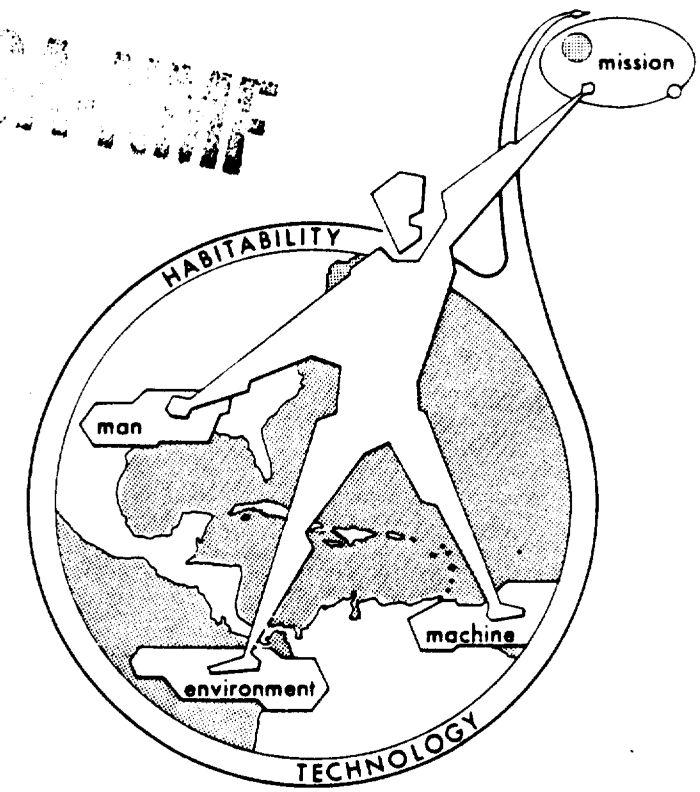
HABITABILITY DATA HANDBOOK
VOLUME 3
HOUSEKEEPING

JULY 31, 1971



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PREFACE

The Habitability Handbook is a collection of data in six volumes which include requirements, typical concepts, and supporting parametric data. The handbook provides an integrated data source for use in habitability system planning and design, intersystem trade-offs, and interface definition. The following volumes comprise the Habitability Data Handbook:

Volume	Title
1	Mobility and Restraint
2	Architecture and Environment
3	Housekeeping
4	Food Management
5	Garments and Ancillary Equipment
6	Personal Hygiene

This volume provides data for housekeeping systems applicable to extraterrestrial habitats and vehicles.

These data are considered preliminary and are predominantly derived from analytical and terrestrial sources and in general lack zero-g verification.

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CONTENTS (CONCLUDED)

1.0 INTRODUCTION

1.1 PURPOSE

This Housekeeping volume was developed to provide handbook data for use by space system planners, designers, and system engineers. The data provided herein is a representation of requirements and concepts for housekeeping systems for both present and future manned space vehicles. The handbook also establishes various areas where future technological development will be needed.

The document integrates habitability technology in handbook format for the following housekeeping functions:

- Waste definition
- Waste collection
- Waste transportation
- Waste sorting
- Waste processing
- Waste utilization and disposal

1.2 MAJOR INTERFACE AREAS

The housekeeping systems interface with the following habitability systems:

- Mobility and Restraint (Volume 1)
- Architecture and Environment (Volume 2)
- Food and Water Management (Volume 4)
- Garments and Ancillary Equipment (Volume 5)
- Personal Hygiene (Volume 6)

The Mobility and Restraint volume discusses devices and techniques for restraints, transfer, and crew mobility within a vehicle. The Architecture and Environment volume provides basic requirements for equipment used within a vehicle and defines areas where waste will be produced. The Food Management volume discusses the waste items generated from consumables and expendable items such as food and food packages.

The Garments and Ancillary Equipment volume provides data for processing soiled clothing and other fabric materials. The Personal Hygiene volume presents techniques for collecting human waste (feces, urine, vomitus) and body grooming wastes.

1.3 HANDBOOK USE

Definition of waste items produced in the space vehicle are given in Section 6, by architectural areas. The items are defined by their physical characteristics and the function performed to produce them. The rate of production of each is also given.

Methods for handling, processing and disposing of waste items are presented in Sections 3, 4 and 5, respectively. Section 2 provides detailed instructions for the use of the concepts presented in Sections 3, 4 and 5.

1.4 DEFINITIONS

Wastes (products, materials) - substances or items produced in the course of spacecraft operations that are no longer useful in their present form. These substances or items may be disposed of or processed for utilization.

Waste Sources - the men, activities, sub-systems, equipments or laboratories which produce the various waste items.

Area (Area of Origin) - the generic name assigned to the architectural area of a spacecraft.

Utilization - the reuse of waste either in its original function or in another function after total or partial conversion.

Process for Utilization - includes any processing, e.g., conversion, conditioning, or extraction of waste materials to facilitate utilization.

Disposal - separation of wastes from the habitable area of the spacecraft.

Process for Disposal - includes any processing, e.g., sterilization, drying, packaging, or compaction of waste material to facilitate disposal.

2.0 HOUSEKEEPING REQUIREMENTS AND DESIGN CRITERIA

Housekeeping for manned space systems includes the routines, equipment and materials to collect, transfer, sort, process, and dispose of or utilize wastes produced by crew members and functions interfacing with the habitable area of the space vehicles. It also includes routines for tasks within the vehicle where no waste is involved, e.g., steward duties and vehicle maintenance.

