmental Restrictions	Threat	Non-Military Personnel
		Type	Aircraft			
Kuwait (SW Asia)	Arid	Combat	Fighters	Higher (FGS)	Standard plus BC[b]	No
Spain (Europe)	Temperate	Peace-keeping	Unspecified[a]	Highest (restrictive FGS)	Standard plus BC	Yes
Costa Rica (Central America)	Tropical	Human-itarian	Unspecified	High (OEBGD)	Standard	Yes

(a) Wastes assumed similar to combat mission wastes.
(b) BC: biological and chemical warfare agent threat.
FGS = Final Governing Standard

Current OEBGD fixed-base restrictions for each waste type are summarized below:

- **Solid and medical wastes:** Restrictions vary little from site to site; they are minimal and are limited primarily to particulate emissions to the air from incineration. Temperature and residence time in the incinerator must be sufficient to destroy pathogens and waste ashes must be assessed for hazardousness and handled appropriately. If solid wastes and hazardous solid wastes are processed in the same unit, the more demanding hazardous-waste control and monitoring requirements would also apply.

- **Wastewaters**: The discharge restrictions can vary from site to site. Effluent limitations in Spain and Kuwait are more restrictive than the OEBGD and include heavy metals, sulfur- and fluoride-compounds, and toxic organics.

However, these components should not be generated in any significant amounts at a Bare Base. Therefore, wastewater control systems required at Bare Bases should be similar for all locations.

- **Hazardous wastes**: The hazardous waste control requirements vary little from site to site. In general, it is expected that hazardous wastes will be disposed of off site. Only in rare situations would on-site treatment/disposal be selected.

Thus, location will generally not be a significant factor in the selection of a control technology for destruction of Bare Base wastes. Some nations, like Spain, require more complete control and have expanded monitoring requirements. Currently only landfilling and incineration are allowed for solid, medical, or hazardous waste control. Selection of plasma or gasification technologies for solid, medical, or hazardous waste control is not currently allowed. Modifications to the environmental regulations for each deployment country would be required to use these alternative technologies unless they could be classified as incinerators.

Future changes to the OEBGD, and subsequent changes to the FGS of each deployment country, will require more thorough emissions control at fixed bases.

1.2 Impact of Mission Parameters on Waste Characteristics

The effects of mission parameters on waste characteristics are noted below:

- **Mission:** the type of mission was found to often be a minor factor. However, two assumptions reduced the normal variability associated with different missions. First, it was assumed that the hospital size was fixed at 50 beds and that the hospital was fully occupied. Second, the aircraft and vehicle wastes were assumed to be the same regardless of mission. Exceptions include certain combat operations. During base attack, attention to certain environmental controls might be reduced. Also, munitions packaging material wastes would increase. If biological or chemical warfare agents were encountered, it is anticipated that decontamination of aircraft, vehicles and patients could significantly increase solid and liquid wastes.

- **Location:** the main effect of location resulted from differences in climates. The effect was relatively minor; it resulted in higher water use in the arid climates and greater wastewater generation rates.

- **Environmental restrictions:** the different levels of environmental monitoring and control requirements did not affect waste quantities or composition.

- **Biological and chemical warfare threat:** BC wastes were found to be a minor factor. Normally, protective clothing would be donned only once per month. If actual attacks were made, the amount of hazardous BC wastes would increase dramatically. The waste factor under attack mode, 21 lb/person-day, is over 40 times the normal BC waste rate. In this mode, BC wastes would represent the most significant solid waste generation source.

- **Support for non-military personnel:** calculations assumed there were no refugees or disaster victims being supported by peacekeeping or humanitarian missions. It can be expected that personal-waste quantities would increase in direct proportion to increases in the number staff plus refugees or victims.

1.3 Waste Totals

Analysis indicates that personal and medical wastes account for nearly all the wastes. A breakdown of the wastes by type and sources, assuming no BC attack and no aircraft or vehicle decontamination, is noted in Table 2.

Table 2. Distribution of Wastes from a 1,100-Man Bare Base

Waste Source	Fraction of Total, %	Fraction of Solid Wastes, %	Fraction of Wastewater, %	Fraction of Hazardous Wastes, %
Personal	71.4	79.1	70.8	1.0
BC	0.3	4.0	0	49.2
Medical	28.1	16.9	29.2	12.9
Aircraft and vehicles	0.2	0	0	36.9
Total, %	100	100	100	100
Total weight, lb/day	196,062	13,900	180,600	1,162

The quantity and composition of the wastes that could be disposed by thermal destruction are noted in Table 3 below.

1.4 Guidelines for Waste Control Technologies

Guidelines for plasma arc vitrification, catalytic hydrothermal conversion (gasification), and incineration were developed based on the above information. The guidelines included current and anticipated emission limitations along with a summary of the quantity and character of the wastes to be controlled

Table 3. Quantity and Composition of Waste that could be Controlled by Thermal Destruction

Breakdown	Quantity, lb/day	Weight Fraction, %
Personal Solid, Biological/Chemical Warfare, and Medical Wastes		
Food wastes	3,510	22.3
Other	1,570	10.0
Wood	990	6.3
Plastics	1,300	8.3
Metals	1,620	10.3
Glass	0	0.0
Paper and paperboard	4,930	31.4
Subtotal	*13,920*	*88.6*
Heating value, Btu/lb	*6,800*	
Sludge Wastes		
Blackwater	1,280	8.2
Gray water	50	0.3
Antifreeze	100	0.6
Subtotal	*1,430*	*9.1*
Heating value, Btu/lb	*5,000*	
Inorganic Wastes		
Personal and office, Ni-Cd batteries	0 [a]	0
Aircraft, vehicle, and aerospace ground equipment oil filters	1	0
Vehicle lead-acid batteries	0 [a]	0
Other solids	3	0
Paint wastes	67	0.4
Polychlorinated biphenyl wastes	0	0
Subtotal	*71*	*0.5*
Heating value, Btu/lb	*0*	
Waste Fuels and Oils		
Waste fuels	74	0.5
Waste oils	168	1.1
Other liquids	47	0.3
Subtotal	*289*	*1.8*
Heating value, Btu/lb	*18,000*	
Total	***15,710***	***100.0***
Total heating value, Btu/lb	***6,850***	

(a) 29 lb/day of batteries segregated and removed prior to processing.

Note: this and other tables will be adjusted so the entire table fits on one page.

Deployable Waste Management System

2. Introduction

2.1 Objective

The project objectives were as follows:

- Identify local environmental regulations in force at potential mission sites
- Determine the effect of mission type and location on waste quantities and composition
- Provide a set of preliminary guidelines for waste control technologies based on the environmental regulations and waste characterization data.

2.2 Background

A growing dependence has been placed on rapid deployment of Bare Base capabilities to protect vital US. interests abroad in light of overseas base closures and increasing destabilization among developing countries. The Bare Base kits provide all essential services and utilities needed by the complement of personnel that will inhabit these deployable bases. Expanded use of military resources for humanitarian missions has further prompted the need for a multi-role support infrastructure to sustain forward-deployed forces. The Bare Base must be a good neighbor to the local community and control not only the local resources it utilizes (water, land area, etc.), but also the wastes it produces so that the local environment is not compromised. Yet, of all the innovative technologies emerging within the Bare Base environment, waste processing remains the least developed. Current waste solutions are largely customized on site, requiring significant logistics support and heavy equipment. Waste control has become critically important, especially within the broadening scope of humanitarian aid where mass population densities and subsequent waste volumes outpace the assimilative ability of either the host nation infrastructure or the surrounding environment. As a result, wastes generated at Bare Bases under such stressed conditions could pose a significant health risk and airlift burden.

Air Force deployments generate large quantities of solid, liquid, and medical wastes and limited, but significant quantities, of hazardous wastes. There is no packaged waste processing kit for handling these wastes; control systems are custom-constructed on site. These facilities require thousands of man-hours to build and operate, as well as a significant quantity of heavy equipment. Solid wastes are typically landfilled, potentially leading to pungent odors and breeding of disease vectors. Landfilling, without proper removal of hazardous materials, can require expensive remediation upon completion of the mission. Wastewater and biological wastes are typically placed into stabilization ponds for evaporation and infiltration. This primary treatment, which is often limited by climate, presents disposal limitations and has the potential for significant health hazards. Environmental concerns also exist in relation to waste treatment/disposal in host nations. Host nation dependence can lead to environmental problems, with resultant political difficulties, as well as loss of control, independence, and flexibility. Movement of waste containers on and off the base for host nation collection and treatment also presents a vector for the introduction of conventional, chemical, and biological weapons and a subsequent force protection liability.

The Air Force, therefore, needs a deployable waste management system, made up of one or more modules, to be used in the field to control the release of Bare Base wastes. In order to minimize waste processing logistics, site cleanup, and force vulnerability, the AFRL/HESR and AFRL/MLQC are jointly initiating a project to develop the next generation of integrated deployable waste disposal system(s). The system should satisfy the following goals:

- Minimize initial deployment size and weight.
- Process wastes to produce an effluent that can be safely disposed of at the site.
- Render medical and hazardous wastes inert at the site.
- Produce a minimum amount of waste materials that must be removed for processing at stationary facilities.
- Obtain useful energy resources from the waste decomposition process.

Baseline information on waste types, characteristics, and quantities that could be generated during a Bare Base deployment have been developed.[1, 2, 3] The typical 1,100-man Bare Base kit includes facilities and support for combat mission, including 18 tactical aircraft.[4] An air transportable hospital, ranging from 10 to 250 beds, can be included based on needs of the mission. For this assessment, it has been assumed that a 50-bed air transportable hospital is included. These facilities produce a range of wastes, which is the function of the deployable waste management system to control.

3. Methods, Assumptions, and Procedures

The project had three tasks:

- Task 1: Assess Impact of Environmental Regulations
- Task 2: Characterize Waste Streams
- Task 3: Generate Guidelines for Waste Control Technologies.

The methods, assumptions, and procedures for each task are noted below.

3.1 Approach for Task 1: Assess Impact of Environmental Regulations

For actions overseas, the Department of Defense (DoD) and the Air Force must comply with pertinent environmental laws and standards. The OEBGD was developed for fixed bases located overseas. The OEBGD requirements may not apply to Bare Base operations, especially for contingency operations under hostile conditions. Specific operational orders outline environmental policy and guidelines for each contingency operation. In the absence of generic Bare Base environmental requirements, the fixed-base regulations were used as a conservative guide for assessing environmental control requirements.

Those OEBGD regulations that could impact the design of a deployable waste management system were identified and reviewed. Locations providing a range of environmental regulations and climatic conditions were reviewed. In a joint meeting with AFRL HESR and MLQC representatives and Battelle, three were selected for further analysis. Each location was examined and the findings were used to determine the impact of location and local regulations on system design.

3.2 Approach for Task 2: Characterize Waste Streams

Battelle examined a wide range of references to estimate the rates and composition of wastes generated in combat, peacekeeping, and humanitarian missions. Four waste-generating sources were examined:

- Personal wastes (solid waste, blackwater, gray water, and hazardous): a function of the Bare Base personnel size and BC threat.

- BC warfare wastes (solid and hazardous wastes): a function of the BC threat.

- Medical wastes (hazardous solid waste (including biohazard wastes such as blood and body fluids), solid waste, and gray water): a function of the number of beds, number of hospital staff, the type of hospital at the base, and the BC threat.

- Aircraft and vehicle (solid wastes, liquid oil and fuel wastes, and hazardous wastes): a function of the number and type of aircraft and vehicles, the number of sorties executed daily, the maintenance functions conducted at the Bare Base, and the BC threat.

The wastes were combined and grouped into one of the following four categories:

- Organic solid wastes
- Inorganic solid wastes
- Wastewater sludge
- Waste oils and fuels.

The data were analyzed to determine the effect of mission type and location on the waste quantities and composition of these four waste categories.

3.3 Approach for Task 3: Generate Guidelines for Waste Control Technologies

Guidelines for three waste control technologies were generated based on the data gathered in Tasks 1 and 2. The technologies selected and waste streams of interest included are noted Table 4 below.

Table 4. Selected Technologies and Waste Streams

Technology	Waste Steams
Plasma-arc vitrification	Hazardous, solid, medical, fuel, and oil
Catalytic hydrothermal conversion (gasification)	Solid, medical, fuel, and oil
Incineration	Solid, medical, fuel, and oil

The guidelines included waste quantities, waste characteristics, and location-specific and technology-specific environmental regulations.

4. Results and Discussion

4.1 Impact of Environmental Regulations

4.1.1 Introduction

The Air Force has established an environmental guidance document for contingency operations.[5] For this project, the scope was limited to contingency operations conducted overseas. Such operations fall into two categories:

- **Deployments to overseas DoD installations**: These include exercises, relocation, and other activities involving the movement of US troops and equipment to a DoD installation in a foreign country or from the US or another foreign country to a country where the US maintains a DoD installation. Troops must comply with environmental requirements outlined in the specific deployment operating plan (OPLAN) and may be required to comply with host nation requirements.

- **Deployment to non-DoD installations**: These include deployments to foreign countries where there is no DoD installation, for routine training exercise, military operations other than war or to engage in combat operations.

The deploying forces are required to prepare and comply with the Environmental Plan, referenced in Air Force publications.[6, 7] This plan must be included as an appendix to the exercise- or contingency-specific OPLAN. The Environmental Plan specifies policies and responsibilities to protect and preserve the environment, including the following:

- Solid and liquid waste management
- Open dumping
- Open burning
- Disposal of gray water
- Disposal of pesticides
- Disposal of human wastes
- Disposal of hazardous wastes
- Hazardous material management
- Certification of local water sources by appropriate medical field units
- Flora and fauna protection
- Archeological and historical preservation
- Spill response.

Achieving and maintaining environmental excellence are important parts of the Air Force mission. Air Force adherence to the laws, regulations, and executive orders that apply to current operations is fundamental to attaining environmental excellence. For actions overseas, DoD and Air Force compliance with environmental laws and standards are set forth in one or more of the following documents:

- Final Governing Standards (FGS) [where there is a DoD base in the host nation]
- Overseas Environmental Baseline Guidance Document (OEBGD) (all other countries)
- Status of Force Agreements (SFA) (covering special treaties and international agreements between the US and a host nation).

To help DoD fully integrate environmental compliance into defense policy, the OEBGD was created. The OEBGD prescribes implementation procedures, criteria, and standards for environmental compliance. It is based on US environmental law and requires fixed overseas bases to comply with US environmental protection requirements in force at the time of the OEBGD release. The current OEBGD was issued in 1992. Some of the requirements fall below current environmental requirements. An updated OEBGD is under review and may be issued in 1999. The OEBGD applies to DoD installations outside the US, but does not directly apply to aircraft or deployments. However, Air Force environmental policy dictates those contingency operations or deployments be planned and conducted with appropriate consideration of their effects on human health and the environment.

The FGS defines environmental compliance requirements in overseas locations where there is a DoD base. The FGS are published for each host nation, and are modeled after the OEBGD. They include technical limitation on effluent discharges, or a specific management practice with which installations and deployments must comply unless a waiver has been approved. Our regulatory review focused on those regulations that might impact the design of the deployable waste system. Primary areas of interest included air emission standards, solid- and medical-wastes, wastewaters, and hazardous waste discharge. Additional environmental compliance consideration may be contained in the country-to-country agreements, treaties, or specific agreements relating to the contingency operations at hand. In the absence of generic Bare Base environmental regulations, Battelle used the OEBGD, or the FGS in nations with DoD bases, to establish a conservative basis for assessing the impact of environmental guidelines on deployable waste control requirements.

4.1.2 Location Selection

The Air Force pamphlet describing Bare Base operations[4] indicated there should be noticeable differences in waste generation rates at different climates, primarily due to different water usage rates. Review of environmental regulations including the October 1992 OEBGD[8] (the most recent version available), and the most recent FGS for Spain[9], Kuwait[10], Germany[11], Greece[12], and Italy[13], indicate there was also a range of environmental requirements for different locations. Less was known about the impact of mission type, but it was expected that this could also affect waste rates and composition. Therefore, overseas deployment locations were selected to quantify their impact on Bare Base waste-treatment equipment. A combination of three climates, three mission types, and three levels of environmental restrictions was desired. It was also decided that the threat from biological and chemical warfare agents should be included. Peacekeeping and humanitarian missions could also expect to service non-military personnel (e.g., refugees or disaster victims). The three locations selected are noted in Table 5.

Table 5. Three Sites Selected for Analysis

Location (Region)	Climate	Mission		Environmental Restrictions	Threat	Non-Military Personnel
		Type	Aircraft			
Kuwait (SW Asia)	Arid	Combat	Fighters	Higher (Standard FGS)	Standard plus BC[(a)]	No
Spain (Europe)	Temperate	Peace-keeping	Unspecified[(b)]	Highest (Extra restrictive FGS)	Standard plus BC	Yes
Costa Rica (Central America)	Tropical	Human-itarian	Unspecified[(b)]	High (OEBGD)	Standard	Yes

(a) BC: biological and chemical warfare.
(b) Wastes assumed similar to combat-mission wastes.

In all cases the following were assumed:

- A runway and a water source are available.
- No host nation support is available.
- Staffing consists of an 1,100-man Harvest Falcon contingent.
- The site supports a 50-bed, air-transportable hospital.

4.1.3 Assess Impact of Deployment Location and Local Environmental Regulations on System Design

Three environmental restriction levels were selected. The OEBGD was used for the baseline "high" level, a standard FGS for a "higher" level, and an extra-restrictive FGS for the "highest" level. It was found that the OEBGD and the FGS were organized by the same categories, and were frequently similar if not identical. The most pertinent sections for the deployable waste system were for the control of air emissions, solid wastes, medical wastes, wastewater, and hazardous wastes. (Note: there was no section on BC wastes.) Each major area is discussed below.

4.1.3.1 Air Emissions. The first sections of both the OEBGD and FGS contain criteria for air emissions and performance standards applied to DoD-owned equipment. The performance standards covered fossil-fuel-fired steam generators, hot-water generating plants, electric utility steam generators, and incinerators. The regulations for incinerators are the only area pertinent to the Bare Base waste-management system. A detailed comparison is provided in Table A-1 in Appendix A. Requirements for Spain are the most stringent; Spanish-specific details are summarized in Table A-2. A comparison of incinerator regulations is provided in Table 6.

Table 6. Comparison of Incinerator Requirements

Environmental Restrictions	Location	Requirement for Incinerators
High (OEBGD)	Costa Rica	Particulate emissions restricted to less than 0.08 grains/dry standard cubic foot for incinerators burning more than 50 tons/day
Higher (Kuwait FGS)	Kuwait	Same
Highest (Spain FGS)	Spain	Restriction based on incinerator capacity. Limits placed on opacity (i.e., particulate matter), SOx, heavy metals, hydrochloric acid, hydrofluoric acid, total organic substances, and carbon monoxide emissions. Requirements also placed on minimum operating temperature (850 C) and a hazardous-organics destruction efficiency (99.99 percent)

The OEBGD and the FGS for most countries, including Kuwait, Greece, and Italy, present only a particulate limit. The Spanish FGS is much more demanding. It requires additional monitoring, plus, most significantly, the emission limits are extended to include sulfur dioxides, heavy metals, hydrochloric and hydrofluoric acids, and organic substances. The limits become progressively more restrictive as the hourly capacity of the incinerator increases. The particulate limit for a less-than 1-ton/hr incinerator in Spain is equivalent to the OEBGD limit. The limit for a 1 to 3-ton/hr incinerator is half the OEBGD limit, and the limit for a greater-than 3-ton/hr incinerator is one-eighth the OEBGD limit. A hazardous organics destruction efficiency of 99.99 percent is required.

4.1.3.2 Solid Wastes. Sanitary landfilling and incineration are the standard methods of solid waste disposal. Waste minimization, recycling, and composting are encouraged. The OEBGD and FGS solid waste disposal requirements are similar, see Table A-3 for details. The requirements common to all locations are summarized in Table 7. For landfilling in Spain, the landfill liner permeability must be maintained at ≤ 7 to 10 cm/sec.

While open burning is prohibited, incineration is allowed. The Spanish FGS incineration requirements are a little more demanding than the requirements for Costa Rica or Kuwait, as the temperature and excess oxygen levels in a secondary combustion chamber are also specified.

Composting is encouraged. Specific methods, operating procedures, and monitoring and reporting requirements are outlined. For Costa Rica and Kuwait, special monitoring and reporting requirements only come into effect if greater than 5,000 tons/year of sewage sludge is composted. The FGS for Spain stipulates this restriction if any domestic wastewater treatment sludge is composted.

Table 7. Summary of Solid Waste Disposal Restrictions

Areas	Restrictions
Reduce solid waste generation	Could include recycling, composting, and waste minimization
Landfill Disposal	
MSW	Landfill primary method
Sanitary operation	Daily cover required
Hazardous, infectious, and PCB wastes	Must detect and prevent disposal of hazardous wastes
Yard wastes, construction, and demolition wastes	Try to exclude
Burning	
Open burning	Not allowed
Incineration	Only burning option allowed
Incineration controls follow air emission control section limits	Yes
Composting	
Preferred methods	Windrow and enclosed-vessel
Special record keeping requirements if exceed noted tonnage of domestic waste water sludge	> 5,000 ton/year
Limits on compost used for agricultural applications	7 heavy metals and PCB

MSW= Municipal solid wastes

4.1.3.3 Medical Wastes. Medical wastes are categorized as microbiological, pathological, bulk blood, suction canister, and sharps. The OEBGD and FGS medical waste disposal requirements are similar, see Table A-4 for details. Infection control procedures assume all blood and body fluids to be infectious. The solid components may be steam sterilized and sent to the municipal solid waste landfill. Sharps are collected at the point of use in "sharps containers" and are disposed of with other solid hazardous medical wastes. Liquid wastes can be steam sterilized and landfilled, incinerated, or in some cases sent to the wastewater treatment plant. The requirements are common to all locations, and are summarized in Table 8.

If the wastes are incinerated, the incinerator must follow the basic emission limitations for solid-waste incinerators, maintain temperature and residence time sufficient to destroy pathogens, and the waste ashes must be assessed for hazardousness and handled appropriately.

Table 8. Summary of Medical Waste Disposal Restrictions

Type of Waste	Method of Treatment	Method of Disposal
Microbiological (cultures)	Steam sterilization Chemical disinfection Incineration	Municipal solid waste landfill (MSLF)
Pathological (tissue, organs, or body parts)	Incineration Cremation	As a solid waste in MSLF
Bulk blood (including serum, plasma, and other blood components)	Steam sterilization Incineration (only blood known to be infectious need be treated)	Domestic wastewater treatment plant
Suction canister waste	Not required	Domestic wastewater treatment plant, or incineration
Sharps in sharps containers (needles, syringes)	Not required	MSLF

4.1.3.4 Wastewater. The OEBGD contains criteria for the control and regulation of wastewater discharges into surface waters. It includes both domestic and industrial wastewater discharges. The OEBGD and FGS wastewater discharge requirements are similar, see Table A-5 for details. Assuming no electroplating wastes are generated at the Bare Base facilities, and the wastewater is not ignitable, reactive, toxic, or corrosive, wastewater treatment facilities at all three locations would have to meet the biochemical oxygen demand (BOD), total suspended solids (TSS), chemical oxygen demand (COD), pH, and toxic organic limits summarized in Table 9.

Table 9. Summary of Wastewater Disposal Restrictions

Analysis Period	BOD, mg/L	TSS, mg/L	COD, mg/L	pH	Prohibited Organic Chemicals, mg/L
Instantaneous	40	No instantaneous requirement	No limit [(a)]	6 to 9	0.01
30-day average	30	30	—		
7-day average	45	45			

(a) There is a COD requirement in Spain of 500 mg/L.

Kuwait and Spain add additional discharge criteria that dramatically expand the monitoring requirements, see Table A-6 for Kuwait and Table A-7 for Spain for details. The discharge restrictions include heavy metals, sulfur- and fluoride-compounds, and toxic organics, but they should not be generated in any significant level in a Bare Base unit. Phosphorous and pesticides discharges are possible, and detergents and oil and grease are likely components of raw wastewater. These can be readily controlled, so in reality the total wastewater control requirements for Spain and Kuwait are not significantly different than for Costa Rica.

4.1.3.5 Hazardous Wastes. The section on hazardous wastes covers used oil disposal/utilization, disposal procedures, and incineration of non-PCB contaminated wastes. A summary is provided in Table 10.

Table 10. Summary of Hazardous Waste Disposal Restrictions

Regulation	OEBGD
Used oil	Ok to burn in industrial and utility boilers and space heaters; can not be used for dust suppression
Disposal procedures	
Normal disposal	Handled through DRMS
If can not be disposed of within host nation	Must be retrograded to US or, if permissible, transferred to another country for disposal
Land disposed	Only in lined and ground-water monitored hazardous waste landfill
Incineration	
Regulation	Must be licensed and permitted by host nation
Destruction and removal efficiency of organic wastes	99.99 percent
CO	Minimize emission
Particulates	Minimize emission
HCl	< 1.8 kg (4 lb)/hour
Treatment	If treated and no longer exhibits the characteristics of a hazardous waste, it can be disposed of as a solid waste
Organics treatment	Acceptable treatments include fuel substitution, biodegradation, recovery, and chemical degradation
Heavy metals treatment	Acceptable treatments include stabilization and recovery

DRMS = Defense Reutilization and Marketing Service.

The requirements outlined in the OEBGD and the FGS reviewed are almost identical. In general, it is expected that hazardous wastes will be handled off site. For example, in Kuwait, due to the lack of hazardous waste landfills or incinerators, hazardous wastes can not be disposed of within Kuwait. All hazardous wastes must be packaged, stored, and disposed of off site. Only in rare situations would on-site treatment/disposal be selected. Incineration and land disposal in special landfills are the only options noted for most hazardous wastes. For incineration, organic wastes must achieve 99.99 percent destruction and CO, particulates, and acid emissions must be monitored and controlled. The treatment residues must be assessed and heavy metals stabilized.

4.1.3.6 Conclusions. Analysis of environmental regulations at different potential overseas deployment locations indicates that most restrictions are identical to those outlined in the OEBGD and therefore are not site specific. Thus, location will generally not be a significant factor in the selection of a control technology for destruction of Bare Base wastes. Nations like Spain, that require more complete control and have expanded monitoring requirements, are the exception. Selection of plasma or gasification technologies for solid, medical, or hazardous waste control is not currently allowed. Modifications to the OEBGD and the FGS of each deployment country would be required to use these alternative technologies unless they could be classified as incinerators.

4.2 Waste Stream Characterization

4.2.1 Introduction

The objective of the waste characterization task was to develop quantity and composition estimates to guide the selection of appropriate waste control/treatment technologies. Data sources were identified to differentiate emissions from combat, peacekeeping, and humanitarian deployment scenarios. Wastes from the following sources were studied:

- Personal wastes
- Biological and chemical warfare wastes
- Medical wastes
- Aircraft and vehicle wastes.

The data were analyzed to determine the effect of mission type and location on the waste quantities and composition of these four waste categories. The wastes from the various sources were then combined and grouped into solid, medical, wastewater (gray water and blackwater), and hazardous wastes categories.