2.1 WASTE CONTROL

The identification and definition of waste items is the first task in designing a housekeeping system. Then the various spacecraft functions and tasks are established and the equipment and routines required to support the subsystems are derived. Based on the operational description of the candidate equipment and routines, a list of potential consumables and expendables is prepared. By correlating these operations and the materials consumed, the wastes produced in accomplishing the task or function may be identified and the rate of production and characteristics (chemical and physical) of each defined. These rates and characteristics may then be used to establish the routines and processes to control each waste. Section 6 provides a means of identifying these waste items, their rates of production, and their characteristics for the architectural area in which they will be produced.

Characteristics of wastes and constituents of consumables and expendables include: physical state (solid, liquid, or gas), material description (metal, plastic, etc.), form factor (tubular, rod-like, slurry), process influencing characteristics (organic, radioactive, toxic, pathogenic), and chemical compounds or elements (NH_4, CO_2, O_2).

A functional block diagram for general waste control tasks is presented in Figure 2-1. The routine and/or equipment used to accomplish each task must be compatible with the waste produced in the area considered.

2.1.1 Identification of Waste Handling Requirements. Waste handling is the collection, transfer, and sorting of waste products for either utilization or disposal processing. The collection process will cover all actions from the placing of waste in containers to placing the filled containers

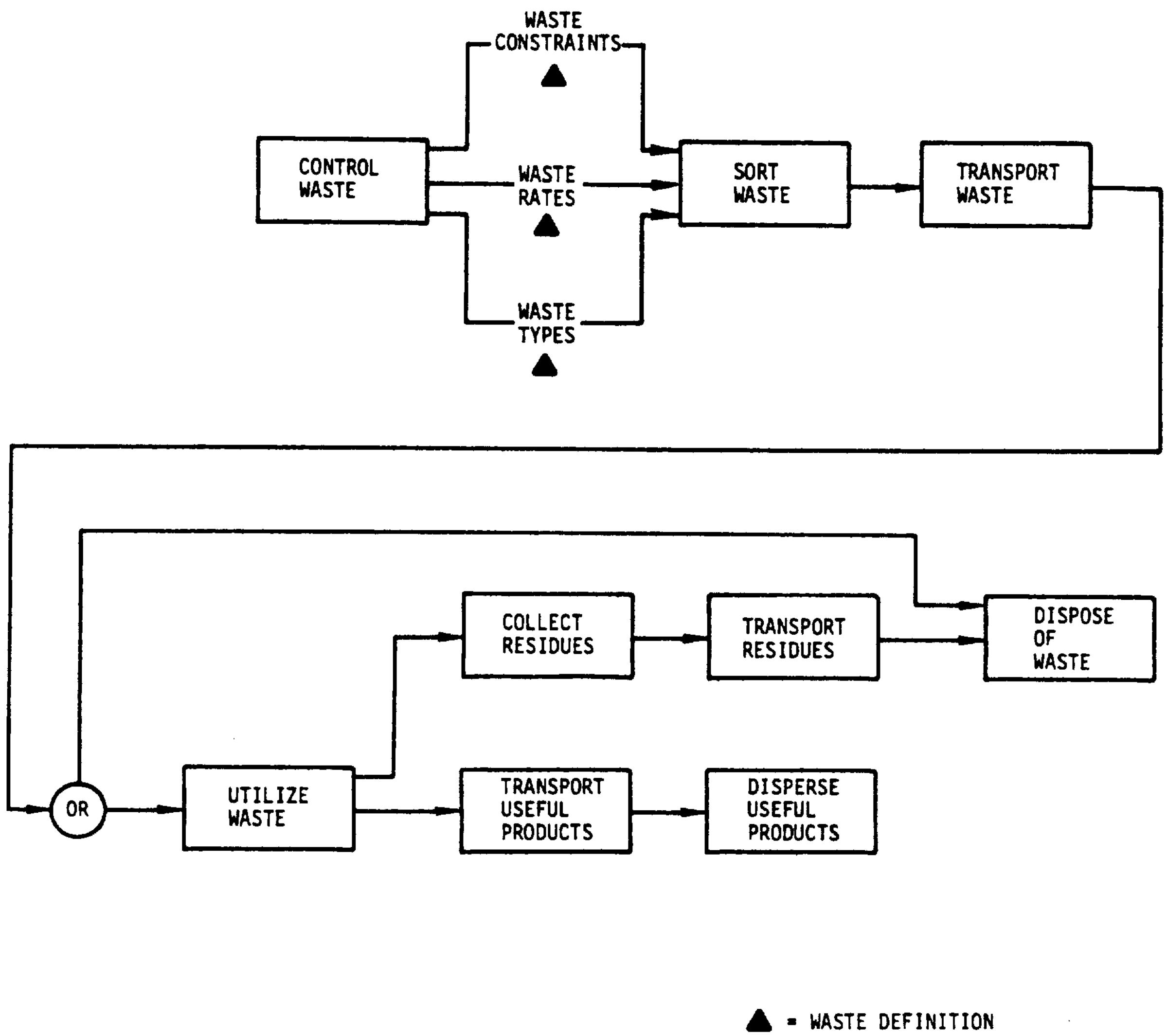

Figure 2-1. Housekeeping Waste Control Tasks

in applicable transporting devices. Transfer will include all movement of waste from collection to final disposition. Sorting will include methods of separating: waste by characteristics, waste containers by types of waste carried and process to be applied, and processed wastes by method of disposal or utilization. Waste handling requirements and concepts are presented in Section 3.

2.1.2 Identification of Utilization Potential. Having identified the consumables and expendables required and the corresponding waste products, the constituents of each can be compared to show whether a correlation exists. The desirability or advantage of replacing consumables and expendables with processed wastes is a matter of economics based primarily on the logistical problem of resupply and the lifetime cost of processing on board, including; the initial processor development, the cost of delivery of the processor to orbit, and the on-board operating cost. Utilization potential is presented in Section 4.