4.2.2 Personal Wastes

Wastes generated by troops located at the Bare Base are by far the most significant waste source. Personal wastes are composed of solid wastes, wastewater (blackwater and gray water), and hazardous wastes. (Personal wastes generated from biological or chemical warfare activities are discussed separately below in Section 4.2.3.) The solid and hazardous waste generation rates are a function of the number of Bare Base personnel. Based on discussion with Air Force staff, the lb/person-day waste rate should not be affected by mission type or location. Personal wastewater generation rates, gal/person-day, are also a function of Bare Base size and should be relatively independent of mission type. However, due to differences in water use rates for differing climates, wastewater generation rates should be affected by location. At peacekeeping or humanitarian Bare Bases providing support to refugees or disaster victims, the total personal solid waste totals (lb/day) and wastewater quantities (gal/day) may be much higher due to the greater number of people using base services.

4.2.2.1 Solid Wastes. The quantity of solid wastes depends primarily on the Bare Base staff size. A solid waste factor of 10 lb/person-day was selected based on Bare Base surveys for the Air Force, and in studies conducted by the EPA, Army, and the Navy. Solid waste factors from these sources are summarized in Table 11.

Table 11. A Comparison of Solid Wastes Factors

Information Source	Reference Number	Solid Waste Factor, lb/person-day	Comments
1. AFPAM 10-219	4	4	Based on Vietnam-era waste rates
2. Georgia Tech	1	85	Value based on solid wastes collected from 21 oversea camps
3. Survey	14	28	Based on survey of the Prince Sultan Air Base located in Saudi Arabia, January 1999
4.a EPA	15	4.3	Annual survey of domestic MSW. Excludes oil and grease and underreports food wastes.
4.b		3.3	Corrected for the removal of yard wastes and glass, and inflated to account for underreporting of food wastes
5.a Navy	16	3.19	1997 survey of several ship classes
5.b		3.5	Corrected for underreporting of food wastes
6. Navy	17	1.64	1998 survey of aircraft carrier
7. Army	18	12.5	Staff in combat
	Average rate	10	Average of factors from sources 1, 3, 4.b, 5.b, and 7

The most striking exception to this range was reported in a study conducted by The Georgia Institute of Technology.[1] Actual data from 21 camps were collected during Operation Joint Endeavor. The waste loads were normalized to calculate a waste factor of 3.2 ft^3/person-day. This figure converted to 85 lb/person-day using a bulk density of 26.7 lb/ft^3. This value is over 20 times greater than the 4 lb/person-day Bare Base guide[4] planning factor. It was speculated that construction or demolition activities may have been ongoing and inflated the figure. The figure was not used in estimating the Bare Base solid waste factor. (Georgia Tech adjusted 1995 EPA figures and derived a value of 4.4 lb/person-day, which they used for their planning purposes.)

As part of the current program, a survey was conducted at an active base in SW Asia.[14] The Prince Sultan Airbase in Saudi Arabia had 3,600 staff and represents a true Bare Base. A waste factor of 28 lb/person-day was calculated based on 3-million lb/month and the base population. The rate is also significantly higher than the 4 lb/person-day figure. These and other data indicate the 4 lb/person-day figure may be too low for an overseas field deployment.

The EPA publishes an annual summary of municipal solid waste generation along with composition estimates and tonnages.[15] Their MSW figures include wastes from yard trimming and glass but not food wastes sent to in-home garbage disposals, oil and grease from food service organizations, wastewater treatment sludge, or construction and demolition wastes. Correcting for these components, and assuming construction and demolition wastes are zero, the waste factor is 3.3 lb/person-day.

The Navy has done extensive survey work on solid wastes generated aboard ships. They have found that the lb/person-day rate varies little even with different ship classes. The rate determined in 1997[16] was 3.19 lb/person-day. It was found to be similar to waste rates for shore-based municipalities. Most food wastes are ground up and discharged to the sea so this figure underestimates the proportion of food wastes. The Navy conducted another survey in 1998[17] on aircraft carriers and found a lower rate of 1.64 lb/person-day. However, even in the report containing the 1.64 lb/person-day finding, the 3.19 lb/person-day rate was used for planning purposes. Correcting for underreporting food wastes, the Navy waste factor is 3.5 lb/person-day.

The Army provides a waste factor of 12.5 lb/person-day for in-field combat deployments.[18] This high value is supportive of the higher figures noted in actual Bare Base surveys.

The 10 lb/person-day waste factor was selected for use in this study based on the average of the 4, 28, 3.3, 3.5 and 12.5 factors noted in Table 11 above. Based on 10 lb/person-day, 11,000 lb of solid waste will be generated every day for an 1,100-man Bare Base.

For purposes of the design of a solid waste treatment facility, information is also needed on size, combustible and inert content, plastics level (particularly polyvinyl chloride content), and heating value. The reported EPA and Navy composition data were corrected to reflect Bare Base conditions (e.g., elimination of yard wastes, adjustment for food wastes, etc.) and are shown on Table 12.

The plastics content, estimated at 9 percent of the total, is composed primarily of polyethylene with only a small proportion of polyvinyl chloride.

AFPAM 10-219 estimates that approximately 1 lb of human wastes/person-day is generated from sanitary wastewater treatment equipment. Heating values are low and may be only 1,000 Btu/lb due to the high moisture content.[19]

The waste factors and composition estimates noted and the human-waste sludge factor were used to estimate the personal solid waste rates and composition listed in Table 13. In some cases a Bare Base will support more than just the military contingent. Personal solid waste would rise in proportion to the total number of military and non-military personnel serviced by the base.

Table 12. Comparison of Solid Waste Composition Data

Waste Category	Composition, as-received basis[a] %				
	EPA Reference 15		Navy Reference 16		Composite Value, %
	As Reported	Corrected [a]	As Reported	Corrected [a]	
Yard trimmings	14.3	0	0	0	0
Food wastes	6.7	18	38	35	27
Other	9.1	13	3.7	3	8
Wood	7.1	9	0.3	9	9
Plastics	9.1	12	6.3	6	9
Metals	7.6	10	16.9	15	12
Glass	6.2	0			0
Paper and paperboard	39.2	38	34.8	32	35
Total	100	100	100	100	100
Estimated heating value, Btu/lb as received					6,500[b]

(a) In a Bare Base there would be no yard waste or glass and all food wastes would be sent to treatment (rather than to garbage disposals). Reported values are corrected to account for these differences and then normalized to 100 percent. Typical moisture levels range from 10 to 25 percent.

(b) Heating value was estimated by assuming the waste was typical of "rubbish," which is a mixture of combustible wastes, paper, cardboard cartons, wood scrap, foliage, and floor sweepings from domestic, commercial, and industrial activities. It contains up to 20 wt. percent restaurant or cafeteria wastes. It typically contains 25 percent moisture, 16 percent incombustibles and has a heating value of about 6,500 Btu/lb.[19]

4.2.2.2 Wastewater. The wastewater generated in a Bare Base is a function of the water usage rate, which is a function of the climate, and the level of BC warfare activity. The Bare Base manual, AFPAM 10-219, provides a total water allocation of 20 gal/person-day at locations where mobile water treatment units are necessary, and an allocation of 50 gal/person-day where permanent, in-place water production and treatment facilities are available. Both assume no BC activity or the need to use water for decontamination of vehicles or aircraft. The manual is written for a combat mission located in an arid climate. Limited information for Bare Bases located in other climates is also provided. A breakdown of water consumption and wastewater rates for the arid climate case is noted in Table 14.

Table 13. Personal Solid Waste Generation Rate and Composition (Independent of location, climate, or mission type)

Component	Composition, as-received basis, %	Waste Factor, lb/person-day	Daily Waste Rate for 1,100-man base, lb/day
Food wastes	27	2.7	2,970
Other	8	0.8	880
Wood	9	0.9	990
Plastics	9	0.9	990
Metals	12	1.2	1,320
Glass	0	0	0
Paper and paperboard	35	3.5	3,850
Solid waste excluding sludge	100	10	11,000 @ 6,500 Btu/lb
Human-waste sludge		1	1,100 @ 1,000 Btu/lb
Total with Sludge		11	12,100
Heating value, as-received basis, Btu/day,			6,000

Table 14. AFPAM 10-219 Water Usage and Wastewater Volumes (Arid climate, combat mission)

Purpose	Water Usage, gal/person-day	Wastewater, gal/person-day	Comments
Drinking	4.0	7.7(a)	Combined to form latrine wastes
Personal hygiene	2.7		
Heat treatment	1.0		
Showers	1.3(b)	1.3	100 % of water usage
Food preparation	3.0	2.0	2/3rd of water usage
Laundry	2.0	2.0	100 % of water usage
Hospital	1.0	1.0	100 % of water usage
Vehicles	0.3	0	Assumed to evaporate
Construction	1.0	0	Assumed to evaporate
Graves registration	0.2	0	Assumed to evaporate
Aircraft cleaning	2.0	0	Assumed to evaporate
Loss factor	1.5	0	Assumed to evaporate
Total	20.0	14.0	--

(a) Blackwater.

(b) Based on two 1.5 gal/min, 3 minute showers each week

The total wastewater volume given in Table 14 is 14 gal/person-day, and represents 70 percent of the water used. This figure is consistent with published data. In the US, typically 60 to 85 percent of per capita water consumption becomes wastewater (the lower percentages are applicable to the semi-arid region of the southwestern US).[20]

The 7.7 gal/person-day figure from Table 14 is categorized as blackwater and represents 55 percent of the wastewater. Blackwater comes from processing human wastes. The balance, 6.3 gal/person-day, is gray water. Gray water represents wastewater from shower, food preparation, and laundry operation. These figure are also supported by data gathered in Operation Joint Endeavor where water usage data from seven camps were obtained over a six-week period.[1] It was estimated that blackwater totaled 5.5 gal/person-day (2.5 gal liquid and 3.0 gal concentrated solids), and gray water totaled 9.5 gal/person-day. Estimates of wastewater generation for different climates are taken from AFPAM 10-219 and are provided in Table 15.

Table 15. AFPAM 10-219 Water Usage and Wastewater Generation as a Function of Climate

Climate	Water Usage, gal/person-day	Wastewater, gal/person-day
Arid	20[a]	14
Temperate	50[b]	35[d]
Tropical	50[b]	35[d]
Frigid	50[c]	35[d]

(a) The 20 gal/person-day rate for arid climates assumes that water is recovered from a river, lake, or well using a reverse-osmosis water purification unit. If a permanent water treatment plant is available, a 50 gal/person-day factor is recommended.

(b) No information on the basis for the 50 gal/person-day was provided. It could mean that a permanent water treatment plan was assumed to be available. Attempts to clarify this point were unsuccessful.

(c) Water usage rate assumed.

(d) Wastewater was estimated based on 70 percent of the water consumption.

The basis for the 50 gal/person-day water consumption level for non-arid climates, as given in Table 15, is not clear. The assumption will strongly affect the calculated gray water rates for the Spanish (temperate) and Costa Rican (tropical) sites selected for this examination.

Other water usage figures were sought to clarify this point. Mike McDonald from Tyndall AFB visited the Ali Al Salem Air Base in Kuwait in November 1998. This 900-man Bare Base had unrestricted water use and all wastewater was sent off base to a permanent wastewater treatment plant. The water supply officer reported than water use was about 50 gal/person-day. The System Requirements Document (SRD) prepared by the WMO[21] for a near-term technology deployable waste management system assumes total water usage is 50 gal/person-day and the wastewater rate is 34 gal/person-day. This high water-use-rate level mirrors the use rate in current Bare Base deployments where water use is unrestricted and the water supply and the wastewater treatment is provided by the host nation. The 34-gal wastewater/person-day requirement also provides a demanding wastewater treatment requirement, so this also represents a conservative design case. The lower 20-gal water/person day rate was selected for this report due to the fundamental assumption that no host nation support will be available.

The literature reports that for a "pioneer-type" recreational camp (basic 24-hours/day camp) water usage was about 25 gal/person-day.[20] It would be expected that at a Bare Base with no host nation support, water use would be similar to this 25-gal/person-day level.

The Army has provided water consumption data for field troops as listed in Table 16. They are taken from Appendix B of Field Manual 10-52, where water consumption rates are provided for different climates and for different size deployments.

Table 16. Army FM 10-52 Water Usage as a Function of Climate and Deployment Size [22]

Climate	Water Consumption, gal/person-day[(a)] Deployment Size: Company (150 – 200)	Battalion (500 – 800)	Brigade (1,200 – 3,500)	Corps and Echelon Above Corps[(b)] (> 3,500)
Arid	5.9	8.7	11.9	18.4
Temperate	3.9	6.6	7.0	7.8
Tropical	5.7	8.5	8.9	9.9
Frigid	4.4	7.2	7.6	8.4

(a) Does not include water use for showers, laundry, vehicles, construction, grave registration, and aircraft cleaning.

(b) Includes large quantity of hospital wastewaters.

The brigade deployment appears the closest in size to the 1,100-man Bare Base. The Army water consumption rates for all other climates are less than for the arid climate and dramatically less than the 50 gal/person-day level included in AFPAM 10-219 for non-arid climates.

A comparison of water consumption estimates in AFPAM 10-219 for arid climates to those in FM 10-52 is noted below. In many areas the figures are similar. To provide a better estimate of water usage under a common basis, the Army factors were adjusted to include showers, laundry, vehicles, construction, graves registration, and aircraft cleaning, see Table 17.

The adjusted values noted above were used for wastewater calculations for tropical and temperate climates, see Table 18.

The composition of the blackwater is important to the design of a proper wastewater treatment plant. The Manual of Grey Water Treatment Practice[23] states that toilet wastes contribute about half of total wastewater flow, 90 percent of nitrogen, 60 percent of COD, and 50 percent of phosphates. The per capita composition of blackwater was also reported, and is noted in Table 19a and b.

Table 17. Adjusted Water and Wastewater Estimates by Climate

Purpose	Water Consumption, gal/person-day				
	AFPAM 10-219, Arid	Army FM 10-52, Brigade Level, by Climate			
		Arid	Temperate	Tropical	Frigid
Drinking	4.0	3.0	1.5	3.0	2.0
Person hygiene	2.7	1.7	1.7	1.7	1.7
Heat treatment	1.0	0.2		0.2	
Showers/centralized hygiene	1.3	1.8			
Food preparation	3.0	2.8	2.8	2.8	2.8
Laundry	2.0	0			
Hospital/medical	1.0	0.4	0.4	0.4	0.4
Vehicles	0.3	0.2			
Construction	1.0	0			
Graves registration	0.2	0			
Aircraft cleaning	2.0	0			
Subtotal	18.5	10.1	6.4	8.1	6.9
Loss factor	1.5	1.0	0.6	0.8	0.7
Total	20.0	11.1	7.0	8.9	7.6
	Adjusted[a]	**20.0**	**16.7**	**19.1**	**17.5**

(a) Adjusted to maintain the same proportions of drinking water, hygiene, etc, and to include showers, laundry, vehicles, construction, graves registration, and aircraft cleaning.

Table 18. Water and Wastewater Quantities for the Three Selected Locations

Value	Water and Wastewater, gal/person-day[a] by Location and Climate		
	Costa Rica Tropical	Kuwait Arid	Spain Temperate
Water consumption	19.1	20.0	16.7
Wastewater[b]	13.4	14.0	11.7
Blackwater[c]	7.4	7.7	6.4
Gray water[d]	6.0	6.3	5.3

(a) Multiply gal/person-day by 8.3 to get lb/person-day.
(b) Wastewater is 70 percent of total water consumption.
(c) Blackwater set at 55 percent of wastewater generation.
(d) Determined by difference.

Table 19a. Personal Blackwater Rate
(Independent of mission type but dependent on location and climate)

Location and Climate	Blackwater Generation Rate, gal/person-day (lb/person-day)	Unit	Daily Waste Rate, gal total/day (lb/day)
Costa Rica, tropical	7.4 (61)	1,100 staff	8,100 (67,600)
Kuwait, arid	7.7 (64)	1,100 staff	8,500 (70,300)
Spain, temperate	6.4 (53)	1,100 staff	7,000 (58,400)

Table 19b. Personal Blackwater Composition

Composition	Waste Loading lb/person-day	Location and Blackwater Concentration, mg/L		
		Costa Rica Tropical	Kuwait Arid	Spain Temperate
COD	0.11[(a)]	1,800	1,700	2,100
BOD	0.11[(b)]	1,800	1,700	2,100
Suspended solids	0.20[(b)]	3,250	3,100	3,800
Total solids (suspended and dissolved	0.24[(b)]	3,900	3,700	4,500
Total Kjeldahl nitrogen	0.032[(a)]	500	500	600
Ammonia nitrogen	0.007[(a)]	110	110	130
Phosphate	0.008[(a)]	130	120	150

(a) Reference 23. (b) Reference 20.

The composition of the gray water is also important to the design of a proper wastewater treatment plant. Correcting for the reduced dilution found in the Bare Base, the literature values for gray water composition were converted into per capita values. The personal gray water estimates are provided in Table 20a and b.

Table 20a. Personal Gray Waste Rate
(Independent of mission type but dependent on location and climate)

Location and Climate	Gray Water Generation Rate, gal/person-day (lb/person-day) [(a)]	Unit	Daily Waste Rate, gal total/day (lb/day)
Costa Rica, tropical	5.1 (42)	1,100 staff	5,600 (46,600)
Kuwait, arid	6.3 (52)	1,100 staff	6,900 (57,500)
Spain, temperate	4.5 (37)	1,100 staff	5,000 (41,100)

(a) Multiply gal/person-day by 8.3 to get lb/person-day.

Table 20b. Personal Gray Water Composition

Composition	Waste Loading, (a) lb/person-day	Location and Gray Water Concentration, mg/L		
		Costa Rica Tropical	Kuwait Arid	Spain Temperate
COD	0.065	1,500	1,200	1,700
BOD	0.065	1,500	1,200	1,700
pH	7	7	7	7
Total solids (suspended and dissolved)	0.053	1,200	1,000	1,400
Suspended solids	0.008	200	200	200
Nitrates	0.0002	5	5	5
Phosphates	0.008	200	200	200
Chlorides	0.00	100	100	100
Sulfates	0.019	400	400	500

(a) Gray water concentrations in Reference 23 adjusted to calculate waste loading factors assuming that gray water contributes 50 percent of the phosphates and 40 percent of the COD to the wastewater. The factors were then applied to the three sites.

The estimated sludge produced from blackwater and gray water from the base personnel is noted in Table 21. The projected sludge weight, 1,144 lb/day corresponds well to the 1,100 lb/day estimated based on the 1.0 lb/person-day waste factor included in AFPAM 10-219.

4.2.2.3 Hazardous Wastes. Information on personal hazardous waste generation is limited. Surveys of air bases indicated total hazardous wastes generated, but could not attribute them to personal use. EPA[24] has presented some information on household hazardous wastes. Examination of the wastes attributed to household generation indicates that the only category obviously associated with a Bare Base application is battery wastes. Batteries were found to constitute 0.1 percent of the total waste stream. This factor was used to estimate per person hazardous waste generation; see Table 22. For comparison purposes, about 8 lb of battery wastes would be generated each day if each staff member used two pair of AA size batteries each month.

Table 21. Sludge from Personal Wastewater Treatment

Sludge Source	Organic Constituents	Wastewater Generation Rate, lb/day	Suspended Solids, lb/day	Sludge (Suspended Solids) Weight, lb/day [(a)]	Weight Fraction, %
Blackwater	Urine, feces, wipes, food particles, cell bio-mass, hygiene products, cleaning solutions, scale prevention chemicals	58,000 to 70,000	220	1,100	96
Gray water	Hair, lint, dirt, detergents, soaps, toothpaste, food particles, disinfectants, and bio-cells	41,000 to 58,000	9	44	4
		Total	229	1,144	100
			Heating value, Btu/lb	5,000	

(a) The sludge from the blackwater and the gray water corresponds to the suspended solids from both sources, and then corrected to the equivalent of a 20 percent solids level.

Table 22. Personal Hazardous Waste Rate and Composition [24]
(Independent of location, climate, or mission type)

Hazardous Waste Generation Rate	Unit	Waste Rate, lb/day
0.1 % of solid wastes, or 0.01 lb batteries/person day	1,100 staff	11

4.2.3 Biological and Chemical Warfare Wastes.

Uncontaminated biological and chemical (BC) warfare personal protection equipment would be handled as solid wastes. The wastage rate will depend on exposure to mission type and to a small degree on climate. The standard procedures for airmen in a high-threat BC area would be to don protective clothing as the threat dictates (e.g., when the enemy prepares for BC agent use). Once protective clothing is donned the Air Force assumes it can be worn indefinitely until the "protectiveness" is compromised; this may be because of a liquid chemical agent, biological agent, rips, oil/grease, etc. The Air Force doctrine is for the individual to get out of the protective clothing within 24 hours of those events. The clothing in question would be hood, gloves (inner and outer), boot covers, jacket, and pants. An individual whose clothing never becomes compromised would wear it for its operational life. The operational life of the battle dress overgarment (BDO) is 22 days. The green vinyl overboot (GVO) and black vinyl overboot (BVO) have 14 day service lives.[24]

Once it has been determined that a BC attack is possible, the commander would increase or decrease the Mission Oriented Protective Posture level based upon the immediate threat. An airman would, at least, be able to remove the clothing when he/she is off duty, assuming that the rest location is free from contamination and the immediate threat.[26]

4.2.3.1 Quantity. Each Bare Base service man is supplied with a C-bag. It contains two complete ground crew ensembles (BDO, consisting of jacket, pants, gloves, glove inserts, and overboots), M8/M9 detection paper, decontamination kits, canteen cap (has adapter to allow person to drink through the mask), gas mask and activated carbon gas-mask canisters. Two additional ensembles will be shipped to the deployment location.[27] The weight of a C-bag is approximately 30 lb (without the gas mask and cartridges). Cartridge weight is 0.6 lb, and each BDO weighs approximately 10 lbs. The ground crew ensemble is to be replaced after 22 days wear time, or no later than 24 hours after being contaminated with chemical agent. Wear time starts once the suit is removed from its bag and donned. The overboots are to be replaced after 14 days of wear or no later than 12 hours after contamination. Other considerations in the BC arena that could increase the per person average would be the decontamination media used in the contamination control areas. The use of decontamination kits and sorbents is standard for this procedure.

The weights of BC wastes were estimated for three scenarios, intense BC threat, minor BC threat (for Kuwait and Spain), and no BC threat (Costa Rica), see Table 23. Under intense attack, the BC waste rate could total over 20 lb/person-day. This is similar to previous estimates of 25 lb/person-day that have been made for BC wastes.[1] Under less severe conditions, but where the chance of exposure is sufficiently large to require service men to don protective equipment, the minimum waste rate would be about 0.5 lb/person-day. When the clothing has been exposed to actual agent, the clothing is treated as hazardous wastes. The Air Force does not have separate guidance for uncontaminated clothing disposal after the service life, so even uncontaminated clothing may have to be disposed of as hazardous solid wastes.

4.2.3.2 Composition. The BDO is made of nylon, cotton, and impregnated charcoal (contained between the layers). The GVO/BVO, hood, and outer gloves are butyl rubber. The inner gloves are made of cotton. T.O. 14P3-1-141 gives a description of the items except for the hood, which is in T.O. 14P4-15-1. No accurate breakdown of the BDO is available, but a rough estimate of the distribution by component is noted in Table 24.

Table 23. Estimated BC Waste Factors by Threat

Items and Weight, lb	BC Waste Factor, lb/person-day (at noted replacement frequency) Intense BC Threat	Minor BC Threat (Spain and Kuwait)	No BC Threat (Costa Rica)
Battle Dress Overgarment (BDO) minus vinyl overboot, 8 lb	8 (1/day)	0.36 (1/22 days)	0
Overboot, 2 lb	2 (1/day)	0.14 (1/14 days)	0
Canister, 0.6 lb	0.6 (1/day)	0.02 (1/22 days)	0
Sorbent, 10 lb[a]	10 (1/day)	0	0
Total	20.6 (22,700 lb/day)	0.52 (572 lb/day)	0

(a) Sorbent weight was estimated based on the weight of the contaminated BDO. There are 3 types of decontamination kits that could be used to neutralize, remove, or encapsulate contamination on protective clothing.[25] Some use powder and some liquid to decontaminate the item.

Table 24. Approximate Weight and Composition of BC Wastes for 1,100 Man Bare Base (Battle Dress Overgarment plus Sorbent)

Compo-nent	Intense BC Threat			Minor BC Threat (don suit once/22 days)		
	Waste Factor, lb/person-day	Approx-imate Weight, lb/day	Compo-sition, %	Waste Factor, lb/person-day	Approx-imate Weight, lb/day	Compo-sition, %
Nylon	2	2,200	10	0.09	99	17
Cotton	2	2,200	10	0.10	110	19
Impreg-nated charcoal	2	2,200	10	0.09	99	17
Butyl rubber	4	4,400	19	0.19	209	37
Canister	0.6	700	3	0.05	55	10
Sorbent	10	11,000	48	0	0	0
Total	20.6	22,700	100	0.52	572	100
Heating value, Btu/lb			8,000			14,000

4.2.4 Medical Wastes

Knowledge of the quantity and composition of medical wastes is needed to properly design control technologies. Medical wastes are composed of solid waste, infectious hazardous solid waste (wastes contaminated with blood, excretions, or secretions) and blackwater and gray water. Medical wastes are a function of the number of beds, staff, type of hospital at the base, and the degree of BC warfare activity. The waste figures reported below assume no BC activity or the need to use water for decontamination of personnel, clothing, or equipment. BC decontamination would significantly increase both solid and liquid waste levels. It is assumed that blackwater is purely a function of the number of soldier and hospital staff assigned to the base. Gray water is greater for hospital personnel and patients than for the troops. The mission may dictate the hospital size and type, in which case the medical waste rates would be dependent on the mission type (however, for this analysis it has been assumed that each mission will include a 50-bed air-transportable hospital (ATH), so hospital wastes are mission independent). Water usage will be different for different climates and thus medical gray-water generation rates will be affected by base location.

4.2.4.1 Solid and Infectious Medical Wastes. The quantity of medical wastes depends on the size and activities conducted in the medical facility. In AFPAM 10-219[4] it states that a Bare Base usually starts with a 10-bed air-transportable clinic. This is often expanded to a 25-bed ATH. Depending on the nature of the deployment, the proximity of the Bare Base to combat activities, etc., the Bare Base could house a 50-bed ATH, a 250-bed contingency hospital, or a 250-bed aeromedical staging facility. For the purposes of this analysis, it was assumed that the 1,100-deployment, whether combat, peacekeeping, or humanitarian mission would include a 50-bed ATH.

Details of a 50-bed air transportable hospital, provided in AFPAM 10-219 include the following:

- Staff of 128
- Billeting for 128
- Latrines and showers for 178 (128 + 50 patients)
- 6,000 lb of laundry per week
- 5,500 gal of water consumed daily
- 4,950 gal of wastewater generated per day
- 18,500 lb of solid waste generated per day.

The solid waste-planning factor (18,500 lb of solid waste per day for a 50-bed ATH) translates into a waste factor of 370 lb/bed-day. This seems extremely high. The Tennessee Valley Authority, Army, and the EPA have provided considerably lower estimates of solid waste production from hospitals.