2.1.3 Identification of Waste Utilization Processes. The objective of any waste utilization process is to convert potential waste products into on-board usable items. These processes can be divided into two basic categories: those applicable to generally recognized high volume waste products for which considerable development effort and money have been spent in the past, and those based on generally accepted principles which can serve as basic building blocks in processing development. This last category consists of physical separation (filtration, centrifugation, distillation, sorption), electrolysis, oxidation (incineration, wet oxidation) and decomposition (thermal, bacterial). Waste utilization processes are presented in Section 4 along with their general applications.

2.1.4 Identification of Waste Disposal Processes. Many of the processes for disposal are the same as those used in processing for utilization; therefore, all processes for disposal and utilization are presented in Section 4 along with their applications.

2.1.5 Utilization or Disposition. This area of consideration includes the routines associated with either separating the waste from the habitable vehicle area if it is not to be reutilized, or rendering it ready to be utilized after processing. Utilization and disposal concepts are presented in Section 5.

2.2 PERSONNEL REQUIREMENTS

Based on the definition of the waste sources, waste products, equipment for collection and transfer, utilization processors and disposal means, a method for the assessment of crew functions and requirements should be derived. This rationale should be developed to include the variables due to zero and partial gravity and variables in the size of the crew as it affects housekeeping tasks.

3.0 WASTE HANDLING

Waste handling functions are primarily manual operations involving the use of relatively simple mechanical aids such as containers, vacuum cleaners, grasping tools, and transport systems. These functions include collection, transportation, and sorting of all waste items.

3.1 WASTE COLLECTION

3.1.1 General Requirements.

- Waste receptacles should be provided at the source of waste materials. The type of container within each receptacle should be characteristic of the state and attributes of the wastes generated in that area.
- Waste collection should be accomplished at the waste source and deposited in the receptacle designated for the particular waste attributes.
- The waste pickup task will begin at the receptacles and will include all actions required to secure the wastes in their containers, remove containers from waste receptacles, install new containers and prepare the wastes for transfer to their designated storage areas.

3.1.2 Predesign Considerations. A functional block diagram of the collection parameters which should be considered in the planning of a waste collection system is shown in Figure 3-1.

3.1.3 Concept Descriptions and Engineering Data.

3.1.3.1 Waste Collection Methods. In zero gravity, a vacuum device such as a vacuum cleaner must be used for the collection of particulate solids, vapors, and fluids generated in small quantities. These vacuum cleaners may be individual modules or they may consist of multiple outlets from a centrally located vacuum source. Each outlet may have its own collector bag or the outlets may feed into a central collection canister. Dry bulky solids may be captured manually and deposited into a container designed to retain wastes of this type.

The collection procedures used in partial gravity are similar to those normally used in one g. Solids and liquids may be collected and retained by gravity; gases, particulates and airborne debris may be collected by a vacuum cleaner. Gases are normally absorbed by the air purification

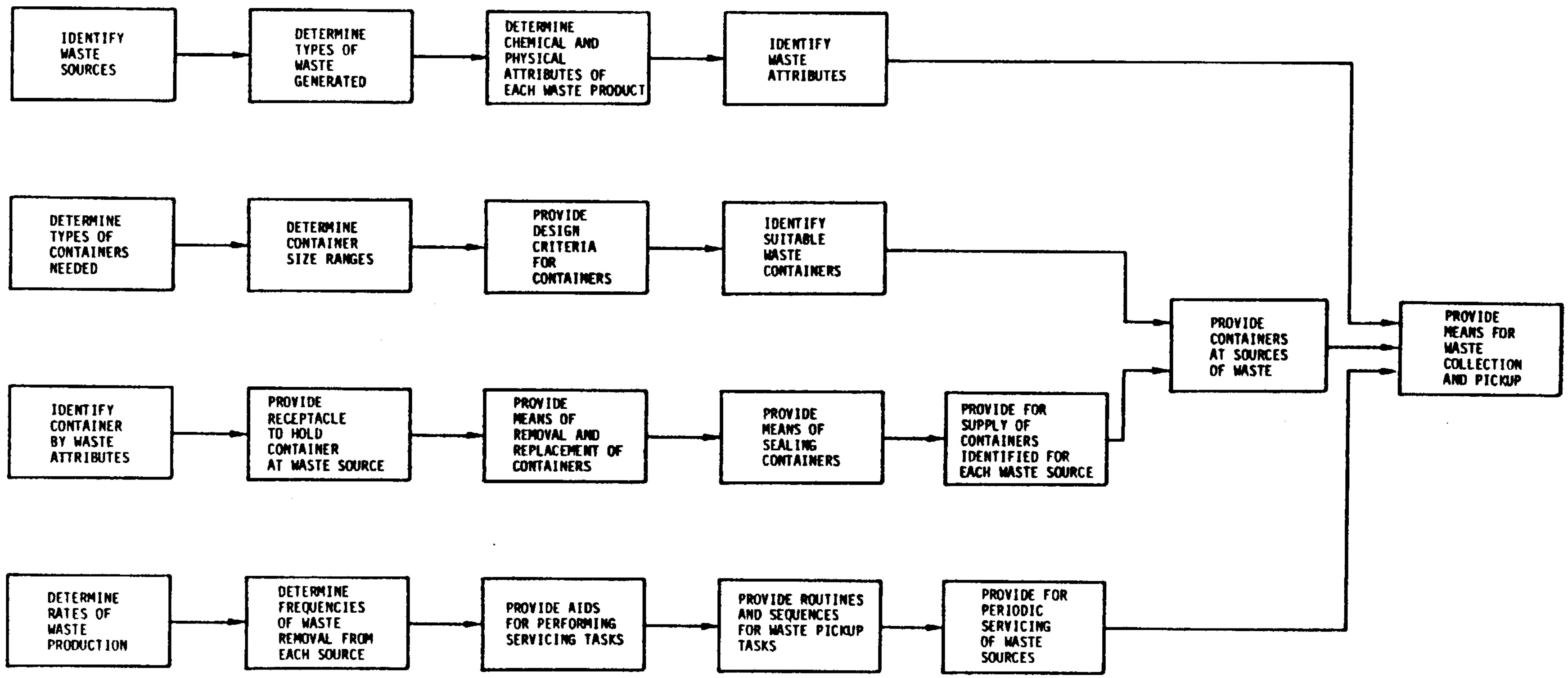

Figure 3-1. Waste Collection Design Considerations

system. Gas collection for analysis in the experimental areas will require the use of a vacuum pump and the types of flasks described in design concepts for gaseous wastes.

3.1.3.2 Waste Container Concepts. Container concepts for the following states and conditions of wastes should be considered.

States	Conditions
Solid	Non-toxic
Liquid	Toxic
Gas	Hot
Solid/liquid mixture	Cold
Liquid/gas mixture	Radioactive

Suitable container types for each state and condition are presented in Table 3-1.

3.2 WASTE TRANSFER

The waste transfer function will embrace all activities required to convey the wastes from pickup points to their ultimate destination. These tasks will include the movement of wastes along corridors, between decks, through hatches and airlocks, along tunnels and into designated storage areas. The equipment normally used in IVA cargo handling will also be used for waste transportation. The transfer task will be a combination of manual subtasks interfacing with the operation of various automated systems.

3.2.1 General Requirements.

- System interface requirements, as described in Volume 1, Mobility and Restraint, apply to transfer of wastes.
- The items of equipment required for transfer of collected wastes include aids for locomotion and associated equipment used to handle waste containers. During transport of harmful wastes, shielding, routes, and transfer times should be such that contamination hazard to personnel and provisions is minimal. When possible, wastes should be deactivated before transfer.

A block diagram identifying the transfer function requirements for waste handling and housekeeping tasks is presented in Figure 3-2.

3.2.2 Predesign Considerations. A functional block diagram of the transportation parameters which should be considered in the planning of a waste control system is shown in Figure 3-3.

Table 3-1. Waste Attributes and Container Concepts

Waste State \ Waste Condition	Non-Toxic, Sterile or Inert	Toxic, Noxious, Contaminated or Active	Hot (Above Safe Skin Contact Temperature)	Cold (Below Safe Skin Contact Temperature)	Radioactive
Solid					
Metal, plastic, glass, textile, paper Flexible, rigid sheet, rod, tube Spongy, bulky, granules, sharp, brittle, dense	Flexible bag	Sealable impermeable bag	Insulated container	Insulated container	Shielded container
Liquid					
Acid, alkali, oil, water, emulsion, gel.	Flexible bag	Sealable impermeable bag	Bag in insulated container	Bag in insulated container	Bag in shielded container
Gas	Flask	Flask	Flask in insulated container	Flask in insulated container	Flask in shielded container
Mixture - Solid and Liquid Suspension, slurry	Flexible bag	Sealable impermeable bag	Bag in insulated container	Bag in insulated container	Bag in shielded container
Mixture - Liquid and Gas	Flask	Flask	Flask in insulated container	Flask in insulated container	Flask in shielded container