In a recent paper by the Tennessee Valley Authority on hospital wastes, presented at the 1998 Joint Services Pollution Prevention Conference,[28] it was stated that the University of Tennessee found that a 100-bed hospital generated about 14.9 tons of solid waste per month. This translates into 9.9 lb/bed-day. About 44 percent consisted of paper and cardboard and 16 percent was plastics.

The Army[22] suggested a solid-waste planning factor of 15 pounds of medical waste/bed/day. A general waste factor of 12.5 pounds of general waste/staff member/day was also provided. Infectious wastes were estimated at 3 pounds/bed/day. Using Army field hospital planning factors, estimated total waste generated by a 50-bed ATH with a staff of 128 would generate 2,350 pounds of solid waste per day, significantly less than the AFPAM 10-219 estimate of 18,500 pounds per day.

In an EPA study[29] of medical wastes generated at civilian hospitals, it was found that the average hospital generated 15 pounds of medical waste per patient per day. The Army and EPA definitions of medical wastes are similar. This figure did not include general or hazardous wastes. Several estimates of the proportion that is infectious were provided; they ranged from 6 to 23 percent. Fifteen percent was suggested as a generally recognized figure. A comparison of the waste projections is provided in Table 25.

If the Army general waste factor is applied to the EPA case, the total would again equal 2,350-lb per day (1,600 + 640 + 110). Discussion with Air Force medical staff indicated that the 370-lb/bed-day factor appeared high. No contacts at Brooks AFB could be identified to discuss the basis for the 370-lb/bed-day factor. Also, the authors of AFPAM 10-219 would not comment on the waste factor. We concluded that the Air Force waste factor is probably too high. We suggest using the 2,350 lb/day value calculated using the Army waste factors for estimation of the general, medical, and infections solid wastes with a breakdown of approximately 1,600 lb of general wastes, 600 lb of medical wastes, and 150 lb of infectious wastes generated each day.

Table 25. A Comparison of Medical Solid Wastes Using Air Force, Army, and EPA Waste Factors for a 50-Bed Hospital

<table>
<tr><th rowspan="2">Hospital Waste Category</th><th colspan="4">Estimated Waste by Reference Number</th></tr>
<tr><th>AFPAM 10-219[4]</th><th>Tennessee Valley Authority[28]</th><th>Army FM 8-10-14[22]</th><th>EPA-453/R-94-042a[29]</th></tr>
<tr><td>General Waste</td><td>--</td><td>--</td><td>1,600 (b)</td><td></td></tr>
<tr><td>Medical wastes, infectious</td><td>--</td><td rowspan="2">500(a)</td><td>150 (c)</td><td>110 (e)</td></tr>
<tr><td>Medical wastes, non-infectious</td><td>--</td><td>600 (d)</td><td>640 (f)</td></tr>
<tr><td>Total, lb/day</td><td>18,500</td><td></td><td>2,350</td><td></td></tr>
</table>

(a) 9.9 lb/bed-day x 50 beds.
(b) 12.5 lb/staff/day x 128 staff.
(c) 3 lb/bed/day of infectious wastes x 50 beds.
(d) (15 lb/bed/day – 3 lb/bed/day of infectious wastes) x 50 beds.
(e) 15 lb/bed/day x 50 bed x 15 percent (fraction representing infectious wastes).
(f) 15 lb/bed/day x 50 bed x 85 percent (fraction representing medical wastes).

For purposes of the design of a medical waste treatment facility, information is needed on combustible and inert content, plastics level (particularly polyvinyl chloride content), and heating value. The available EPA literature[29] indicates that 10 to 30 percent of medical wastes may be plastics; no data are available on metals content. Eco Waste

Solutions, an incinerator manufacturer, provided some information on inerts content, moisture levels, and heating values. Using these figures, the composition for Bare Base medical wastes was estimated; see Tables 26a and b.

Table 26a. Medical Solid Waste Generation Rates for a 50-Bed Hospital (Independent of location, climate, or mission type)

Waste Category	Characteristics	Waste Factor	Unit	Daily Waste Rate, lb/day
General waste	A mixture of combustible paper, cardboard, wood scraps, with cafeteria wastes: typically 25 percent moisture, 16 percent inerts, and a 6,500 Btu/lb heating value	12.5 lb/staff /day	128 staff	1,600
Medical wastes, infectious	Human remains, organs and solid organic wastes from hospitals, laboratories and similar sources: typically contain up to 85 moisture and 5 percent inerts with a 1,000 But/lb heating value	3 lb/bed/ day	50 beds	150
Medical wastes, non-infectious	A mixture of highly combustible wastes, papers, cardboard, plastic bags, coated paper, plastics, etc: typically contain 10 percent moisture, 5 percent inerts and a 8,500 Btu/lb heating value	12 lb/bed/ day	50 beds	600
			Total	2,350

Table 26b. Medical Solid Waste Composition

Components	Composition	
	Percent	**lb/day**
Food wastes	23	540
Other	5	120
Plastics	13	310
Metals	13	300
Paper and paperboard	46	1,080
Total	100	2,350
Heating value, Btu/lb		6,600

4.2.4.2 Wastewater. Wastewater from medical wastes includes blackwater and gray water. Blackwater is based on the number of staff and patients at the hospital. Similar to the personal blackwater data reported above, the per capita generation and composition of blackwater is noted in Tables 27a and b.

The quantity of gray water produced is much greater in hospital operations because of the need for better hygiene. Gray water estimates are available from both Air Force and Army sources; see Table 28.

Table 27a. Medical Blackwater Rate for a 50-Bed Hospital (Independent of mission type but dependent on location and climate)

Location and Climate	Blackwater Generation Rate, gal/person-day (lb/person-day)	No. of Staff and Patients	Daily Waste Rate, gal total/day (lb/day)
Costa Rica, tropical	7.4 (61)	178	1,300 (10,900)
Kuwait, arid	7.7 (64)	178	1,400 (11,400)
Spain, temperate	6.4 (53)	178	1,100 (9,400)

Table 27b. Medical Blackwater Composition

Composition	Waste Loading lb/person-day	Location and Blackwater Concentration, mg/L		
		Costa Rica Tropical	Kuwait Arid	Spain Temperate
COD	0.11[a]	1,800	1,700	2,100
BOD	0.04[a]	650	620	750
Suspended solids	0.20[b]	3,250	3,100	3,800
Total solids (suspended and dissolved)	0.24[b]	3,900	3,700	4,500
Total Kjeldahl nitrogen	0.032[a]	500	500	600
Ammonia nitrogen	0.007[a]	110	110	130
Phosphate	0.008[a]	130	120	150

(a) Reference 20.
(b) Reference 23.

Table 28. Estimates of Hospital Gray Water Generation for a 50-Bed Hospital (Assumed independent of mission type, location, and climate)

Source	Unit	Gray Water Generation, gal/day per unit (gal/day)		
		AFPAM 10-219, p. 158[4]	AFPAM 10-219, p. 88[4]	Army FM 8-10-14[18]
Staff	128 staff	--	10 (1,280)	7 (900)
Patient				
Patient care	50 beds	--	65 (3,250)	12 (600)
Surgical	50 cases/day	--		13 (650)
Laundry	50 beds	--		41.4 (2,100)
	Total, gal/day	(4,950)	(4,580)	(4,250)

As noted, the gray water rates are similar. For the purposes of this report the 4,950-gal/day figure was accepted and rounded off to 5,000 gal/day. A 50-bed hospital was selected for all mission types; therefore, the water rate is independent of mission type. However, if BC warfare activity was on going, such as in a combat or peacekeeping mission, the medical wastewater rates could increase significantly. Examination of the wastewater sources indicates that the generation rate should be relatively independent of climate. The gray water composition was assumed to be the same as for personal gray water. The values are noted in Tables 29a and b below. The projected sludge weight from medical wastewater is provided in Table 30.

Table 29a. Medical Gray Waste Rate for a 50-Bed Hospital (Assumed independent of mission type, location, and climate)

Location and Climate	Gray Water Generation Rate, gal/person-day (lb/person-day)	No. of Staff and Patients	Daily Waste Rate, gal total/day (lb/day)
All	28 (233)	178	5,000 (41,400)

Table 29b. Medical Gray Water Composition

Components	Gray Water Concentration, mg/L [(a)]
BOD	800
COD	1,200
pH	7
Total solids (suspended and dissolved)	1,000
Suspended solids	200
Nitrates	5
Phosphates	200
Chlorides	100
Sulfates	400

(a) Gray water concentrations assumed same as for personal gray water wastes in an arid climate.

Table 30. Sludge from Medical Wastewater Treatment

Sludge Source	Wastewater Generation Rate, lb/day	Suspended Solids, lb/day	Sludge (Suspended Solids) Weight, lb/day [(a)]	Weight Fraction, %
Blackwater	9,000 to 11,400	36	178	96
Gray water	41,400	1.4	7	4
	Total	37	185	100
	Heating value, Btu/lb		5,000	

(a) The sludge from the blackwater and the gray water corresponds to the suspended solids from both sources, and then corrected to the equivalent of a 20 percent solids level.

4.2.5 Aircraft and Vehicle Wastes

The quantity and composition of hazardous wastes generated by aircraft and vehicle operation and maintenance at the Bare Base are needed to properly design control technologies. Hazardous aircraft and vehicle wastes are composed of solid and liquid wastes. It was assumed that the quantity and composition of hazardous wastes produced from aircraft and vehicles would be similar for the three different missions at the different sites.

Hazardous wastes from aircraft and vehicle operation and maintenance are available from Prince Sultan Air Base located in Saudi Arabia, Carswell Air Reserve Station (ARS) located near Fort Worth, TX, and Homestead ARS located near Miami, FL. The data and estimated waste factors for solid and liquid hazardous wastes are noted in Table 31.

The Prince Sultan hazardous solid waste factor was 0.03 lb/person-day from the combined aircraft and vehicle operation and maintenance. Factors calculated from the

Carswell and Homestead ARS, 0.02 and 0.05 lb/person-day, respectively, were similar. The factor for liquid hazardous wastes was 0.04 gal/person-day. Again, the factors calculated for the air reserve stations, 0.03 and 0.07 gal/person-day, were similar to the Prince Sultan number. The estimated waste rate and composition for an 1,100-man Bare Base are noted in Tables 32a and b.

If BC warfare activities were on going, the decontamination of aircraft could significantly increase the solid and wastewater generation rates. BC wastes could be orders of magnitude greater than the minor quantities of hazardous wastes generated during normal operation and maintenance.

4.2.6 Summary

The quantities and compositions of solid, liquid, and hazardous wastes from a Bare Base have been estimated. The quantities, by location, are summarized in Table 33. The following describes the effects of the variables studied:

- **Mission:** the type of mission was found to be a minor factor.

- **Location:** the main effect of location was due to the different climates. The effect was relatively minor, resulting in slightly higher water use in the arid climates with slightly greater wastewater generation rates.

- **Environmental restrictions:** the different levels of environmental monitoring and control requirements did not affect waste quantities or composition.

- **Biological and chemical warfare threat:** the generation of BC wastes corresponded to the threat of BC warfare. In all cases the threat was considered low, so BC wastes were low.

- **Non-military personnel:** the tables above were generated assuming there were no refugees or disaster victims supported. It can be expected that personal-waste quantities from a peacekeeping or humanitarian Bare Base would increase in direct proportion to the increase in the number staff plus refugees or victims supported.

Table 31. Aircraft Hazardous Waste Rates and Composition Data from Prince Sultan Air Base, Carswell ARS and Homestead ARS

Parameter	Sites and Reference Number		
	Prince Sultan Air Base[14]	Carswell ARS[30]	Homestead ARS[31]
Base type	Bare Base	Reserve base	Reserve base
Staff	3,600	NA, 500 estimated [(a)]	NA, 225 estimated [(a)]
Aircraft	Varied, combat	17 F-16 fighters	18 F-16 fighters
No. of AGE equipment	526	NA	NA
No. of vehicles	1,180	NA	NA
Hazardous Solid Wastes, lb/year			
Personal and office Ni-Cd batteries	25,000	134	161
Aircraft, vehicle, and aerospace ground equipment (AGE) oil filters	1,000	600	1231
Vehicle lead-acid batteries	9,000	NA, 1,250 estimated [(b)]	NA, 560 estimated [(b)]
Other (including tires)	5,000	~1,400	~1,900
Total hazardous solid wastes	40,000	~3,400	~3,840
Total hazardous solid wastes factor, lb/person-day	0.03	0.02	0.05
Hazardous Liquid Wastes, gal/year			
Aircraft, vehicle, and AGE waste fuels	11,000	NA	NA
Aircraft, vehicle, AGE, waste engine, turbine, transmission, and hydraulic oils	25,000	3,584	4,112
Vehicle waste antifreeze	6,000	780	1,990
Aircraft, vehicle, and AGE paint wastes	10,000	325	147
Other	7,000	NA	NA
Total hazardous liquid wastes	59,000	4,689	6,249
Total hazardous liquid wastes factor, gal/person-day	0.045	0.03	0.07

(a) NA: not available; estimated full-time equivalent obtained by dividing annual solid waste rate by 365 days/year and by the domestic-base waste rate of 4 lb/person-day.

(b) NA: not available; estimated assuming a waste factor of 0.0068 lb/person-year (based on 9,000 lb lead-acid batteries per year/365 days per year/3600 staff).