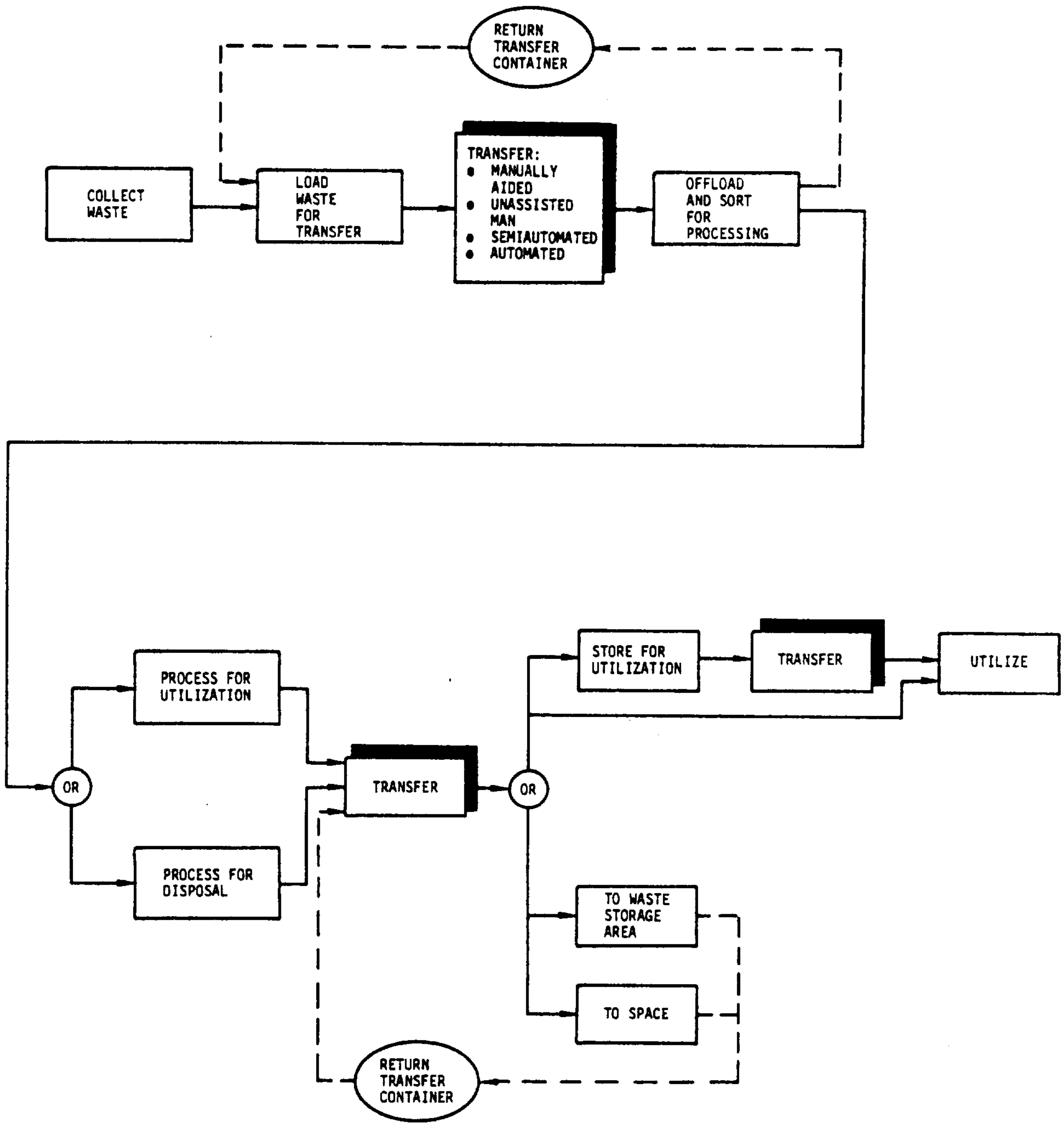

Figure 3-2. Waste Transfer Functions

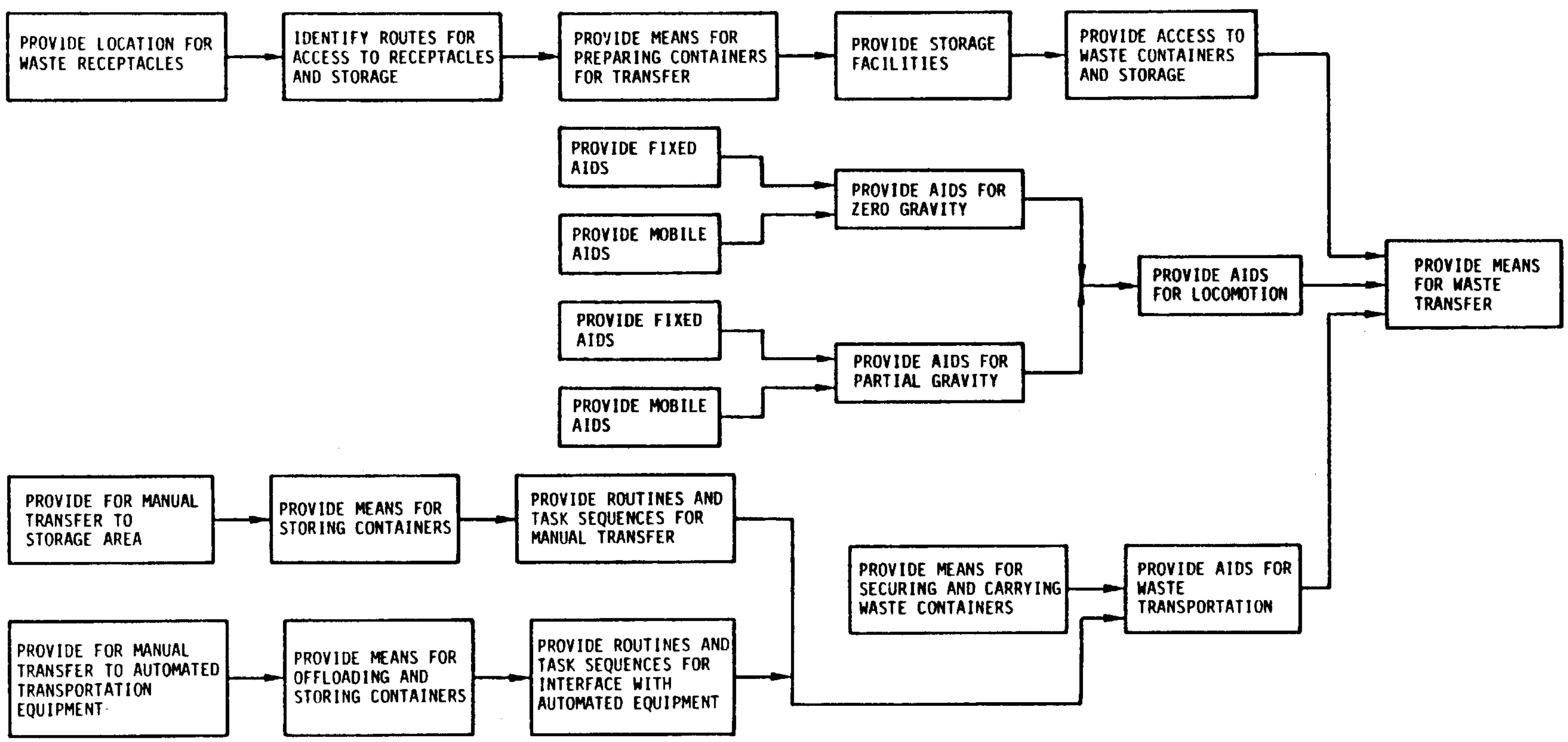

Figure 3-3. Waste Transfer Design Considerations

3.2.3 Concept Descriptions. The transfer of a variety of packages, containers, bulk and specialty items will occur on a periodic basis during the operational life of the space vehicle. Concepts for waste transfer are the same as those applied to cargo and equipment transfer. A description of these concepts may be found in Volume 1, Mobility and Restraint.

3.3 WASTE SORTING

The function of waste sorting will begin at the waste source. Sorting will be performed by segregating identifiable wastes in preparation for final disposition.

3.3.1 General Requirements.

- The waste receptacles should be placarded and coded to indicate the types of wastes to be deposited.
- The container inside each receptacle should bear the same color and number code. By referring to the list of container codes, the contents of the container, their attributes, densities and handling constraints may be readily determined. The codes should be selected so that compatible wastes are collected in the same container. They may then be reclaimed or processed without separation.

3.3.2 Predesign Consideration. A functional block diagram of the sorting system parameters which should be considered in the planning of a waste control system is shown in Figure 3-4.

3.3.3 Sorting Method Concepts. The method of sorting waste will depend on the waste control function to be satisfied. Waste control function decisions and the method of waste sort most useful for each are presented in Table 3-3. This table is based on the assumption that the primary objective of waste sorting is to expedite the disposition of waste.

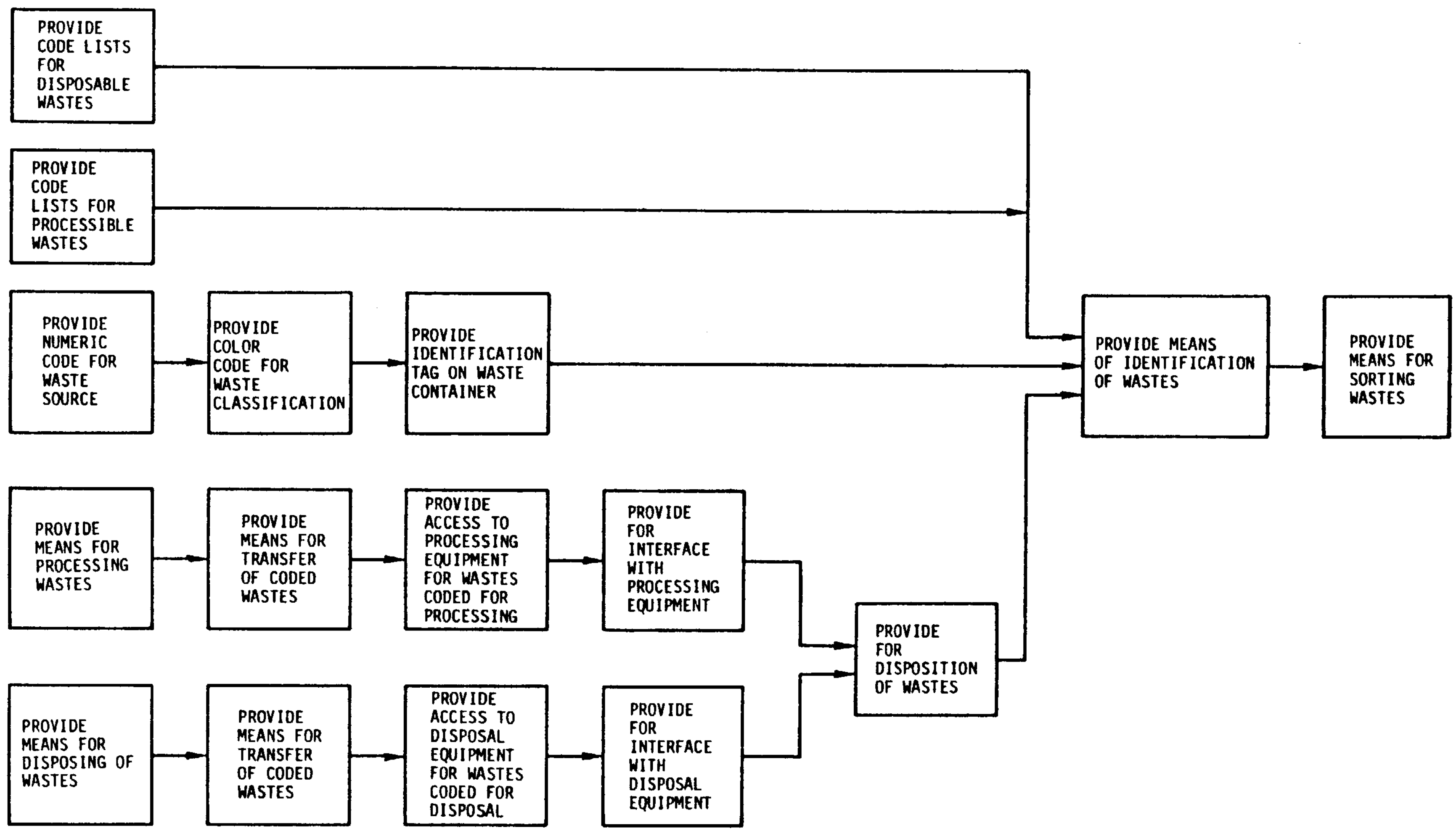

Figure 3-4. Waste Sorting Functions

Table 3-3. Waste Control Function Decisions vs Waste Data Sorts

Waste Control Function Decisions	Useful Waste Sort
Collection Requirements	
Collection routines and equipment	Sort by area of origin Sub-sort by waste characteristics
Sorting Requirements	Sort by area of origin Sub-sort to a destination
Destination Decisions	
Utilize/dispose	Sort by waste type totals; high rates should be analyzed further for methods of utilization and compared to resupply costs
Pretreatment	Sort by waste characteristics that require pretreatment
Handling/transporting	Sort by waste characteristics that require care in handling
Crew Task Decisions	Sort by area of origin Sub-sort by waste characteristics Sub-sort by crew or skill availability

4.0 WASTE PROCESSING FOR UTILIZATION/DISPOSAL

Waste processing will include all functions performed on wastes which prepare it for disposal or utilization. These functions will interface with the waste transfer equipment and personnel requirements both before and after processing.