Table 32a. Aircraft and Vehicle Hazardous Waste Rate (Independent of location, climate, and mission type)

Hazardous Waste Type	Hazardous Waste Factor	Unit	Waste Rate
Solid	0.030 lb/person-day	1,100 staff	33 lb/day
Liquid	0.045 gal/person-day or 0.36 lb/person-day at 8 lb/gal	1,100 staff	49.5 gal/day or 396 lb/day
		Total	429 lb/day

Table 32b. Aircraft and Vehicle Waste Composition

Composition	Waste Factor, lb/person-day	Waste Rate for 1,100 man Bare Base, lb/day	Percentage, %
Personal and office Ni-Cd batteries	0.019	21	5
Aircraft, vehicle, and AGE oil filters	0.001	1	0
Vehicle lead-acid batteries	0.007	8	2
Other solids (including tires)	0.004	3	1
Aircraft, vehicle, and AGE, waste fuels	0.067	74	17
Aircraft, vehicle, AGE, waste engine, turbine, transmission, and hydraulic oils	0.152	168	39
Vehicle waste antifreeze	0.037	40	9
Aircraft, vehicle, and AGE, paint wastes	0.061	67	16
Other liquids	0.043	47	11
	Total	429	100

Table 33. Summary of Bare Base Wastes

Waste Area	Waste Factors by Location, lb/person-day			Waste Quantity by Location for 1100 man Bare Base, lb/day		
	Costa Rica	Kuwait	Spain	Costa Rica	Kuwait	Spain
Personal Wastes						
Solid		10[a]			11,000	
Water treatment sludge		1			1,100	
Blackwater	61	64	53	67,600	70,300	58,400
Gray water	42	52	37	46,600	57,500	41,100
Solid, hazardous		0.01			11	
Subtotal	114.01	127.01	101.01	126,311	139,911	111,611
Biological, Chemical Warfare Wastes						
Protective clothing	0	0.5	0.5	0	550	550
Carbon canisters	0	0.02	0.02	0	22	22
Subtotal	0[b]	0.52	0.52	0	572	572
Medical Wastes[c]						
Solid		13			2,350[d]	
Blackwater	61	64	53	10,900	11,400	9,400
Gray water		233			41,400	
Subtotal	307	310	299	54,650	55,150	53,150
Aircraft and Vehicle Wastes						
Solid		0.03			33	
Liquid		0.36			396	
Subtotal	0.39	0.39	0.39	429	429	429
Total	421.4	437.9	400.9	181,390	196,062	165,762

(a) Value is not location dependent when centered across the three columns.
(b) No BC attack considered for Costa Rica; BC attack for the other two locations considered minimal, requiring the donning of a set of protective clothing each month.
(c) Based on 178 staff and patients housed at the 50-bed hospital.
(d) Approximately 150 lb of the total are infectious medical wastes.

The analysis indicates that personal and medical wastes account for nearly all the wastes. A breakdown of the wastes by type and sources is noted in Table 34.

Table 34. Proportion of Bare Base Wastes from Personal, BC, Medical, and Aircraft and Vehicle Sources

Waste Source	Fraction of Total, %	Fraction of Solid Wastes, %	Fraction of Wastewater, %	Fraction of Hazardous Wastes, %
Personal	71.4	79.1	70.8	1.0
Biological/ chemical warfare	0.3	4.0	0	49.2
Medical	28.1	16.9	29.2	12.9
Aircraft and vehicles	0.2	0[(b)]	0[(b)]	36.9
Total, % Total, weight[(a)]	100 196,062 lb/day	100 13,900 lb/day	100 180,600 lb/day 21,760 gal/day	100 1,162 lb/day

(a) Weight and proportions based on figures estimated for a Bare Base located in Based on Kuwait.

(b) Wastes from aircraft and vehicles in this category included with personal wastes.

4.3 Guidelines for Waste Control Technologies

4.3.1 Introduction

The objective of this guidelines' task is to provide a final set of guidelines/data points to be used as the basis for waste technology selection and design.

The AFRL conducted an extensive review of emerging waste-control technologies. They selected plasma arc vitrification and gasification as having the greatest potential to provide next-generation capabilities to control solid, liquid, and hazardous wastes at Bare Bases. A third, conventional technology, incineration, was added to provide a point of comparison to the emerging technologies.

Design parameters for the deployable waste management system were based on the regulatory requirements for fixed overseas bases. In the absence of any generic regulations for Bare Base environmental operations, the OEBGD was used to provide a conservative basis for assessing possible control requirements. The mass and characteristics of the wastes to be processed was also summarized. The environmental regulations were discussed in section 4.1. Waste stream data, covered in Section 4.2, provide the waste volumes and characterization information required.

Each technology is briefly discussed below. Special waste characterization needs are noted.

4.3.1.1 Plasma. Plasma systems represent emerging technology. These systems operate at temperatures far above conventional incineration temperatures to convert organics into CO_2 and water, while most non-organic materials are reduced to an inert slag. The process can reduce the volume of wastes by over 90 percent. But, the ash may still contain 30 to 50 percent of the dry feed weight. Plasma systems have the potential to:

- Process wastes to produce an effluent that can be safely disposed of at the site.
- Render medical and hazardous wastes inert at the site.
- Produce a minimum amount of waste materials that must be removed for processing at stationary facilities.

Plasma vendors assert that "plasma can treat any waste stream;" however, researchers at the Naval Research Laboratory studying plasma-arc systems for waste disposal have found that even some organic material remains in the plasma crucible following treatment. The Navy believes waste streams will require preprocessing prior to treatment. For instance, certain metals, such as lead and mercury, are vaporized rather than being captured in the slag during plasma processing. If not removed prior to treatment, the metals would be transferred to the off-gas stream. Also, salts are not completely captured and a water scrubbing system is required for final cleanup. Halogens like chlorine and fluorine are released as corrosive HCl and HF acids that must be neutralized in the scrubbing water.

4.3.1.2 Gasification. Catalytic hydrothermal conversion (CHC) is a gasification system. It also represents an emerging technology. The system operates at moderate temperatures. The action of heat and steam serves to convert most of the organics into a fuel gas. The product gas would have to be cleaned to remove particulates and tars prior to disposal or use. Inerts and unconverted organics are output as a solid char. The char would contain hazardous components and must receive further treatment prior to disposal. One option under consideration is to send the char to a plasma unit for vitrification. By first gasifying the wastes, the quantity of wastes requiring plasma treatment could be significantly reduced. Like plasma treatment, volatile metal would have to be segregated prior to treatment to avoid introduction into the air. Again waste volume is dramatically reduced and the ash is converted in to a safe and easy to dispose of slag.

4.3.1.3 Incineration. Incineration involves controlled burning of solid and liquid wastes. Heavy metals like batteries are excluded prior to combustion. Volatiles are driven off by destructive distillation and ignite. Gases pass through a series of oxidation changes where the hydrocarbons are converted into CO_2, CO, and water. Incineration also allows substantial volume reduction. However, it may still be hazardous and require special treatment prior to disposal. Thus, the ash may not be disposed of on site like the plasma slag. The off gases contain particulate matter, SO_2, NOx, acid gases, metals, and unburned organics such as dioxins and furans. In recent years great concern has been raised regarding the products of this incomplete combustion. Because of these concerns regulation of incineration has increased dramatically. Secondary combustion chambers are now specified to ensure these organics are fully oxidized and downstream air-pollution control equipment is required to prevent particulates, acid gases, and noxious gases from entering the atmosphere. Even with these controls, siting is now difficult. Incineration represents an established technology. Suitable units meeting all environmental requirements can be procured through a number of vendors. The main advantage of incineration is its ability to dramatically reduce the volume of wastes requiring land disposal. However, in addition to lingering concerns about air emissions, the ash produced may still be hazardous and may not be able to be safely disposed of on site.

4.3.2 Air Quality Requirements

The contractor will have to design the waste control system to meet the specific air quality control levels. Plasma arc and gasification are emerging waste control technologies. They are not mentioned in the OEBGD or FGS. The only thermal destruction method described for Bare Base waste destruction is incineration. In most cases, including Kuwait and Costa Rica, the only incineration specification is a particulate limit of less than 0.08 grains/dry standard cubic foot, or expressed in metric terms 200 mg/Nm^3 (normal cubic meter). The limit for Spain is more stringent (see Table A-2 in Appendix A for details). It can be anticipated that control requirements will increase with time. Therefore, the Spanish requirements have been summarized here as representative of the degree of control required. The Spanish requirements become more stringent as the hourly incinerator capacity is increased. The least stringent is for incinerators with less than 1 ton/hr capacity.

The projected solid waste rate is 16,639 lb/day derived from the following:

- 11,000 lb/day solid waste
- 2,350 lb/day medical solid wastes
- 570 lb/day biological/chemical warfare wastes
- 290 lb/day waste fuel and oils
- 1,430 lb/day waste sludges from wastewater treatment.

On an 8-hour burn time/day basis this represents a 1,950-lb/hr rate. The control requirements for fixed overseas bases are summarized in Table 35. The requirements noted above were based on the 1992 OEBGD. We can speculate on the requirements that may be placed on new waste control devices by assuming the new guidelines will reflect current US environmental guidelines. New hospital/medical/infectious waste incinerator (HMIWI) guidelines were signed by the EPA administrator in August of 1997. These requirements are in effect for US stateside fixed bases. They may, however, not be fully applicable to Bare Base deployments. Emissions limits were established for new HMIWI units for three size ranges:

- Small ($\leq$ 200 lb/hr)
- Medium (> 200 to 500 lb/hr)
- Large (> 500 lb/hr).

A Bare Base unit firing 16,639 lb/day would fall in the large category. If less than 10 percent of the waste is hospital and medical/infectious wastes the unit can be exempted from these new requirements. However, in the Bare Base case described in this report (with a 50-bed hospital), medical wastes represent about 14 percent of the wastes. The new source performance standards for medium and large hospital/medical/infectious waste incinerators are noted in Table 36.

Table 35. Waste Destruction System Air Pollution Control Requirements Based on OEBGD and FGS

Pollutant	Control Required
Solid Waste Incineration	
Particulate matter	< 0.08 08 grains/dry standard cubic foot (< 200 mg/Nm^3[normal cubic meter])
Hydrochloric acid	250 mg HCl/Nm^3
Medical Waste Incineration	
Post-combustion chamber	Required
Temperature	1,050 °C
Excess air	Maintained at 6 percent
Residence time	2 seconds
Ash	Hazardousness must be assessed and handled appropriately
Hazardous Waste Incineration	
Permit	Must be licensed and permitted
Destruction and removal efficiency of organic wastes	99.99 percent
CO	Minimize emissions
Particulates	Minimize emissions
Hydrochloric acid	< 1.8 kg (4 lb)/hr

The requirements outlined are dramatically more restrictive than those outlined in the current OEBGD. The emission limits have been tightened (e.g., particulate matter limit was dropped from 200 to 34 mg/dscm) and the control requirements expanded to include many more species. Good operation is no longer adequate to meet the emission limits; now extensive downstream scrubbing equipment and sorbents are required to control emissions.

The standards require the facility staff to monitor operating parameters, including charge rate, secondary combustion chamber temperature, and bypass stack temperature. A HMIWI equipped with a dry scrubber (dry injection or spray dryer with a fabric filter) must monitor dioxin/furan and mercury sorbent (i.e., carbon) flow rate, HCl sorbent (i.e., lime) flow rate, and fabric filter inlet temperature. A HMIWI with a wet scrubber must monitor pressure drop, pH, and flue gas temperature. These monitoring requirements may not be appropriate for a Bare Base, especially during hostile deployments.

Table 36. Pollutant Emission Limits for New Medium and Large Hospital/Medical/Infectious Waste Incinerators[32]
(Applicable to US stateside bases. These requirements may not be appropriate for Bare Base deployments)

Pollutant	Emission Limit	Control Method Required to Meet Emission Limit
Particulate matter	34 mg/dscm (dry std. cu. meter)	High efficiency wet scrubber or dry injection/fabric filter or spray dryer/fabric filter
Opacity	10 percent	--
Visible emissions	5 percent	Fugitive fly ash or bottom ash emissions from any fly ash or bottom ash storage or handling area
CO	40 ppmdv (parts per million by dry volume)	Good combustion
Dioxin/furan	0.6 ng/dscm total equivalent or 25 ng/dscm total dioxin/furan	Dry injection/fabric filter with carbon sorbent or spray dryer/fabric filter with carbon sorbent
HCl	15 ppmdv or 99 percent reduction	Wet scrubber or spray dryer/fabric filter
SO_2	55 ppmdv	No control required
NOx	250 ppmdv	No control required
Lead (Pb)	0.07 mg/dscm or 98 percent reduction	Dry injection/fabric filter or spray dryer/fabric filter
Cadmium (Cd)	0.04 mg/dscm or 90 percent reduction	Dry injection/fabric filter or spray dryer/fabric filter
Mercury (Hg)	0.55 mg/dscm or 85 percent reduction	Wet scrubber or dry injection/fabric filter with carbon sorbent or spray dryer/fabric filter with carbon sorbent

4.3.3 Waste Quantities and Composition Data

In order to size a waste control system, contractors plug the feed materials and amounts on an average per day basis into computer models to predict the following:

- Off-gas volume and rate
- Slag forming rate (plasma), char forming rate (gasification), or ash forming rate (incineration)
- Thermal generation rate
- Acid gas generation rate.

Waste characterization data needed for design of a plasma-arc waste destruction system were obtained from the Navy. The waste quantities for organic, inorganic, and waste sludge materials are required. Heating value data are desirable but not critical as they can be estimated from composition data. The quantities of food, cellulose, plastic, oily liquids, and dunnage (packaging materials) that must be disposed of are needed for plasma systems. These materials have distinctly different needs for oxidizing gas and have some bearing on the system gas volume. The relative proportion of chlorinated plastics and polyethylene is also needed. Plastics like polyvinyl chloride have a lower calorific value and contribute to acid gas formation. For metals, it is important to separately report the common metals like aluminum and steel from any heavy metals such as lead, barium, cadmium, etc. The primary source of the heavy metals is batteries. The heavy metal type and amounts tell them what kind of off-gas system needs to be supplied.