4.1 GENERAL REQUIREMENTS

- Compactors, macerators, incinerators and similar equipment for waste processing will receive the containerized waste. When the container interferes with the specific process, the contents are processed separately.
- In general, processing would not be continuous or concurrent with the generation of the many types of waste; therefore, storage should be provided on the space vehicle. For this storage and the processing alternatives, various types of prestorage and preprocessing treatments will be required, e.g., deactivation or compaction of the waste.
- The general interface tasks will consist of loading, unloading, and operation of the processing equipment.

4.2 PREDESIGN CONSIDERATION

Before a waste processing system can be designed, the decision of whether to dispose of or utilize the wastes must be made. In order to resolve "utilize/dispose" design decisions concerning waste products, an examination of the probable products must be made and their utilization potential identified. The utilization potential of a waste material can only be determined by an extensive trade-off study for a specific mission with a known resupply arrangement.

4.3 CONCEPT DESCRIPTIONS AND ENGINEERING DATA

Having decided whether to utilize or dispose of the waste, the most applicable method of processing should be chosen according to some predetermined criteria such as product characteristics or size. Many of the concepts presented apply to processing for waste disposal or utilization equally well. For example, incineration of waste clearly was developed for waste disposal, but is described including its potential for mineral recovery.

The waste processing categories presented are:

- Microbial control
- Physical separation
- Electrolysis
- Oxidation
- Decomposition
- Compaction
- Shredding
- Food preparation

The area of microbial control is a special processing category in that it is a preprocessing treatment for both disposal and utilization. The processing methods with a brief summary of waste material accommodated and the utilization potential of each are presented in Table 4-1.

4.3.1 Microbial Control for the General Treatment of Contaminated Waste. The bulk of the waste generated in a space vehicle will require some degree of microbial control prior to its disposal. The basic reasons for controlling the bacterial content of the waste are:

- To prevent transmission of disease and infection
- To prevent decomposition (deterioration) and spoilage
- To prevent contamination

The required degree of control will depend upon the nature of the waste and the frequency at which the waste is isolated from the spacecraft. Aside from deactivating waste for safe storage prior to disposal, microbial control has the additional function of sterilizing certain waste, thereby conditioning it for reuse. Feces, urine, and food waste will represent the major portion of the waste requiring deactivation during its storage period. Soiled clothing, linens, wash cloths, and towels represent the major source of waste requiring washing or sanitization before reuse. All of the methods employed for inhibiting or destroying micro-organisms are based on subjecting them to a chemical substance or to an unfavorable environment. Some of the methods employed are bacteriocidal in nature, the intent being to destroy the bacteria. Other methods are essentially bacteriostatic, and act to prevent the growth and activity of the bacteria. Candidate methods are described in the following paragraphs.

Table 4-1. Summary of Processes for Waste Utilization/Disposal (Page 1 of 2)

Processing Method	Types of Waste Accommodated	Utilization Potential
Physical Separation		
Filtration	Potentially most fluids, acid, alkali, oils, slurries, suspensions, colloids, etc.	Closure of water cycle loop, separation and isolation of mutually contaminating media
Centrifugation	Two-phase mixtures of fluids, single phase mixtures of distinctive density fluids	Separation and isolation of mutually contaminating media
Distillation	Easily volatilized hydrocarbons and contaminated water	Closure of water cycle loop, recovery of contaminated fluids, recovery of dissolved solids
Sorption	Contaminated, low viscosity fluids, water vapor, CO_2, trace contaminants	Purification and recovery of contaminated media
Electrolysis	Waste or excess water	Recovery of oxygen and/or hydrogen
Oxidation		
Incineration	Combustible-oxidizable materials, eg, plastics, textiles and paper	Deactivation and reduction of organic wastes
Wet oxidation	Raw urine and/or feces, urine distillation residue, food wastes	Production of fertilizers and minerals

Table 4-1. Summary of Processes for Waste Utilization/Disposal (Page 2 of 2)

Processing Method	Types of Waste Accommodated	Utilization Potential
Decomposition		
Thermal (Pyrolysis)	Feces, paper, natural textiles, plastics	Production of hydrocarbon fuels and solvents, fertilizer, and minerals
Bacterial (Aerobic/Anaerobic)	Organic wastes; textile, paper, fluids, gels, etc., in a granular or easily granularized state	Disposal of human wastes or contaminated debris needing no pretreatment Production of edible biomass
Compaction	Packaging wastes, full debris bags, compressible failed components, film, paper, wipes	Creation of blocks for radiation or meteorite shielding
Food Preparation		
Physiochemical	Metabolic wastes, feces, CO_2, urine, atmospheric condensate	Creation of carbohydrates
Bioenergetic photosynthesis	CO_2, mineral residue of oxidation	Creation of edible biomass
Bioenergetic non-photosynthesis	Metabolic wastes, feces, CO_2, urine, atmospheric condensate, volatile organic compounds	Creation of edible biomass
Shredding	Solid wastes	Creation of materials which can be compacted into blocks and used for shielding

4.3.1.1 Desiccation. Desiccation, or dehydration of the microbial cell and its environment, imposes a static condition upon the micro-organism because moisture is required for the normal growth processes. The degree of dryness required to deactivate a given material is a function of the salt content of the dried residue. The fecal drying chambers used in a waste management system should be designed to dry fecal material and urine residue to a maximum liquid/solid ratio of .20. Food waste will have to be dried to a greater degree to prevent putrefaction or decomposition. To maintain the deactivated state, the wastes must be kept dry during their storage period. Desiccation concepts employ heat to vaporize moisture in the waste material and vacuum to vent the moisture from the drying chamber. The thermal power and internal chamber volume required to desiccate waste may be derived per the following calculation.