Medical waste needs to be broken down at least in terms of infectious wastes and non-infectious medical waste, paper and plastics. According to the Navy, it would also help to know how much plastic, paper, cloth, tissue, glass, and metal could be expected with the medical wastes.

The silica content will reveal how much slag formers are in the waste stream and will contribute to the slag formation rate. One common source of silica is "Floor-Dri" or similar absorbents found in a maintenance shop.

Knowledge about the presence of hazardous organic compounds, such as PCB, is necessary when designing a system to achieve 99.9999 percent destruction, as required by the EPA for hazardous-waste disposal in the US

Examples of the type of waste characterization data needed are shown in Table 37.

Table 37. Compositional Breakdown Desired for Plasma System Design

Organic Wastes	Inorganic Wastes	Sludge Wastes
Food	Metal/glass	Blackwater
Paper	Oily rags	Gray water
Cardboard	Non-oily rags	Oily waste
Heavy Cardboard	Paint rags	
Wax-Coated Cardboard	Dunnage	
Wax Paper	Wood	
Kimwipes	Incidental plastics	
Food Contaminated Plastic	Other (ashes, sweepings, etc.)	
	Bones and shells (from food)	
	Noninfectious medical waste, paper and plastic	
	Fuel filters	
	Cloth lifting straps	

The data obtained or estimated for personal, BC, medical, aircraft, and vehicles waste sources were less detailed than outlined in Table 37 above. The available data from Section 4.2 were divided into organic, inorganic, sludge, and fuel and oil wastes and summarized in Tables 38 through 41. The information should be sufficient for initial design of a plasma, gasification, or incineration system.

Table 38. Organic Solid Waste Composition Data Required for Waste Destruction System Design

Waste Component	Waste Generation Rate by Source, lb/day				Weight Fraction, %
	Personnel	Medical	BC	Total	
Food wastes	2,970	540	--	3,510	25
Other	880	120	570[(a)]	1,570	11
Wood	990	0	--	990	7
Plastics	990	310	--	1,300[(b)]	9
Metals	1,320	300	--	1,620	12
Glass	0	0	--	0	0
Paper and paperboard	3,850	1,080	--	4,930	36
Total	11,000	2,350[(c)]	570	13,920	100
Heating value, Btu/lb	6,500	6,600	14,000	6,800	--

(a) Approximately 210 lb/day of rubber, 210 lb/day of fabrics, and 150 lb/day of activated carbon.

(b) The vast majority of the plastics are made of polyethylene with only a small proportion of polyvinyl chloride.

(c) Medical waste: 150 lb/day of infectious wastes and 2,200 lb/day of non-infectious medical waste, paper, and plastics.

Table 39. Inorganic Solid Waste Composition Data Required for Waste Destruction System Design

Waste Component	Generation Rate, lb/day	Weight Fraction, %
Personal and office Ni-Cd batteries	21	21
Aircraft, vehicle, and AGE oil filters	1	1
Vehicle lead-acid batteries	8	8
Other solids	3	3
Paint wastes	67	67
PCB wastes	0	0
Total	100	100
Heating value, Btu/lb	~0	--

The quantity of wastewater treatment sludges is also necessary for system sizing; see Table 40.

Table 40. Wastewater Sludge Waste Composition Data Required for Waste Destruction System Design

Sludge Source	Organic Constituents	Wastewater Generation Rate, lb/day	Sludge (Suspended Solids) Weight, lb/day [(a)]	Weight Fraction, %
Blackwater	Urine, feces, wipes, food particles, cell bio-mass, hygiene products, cleaning solutions, scale prevention chemicals	81,700	1,280	90
Gray water	Hair, lint, dirt, detergents, soaps, toothpaste, food particles, disinfectants, and bio-cells	98,900	50	3
Antifreeze	Vehicle antifreeze/coolant replacement	40	100	7
		Total	1,430	100
		Heating value, Btu/lb	--	5,000

(a) Based on figures for the Bare Base located in Kuwait. The sludge from the blackwater and the gray water corresponds to the suspended solids from both sources, corrected to the equivalent of a 20 percent solids level.

The liquid oils and fuels data are also important. They are summarized on Table 41.

Table 41. Waste Oils and Fuels Data Required for Waste Destruction System Design

Waste Source	Waste Type	Amount, lb/day
Aircraft, vehicles, and AGE	Waste fuel	74
Aircraft, vehicles, and AGE engine repair	Engine, turbine, transmission, and hydraulic oils	168
Various	Other liquids	47
	Total	289
	Heating value, Btu/lb	18,000

4.3.4 Other Information

Other useful information for the contractor would be maximum waste length, to size the shredder. Container size information would also be useful. For example, whether food waste is brought to the system in a dump truck or in 55-gallon drums, or whether liquids are to be piped in or brought in by drum or other container. This information is provided in Table 42.

Table 42. Other Data Required for Waste Destruction System Design

Waste	Container	Waste size	Transport Method
Solid	Dump truck	4-ft by 4-ft or smaller	Dump truck
Liquid	Tank truck or 55-gal drum	--	Tank truck or flatbed truck
Sludge	Tank truck or 55-gal drum	--	Tank truck or flatbed truck

Deployable Waste Management System

5. Conclusions and Recommendations

5.1 Conclusions

The WMO at Eglin AFB is currently soliciting proposals for a deployable waste management system using proven available technology. The proposed system may include incineration units, as incineration is generally recognized as a proven solution to the disposal of combustible solids and liquid Bare Base wastes. The AFRL's HESR and MLQC are looking at systems with superior capabilities. They identified plasma-arc vitrification and gasification as mid-term (i.e., 7 years) solutions. They believe these technologies have the potential to meet future environmental requirements to safely and efficiently dispose of Bare Base wastes.

In order to specify plasma or gasification systems, information on environmental regulations in force at potential overseas Bare Base sites was needed. No generic guidelines for environmental control requirements are available for Bare Base operations. Specific details are provided for each deployment in its Operating Plan. The OEBGD and FGS, although designated for fixed bases, were used to provide a conservative guideline for control requirements for Bare Base operations. After study of the OEBGD and the FGS for Kuwait and Spain, it was determined that neither plasma nor gasification technologies for solid, medical, nor hazardous waste control are currently allowed. Modifications to the OEBGD and the FGS of each deployment country would be required to use these alternative technologies unless they could be classified as incinerators. It was found that the regulations for incineration control varied from site to site. However, in general, the requirements were not prohibitive and could be met.

The current OEBGD and FGS were based on US environmental law in force in 1992. A new OEBGD is expected in early 1999. It is anticipated that the new guidance document will include much more demanding requirements. Current US environmental laws severely limit emissions. Also, the number of species that must be monitored and controlled has been vastly expanded. The 1997 hospital waste incinerator requirement provides a possible standard that could have to be met by plasma or gasification systems processing combined solid and medical wastes from a Bare Base. The standard is quite severe and requires extensive monitoring. This requirement may not be appropriate for combat or peacekeeping deployments.

Waste quantity and composition data are also needed to specify plasma or gasification systems. Air Force, Army, Navy, EPA, and industrial data were used to estimate the quantity of wastes that will be generated from personal, BC, medical, and aircraft and vehicle sources at a Bare Base. These waste projections and possible environmental requirements formed the basis for plasma and gasification system guidelines.

5.2 Recommendations

It is recommended that additional information be gathered to resolve the following issues:

- **Per Capita Solid Waste Data**. Values for the per capita solid waste generation rate varied from 3.3 to 28 lb/person-day. The seemingly most accurate figure was 28 lb/person-day, which was obtained from a survey of an actual Bare Base in Saudi Arabia. Four representative numbers were found in the literature. They were averaged with the survey data to obtain a 10 lb/person-day average. This figure was used for waste projections. This value is significantly higher than the 4 lb/person-day often used by the Air Force for Bare Base solid waste projections. An expanded survey of Bare Bases to gather solid waste generation should be conducted to gather more data to confirm the per capita figure.

- **Solid Waste Composition Data**. Solid waste composition data were not available from the Bare Base survey. Therefore, existing EPA and Navy composition data were used to project waste composition. The EPA solid-waste composition data were obtained from a national survey that found per capita rates of 3.3 lb/person-day. The Navy solid waste breakdown found for aircraft carriers corresponded to a 3.5 lb/person-day rate. Using composition data generated at such low per capita waste generation rates may not provide an accurate estimate of waste composition at higher generation rates. Solid waste composition data should also be gathered from actual Bare Base operations to provide a better compositional estimate.

- **Medical Wastes**. Medical waste rates also varied widely by information source. The EPA and Army figures for a 50-bed hospital were 2,350 lb/day. The Bare Base manual indicated an 18,500-lb/day rate for this size hospital. Discussions with Air Force staff could not identify the source of the 18,500 lb/day figure, but medical staff with some experience in Bare Base operations believed the figure was too high. The lower Army rate was used for estimating wastes from hospitals. Additional data for hospital wastes from operations simulating Bare Base activities should be gathered.

- **Non-Combat Missions**. Little is known about the differences in Bare Base deployments for peacekeeping or humanitarian missions. This issue should be explored to determine the number and type of aircraft and the amount and composition of the wastes generated. Also, the extent which Bare Base operations would supply food-, sanitary-, and hospital-services to refugees or disaster victims should be determined.

- **Environmental Regulations**. No general Bare Base environmental guidelines are available. The Air Force has provided guidance for fixed bases operated overseas. The OEBGD and the FGS provide requirements that could serve as such a guideline. A clarification of the extent that the OEBGD or FGS limit the type and amount of emissions from a Bare Base should be obtained.

- **Impact of New OEBGD**. A revised OEBGD is expected in mid 1999. The new regulations are anticipated to be more restrictive than current fixed-base requirements. If Bare Base operations must conform to the new OEBGD requirements then the impact of these new regulations should be assessed.

Deployable Waste Management System

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APPENDIX A
OEBGD and FGS Country by Country Comparison

Appendix A includes the following eight tables.

Table A-1. Comparison of Incinerator Requirements[9,10,11,12,13(a)]

Regulation	OEBGD	Final Governing Standards: Germany	Kuwait	Spain	Greece	Italy
Particulates	$\leq$ 0.08 grains/dry standard cubic foot [(b)]	No incinerators are operated at DoD installations in Germany. FGS for incinerators would depend on a number of variables. No guidance on requirements provided. Coordination with appropriate German officials was advised.	Same [(c)]	Same	Same	Same
Special	None		Same	Meet requirements of Table 2-5[(d)]	Same	Same
Monitoring requirements for municipal incinerators with greater than 1 ton/day capacity	None		Same	Temperature, particulate matter (expressed in opacity units), CO, O_2, and HCl	Same	Same
Compliance criteria	None		Same	In compliance if 7-day average does not exceed limits, and 1-day average does not exceed 30 percent of limits	Same	Same

(a) The OEBGD and FGS regulations apply only to new or substantially modified (N/SM) incinerators. N/SM incinerators are defined as units that burn more than 50 tons/day of waste, or burn more than 10 percent sewage sludge.
(b) Corrected to 12 percent CO_2. Note: there are 7,000 grains in a pound.
(c) Same: means the same as the OEBGD requirement
(d) Table 2-5 was not provided with Internet-available Spanish FGS. The table was subsequently downloaded, see Table A-2. These standards are established as a function of the nominal capacity of the incineration plant.

Table A-2. Downloaded Table 2-5 from FGS for Spain[9]
(Source: DENIX on the Web, 28 Sept 98)

TABLE 2-5

EMISSION LIMIT VALUES IN mg/Nm³ AS A FUNCTION OF THE NOMINAL CAPACITY OF THE MUNICIPAL SOLID WASTE INCINERATION PLANT [(a)]

POLLUTANT	CAPACITY		
	< 1 Ton/hr	< 3 Ton/hr but > 1 Ton/hr	> 3 Ton/hr
Particulate matter	200 [0.08] [(b)]	100 [0.04]	30 [0.01]
SOx	-	300	300
Heavy metals: Pb+Cr+Cu+Mn Ni+As	 - -	 5 1	 5 1
Hydrochloric acid (HCl)	250	100	50
Hydrofluoric acid (HF)	-	4	2
Organic substances (TOC)	-	20	20
CO	-	100	100

(a) Values refer to a temperature of 273 C *[this almost has to be a typo; the correct reference temperature should be 273 K = 0 C]*, 101.3 Kpa *[equivalent to 14.7 psi]* of pressure, and an 11percent oxygen or 9 percent CO_2 content. For a capacity <1 ton/hr, emission limit values can refer to an oxygen content of 17percent. In this case, the limit values cannot be greater than those indicated in Table 2-4 divided by 2.5. *[This final sentence does not make sense. Table 2-4 is related to the compositon of fuel oil.]*

(b) The downloaded table was augmented. Numbers in [ ] were converted from milligrams per normal meter cubed to grains/dry standard cubic feet for comparison to the 0.08 grains/dSCF standard in the FGS.

Table A-3. Comparison of Solid Waste Handling and Disposal Requirements[9,10,11,12,13]

Solid Waste Disposal Requirements	OEBGD	Final Governing Standards				
		Germany	Kuwait	Spain	Greece	Italy
Reduce solid waste generation	Could include recycling, composting, and waste minimization	Same. Also, waste generated in a state must be disposed of in that state	Same	Same	Same	Same
Landfill disposal						
MSW	Landfill primary method	Not designated	Same	Same	Same	Same
Sanitary operation	Daily cover required	Same	Same	Same	Same	Same
Landfill bottom permeability	No mention	Same	Same	10-7 cm/s	6-10 cm/s	6-10 cm/s
Leachate, if collected, must meet wastewater discharge criteria	No mention	Specific list of ground- and surface water analyses listed	Same	Required	No mention	Required
Hazardous, infectious, and PCB wastes	Must detect and prevent disposal of hazardous wastes	Same	Same	Same	Same	Same
Yard wastes and construction and demolition	Try to exclude	Same	Same	Same	Same	Same
Burning						
Open burning	Not allowed	Same	Same	Same	Same	Same
Open burning exception: infrequent burning of agricultural wastes	No mention	Allowed if in outlying areas	Allowed	Allowed	Allowed	Allowed

Table A-3. Comparison of Solid Waste Handling and Disposal Requirements, Continued

Solid Waste Disposal Requirements	OEBGD	Final Governing Standards				
		Germany	**Kuwait**	**Spain**	**Greece**	**Italy**
Incineration	Only allowed burning option	No incineration instructions provided in FGS	Same	Same	Incineration section not included in FGS	Same
Incineration controls follow Air Emission control section limits	Yes		Same	Same		If burn > 50 ton/day, follow incineration requirements
Post-combustion gas temperature	No mention		Same	8500 C [*must be typo, maybe 850 C*]		1050 C
Minimum excess oxygen	No mention		Same	6 percent		6 percent
Residence time	No mention		Same	Same		2 s
Gas emissions and ash analysis for dioxins	No mention		Same	Same		Analyze periodically
Composting						
Preferred methods	Windrow and enclosed vessel	Same	Same	Same	Same	Same
Special record keeping requirements if exceed noted tonnage of domestic waste water sludge	> 5,000 ton/year	Same	Same	Any	Any	Any
Limits on compost used for agricultural applications	7 heavy metals and PCB	Same	Same	Same	Same	Same

Table A-4. Comparison of Medical Waste Handling and Disposal Requirements[9,10,11,12,13]

Medical Wastes						
Incinerator Regulation	OEBGD	Final Governing Standards				
		Germany	Kuwait	Spain	Greece	Italy
Controls outlined in air emission control section	Must follow, size not specified	Same (but note: no requirements stipulated in German FGS air emissions section)	Same	Must follow if greater than 50 ton/day of medical wastes	Same as Spain	Same as Spain
Design and operation	Maintain minimum temperature and residence time to destroy pathogens	Same	Same	Same	Same	Same
Post-combustion chamber	Not mentioned	Same	Same	Not mentioned	Not mentioned	Required conditions: Temp. > 1,050 °C Excess oxygen: 6 % Res. time: 2 sec
Incinerator ash	Hazardousness must be assessed and ash handled appropriately	Same	Same	Same	Same	Same
Treatment (sterilization, etc.) required if wastes incinerated	Yes, in some cases	Same	Same	Same	Same	No

Table A-5. Comparison of Wastewater Requirements[9,10,11,12,13]

Regulation	OEBGD	Final Governing Standards				
		Germany	Kuwait	Spain	Greece	Italy
New point source						
BOD_5[a] (or $CBOD_5$)[b]	30-day avg. $\leq$ 30 mg/L 7-day avg. $\leq$ 45 mg/L 30-day avg. $\leq$ 25 mg/L 7-day avg. $\leq$ 40 mg/L	40 mg/L [e, f]	10 mg/L	Same	Same	Same
Total Suspended Solids	30-day avg. $\leq$ 30 mg/L 7-day avg. $\leq$ 45 mg/L	Same[g]	10 mg/L	Same	Same	Same
pH	6.0 to 9.0	Same	6 to 8	Same	Same	Same
Existing point source						
BOD_5	30-day avg. $\leq$ 45 mg/L 7-day avg. $\leq$ 65 mg/L	40 mg/L [e, f]	10 mg/L	Same	Same	Same as new source
Total Filterable Suspended Solids (TSS)	30-day avg. $\leq$ 45 mg/L 7-day avg. $\leq$ 65 mg/L	Same	10 mg/L	Same	Same	Same
pH	6.0 to 9.0	Same	6 to 8	Same	Same	Same
COD [c] to surface waters	No limit specified	150 mg/L[f]	No limit specified	500 mg/L	No limit specified	160 mg/L
Monitoring	BOD_5/COD, TSS, pH: referred to table for frequency [d]	Same [h]	Same	Same	Same	Same
Other conventional and non-conventional pollutants	No procedure specified	None[i]	Refer to Table A-7	Refer to Table A-7 (Table 4-2 of FGS)[k]	No procedure specified	Refer to Table A-7 (Table 4-2 of FGS)[k]
Indirect discharge to domestic wastewater treatment plant	Solid or viscous wastes prohibited; hazardous wastes (ignitable, reactive, toxic, or corrosive) prohibited	Same	Same	Same	Same	Same
Toxic organics	Prohibited chemicals listed; total limit 0.01 mg/L	Same	Same	Same	Same	Same
Industrial discharges	Special limits and monitoring requirements stipulated for electroplating wastes	Same	Same	Same	Same	Same
Other	Not stipulated	See footnote[j]	Not stipulated	Coordinate with Spanish authorities	Not stipulated	Not stipulated

Footnotes for Table A-5

(a) BOD_5: 5-day measure of biochemical oxygen demand.
(b) $CBOD_5$: 5-day measure of carbonaceous biochemical oxygen demand. The Executive Agent can, at his discretion, substitute $CBOD_5$ for BOD_5
(c) COD: Chemical oxygen demand
(d) Sampling frequency: see below.

Plant Capacity, million gal/day	Monitoring Frequency	Plant Capacity, MGD	Monitoring Frequency
0.0 – 0.099	Quarterly	1.- 4.99	Weekly
0.1 – 0.99	Monthly	> 5.0	Daily

(e) No 7- or 30-day averaging specified for BOD. Also, no distinction made between new and existing point sources.
(f) Requirements are size dependent. Figures are reported for size category No. 1 (<60 kg BOD/day, which corresponds to approximately 2,500 people)
(g) Same: same as OEBGD
(h) While the monitoring frequency references the noted table, see footnote (d). More frequent monitoring and the monitoring of additional components are required in certain specific German states. Analysis requirements are dependent on the plant size and the inclusion of a biological wastewater treatment plant.
(i) Because of the small size of the anticipated wastewater treatment plant for a Bare Base installation, no limits are placed on NH_4-N or total phosphorus.
(j) Hazardous substances must be kept to the minimum achievable in accordance with generally recognized technical practices.
(k) Table 4-2 downloaded, see Table A-7.

Table A-6. Additional Wastewater Requirements
Source: FGS for Kuwait[10]

Point Source Discharges to the Natural Environment (where no further wastewater treatment is expected)
a. BOD (Biochemical Oxygen Demand) must not exceed 10 mg/L. b. SS (Suspended Solids) must not exceed 10 mg/L. c. Residual chlorine must not be less than 1 mg/L. d. Maximum coliform number not to exceed 100/100mL. e. Fecal coliform not detectable (0 /100mL). f. H_2S emission must not exceed 0.02 ppm. g. NH_3 emissions must not exceed 0.05 ppm. h. pH for treated effluent must be between 6-8.
Limitations on Industrial Discharges to Public Owned Treatment Works (POTW).
a. Temperature not to exceed 40°C. b. pH must be between 6-9. c. Settleable SS must not exceed 500 mg/L. d. BOD must not exceed 400 mg/L. e. COD must not exceed 700 mg/L. f. H_2S and sulfides must not exceed 10 ppm. g. Cyanide must not exceed 0.1 ppm. h. Phosphates must not exceed 5 ppm. i. Nitrates must not exceed 30 ppm. j. Fluoride must not exceed 1 ppm. k. Ammonia must not exceed 100 ppm. l. Heavy metals must not exceed separately or in total more than 10 ppm, if flow is less than 50 M^3/day, and must not exceed 5 ppm if flow is more than 50 M^3/day. m. Mercury and silver must not exceed 1 ppm for both. n. No detectable radioactive materials are accepted.

Table A-7. Downloaded Table 4-2 from FGS for Spain[9]
(Source: DENIX on the Web, 28 Sept 98)

TABLE 4-2

LIMITS ON POLLUTANT DISCHARGE (Direct and Indirect)

Parameter	Discharge Limits, (mg/l)	Notes
Settleable Solids	2	(a)
Total Particulates	Absent	--
Temperature	3 C	(b)
Color	Not perceptible after 1/40 dilution	(c)
Aluminum	2	(d)
Arsenic	1	(d)
Barium	20	(d)
Boron	10	(d)
Cadmium	0.5 /0.4 (K)	(d)
Chrome III	4	(d)
Chrome VI	0.5	(d)
Iron	10	(d)
Manganese	10	(d)
Nickel	10	(d)
Mercury	0.1	(d)
Lead	0.5	(d)
Selenium	0.1	(d)
Tin	10	(d)
Copper	10	(d)
Zinc	20	(d)
Total toxic metals	3	(e)

Table A-7. Downloaded Table 4-2 from FGS for Spain, Continued

TABLE 4-2, CONT. LIMITS ON POLLUTANT DISCHARGE (Direct and Indirect)		
Parameter	**Discharge Limits, (mg/l)**	**Notes**
Chlorides	2000	-
Sulphides as H_2S	2	-
Sulfites as SO_3	2	-
Sulfates as SO_4^{2-}	2000	-
Fluorides as F^-	12	-
Total phosphorous	20	(f)
Ammonium as NH_4^+	50	(g)
Nitrite N	20	(g)
Cyanide	1	-
Phenols	1	(h)
Aldehydes	2	-
Detergents	6	(i)
Pesticides	0.05	(j)
Oil and grease	40	-

(a) Measured after 2 hours in an Imhoff cone in mL/L.
(b) Will not cause a difference of more than 3°C of receiving water temperature.
(c) Not perceptible after 1:40 dilution through a 10-cm wedge.
(d) Limit refers to the dissolved elements such as ions and complex forms.
(e) The sum of the fractional proportions of the actual amount of the toxic elements (arsenic, cadmium, chrome VI, nickel, mercury, lead, selenium, copper and zinc) to the maximum allowable amount for those elements shall not exceed 3.
(f) If discharging to rivers or reservoirs, the limit should not exceed 0.5 mg/L in order to prevent eutrophication blooms.
(g) Total nitrogen in rivers and reservoirs should not exceed 10 mg/L, expressed as N.
(h) Expressed as $C_6 H_5 OH$.
(i) Expressed as lauryl sulphate.
(j) For organophosphorus pesticides, the maximum level is 0.1 mg/L.
(k) Applicable to cadmium containing discharges from electroplating operations using cadmium.

Table A-8. Comparison of Hazardous Waste Handling and Disposal Requirements[9,10,11,12,13]

Regulation	OEBGD	FGS				
		Germany	**Kuwait**	**Spain**	**Greece**	**Italy**
Used Oil	Ok to burn in industrial and utility boilers and space heaters; cannot be used for dust suppression	Same	Same [a]	Same	Same	Same
Disposal procedures						
Normal disposal	Handled through DRMS	DRMR-E	Same	Same	Same	Same
If can not be disposed of within host nation	Must be retrograded to US or, if permissible, transferred to another country for disposal	Same	Same	Same	Same	Same
Land disposed	Only in lined and groundwater monitored hazardous waste landfill	No DoD landfilling	Same	Same	Same	Same
Incineration						
Regulation	Must be licensed and permitted by host nation	No incineration conducted by DoD installations in Germany	Same	Same	Same	Same
Destruction and removal efficiency of organic wastes	99.99 percent		Same	Same	Same	Same
CO	Minimize emission		Same	Same	Same	Same
Particulates	Minimize emission		Same	Same	Same	Same
HCl	< 1.8 kg (4 lb)/hour		Same	Same	Same	Same
Treatment	If treated and no longer exhibits the characteristics of a hazardous waste, it can be disposed of as a solid waste	Not addressed	Same	Same	Same	Same
Organics treatment	Acceptable treatments include fuel substitution, biodegradation, recovery, and chemical degradation	Not addressed	Same	Same	Same	Same
Heavy metals treatment	Acceptable treatments include stabilization and recovery	Not addressed	Same	Same	Same	Same

(a) Due to the lack of hazardous waste landfills or incinerators, hazardous wastes should not be disposed of within Kuwait. All hazardous wastes should be packaged, stored, and disposed according to the guidance of the Army Central Command.

LIST of ABBREVIATIONS AND ACRONYMS

AFB	Air Force Base
ARS	Air Reserve Station
AFRL/HESR	Air Force Research Laboratory Logistics Support
AFRL/MLQC	Air Force Research Laboratory Air Base Technology Branch
AGE	aerospace ground equipment
ARS	Air Reserve Station
ATH	air-transportable hospital
BC	biological and chemical warfare agent threat
BDO	battle dress overgarment
BOD, BOD_5	5-day measure of biochemical oxygen demand
Blackwater	wastewater from toilets
Btu	British thermal unit
BVO	black vinyl overboot
BC	biological or chemical warfare agents
CBOD, $CBOD_5$	5-day measure of carbonaceous biochemical oxygen demand
CHC	Catalytic Hydrothermal Conversion
DoD	Department of Defense
DRMS	Defense Reutilization and Marketing Service
dscm	dry standard cubic meter (measure of gas volume)
EPA	Environmental Protection Agency
FGS	Final Governing Standards
GVO	green vinyl overboot
Gray water	wastewater from showers, lavatories, laundries, etc. (also referred to as grey water)
HCl	hydrochloric acid
HESR	Logistics Support Technology Branch of AFRL
HMIWI	hospital, medical, infectious waste incinerator
MLQC	Air Base Technology Branch of AFRL
MSW	municipal solid waste
MSWL	municipal solid waste landfill
OEBGD	Overseas Environmental Baseline Guidance Document
OPLAN	operating plan
N/MS	new/substantially modified
Nm^3	normal cubic meter (measure of gas volume)
ppmdv	parts per million by dry volume
PCB	polychlorinated biphenyl
SFA	Status of Force Agreements
SRD	Systems Requirements Document
TSS	total suspended solids
WMO	Air Base Systems Office under the Air Armament Center