Sample Calculation

Let:

V_c = Internal chamber volume - ft^3

T = Cycle time - hours

U = Usage factor - hours of operation/day

L = Loading factor - $\frac{ft^3 \text{ waste as collected}}{ft^3 \text{ chamber}}$

$\dot{V}$ = Characteristic chamber volume - ft^3/day

$\bar{P}$ = Average power - watts

U' = U/24 - dimensionless

Then:

$$V_c = \frac{\Sigma \dot{V} T}{UL}$$

Given: The waste rate, $\dot{V}$ and $\bar{P}$ can be found from Figure 4-1. These curves are based on 100 percent thermal efficiency and a liquid/solid ratio of .20 for feces and urine and .188 for food waste. The loading factor is dependent on the waste preparation for desiccation and will range from .40 to .80. U and T are process data and will be known.

Then: V_c may be calculated according to the equation above and the desiccator weight corresponding to the dessicator type can be found on the curve of Figure 4-2. The power associated with a given usage factor may be calculated according to:

$$P = \bar{P}/U'$$

Example: A 10-man space vehicle generates 8 pounds of food waste per day, and 12 hours are allowed for processing the waste. What chamber volume and desiccator weight would be required with a loading factor of .40 and a two hour drying cycle? What power is required to process this waste?

$$V_c = \frac{\Sigma\dot{V}T}{UL} = \frac{.20(2)}{12(.40)} = .0833 \text{ ft}^3$$

W_c = 11.2 lb from Figure 4-2 for a static desiccator

$$P = \frac{\bar{P}}{U'} = \frac{65}{0.5} = 130 \text{ watts}$$

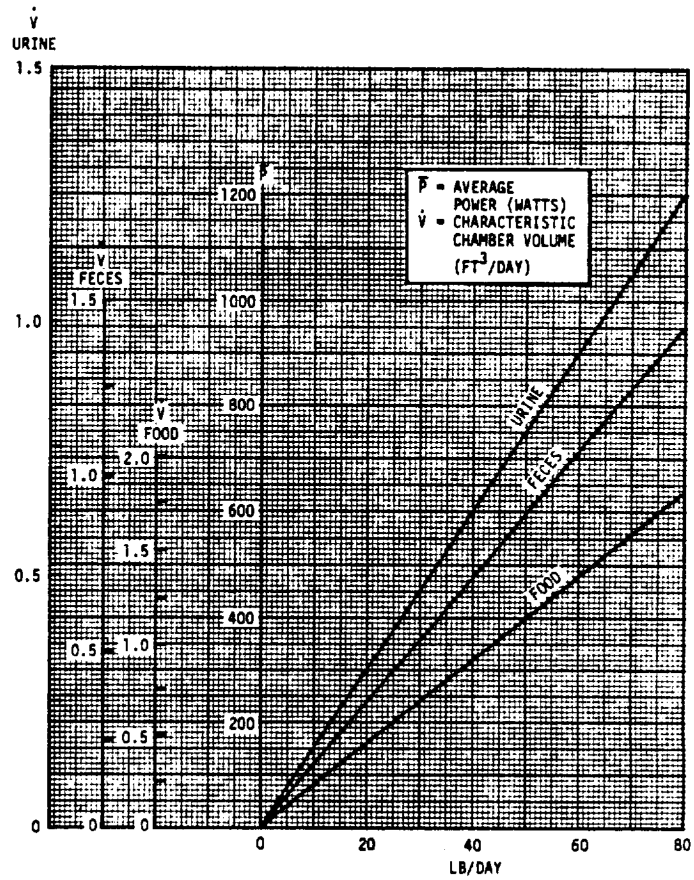

Figure 4-1. Average Power and Characteristic Chamber Volume vs Pounds per Day Dessicated

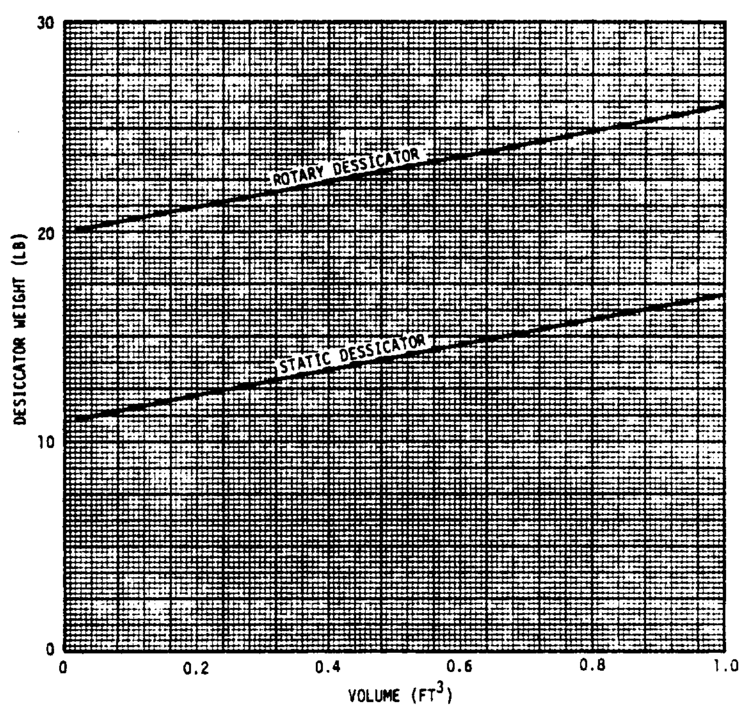

Figure 4-2. Dessicator Weight vs Internal Volume

4.3.1.2 Condensation. Metabolic waste and food waste represent both the major source of waste generated requiring deactivation and the major source of water available for recovery. Approximately 3.25 pounds of water per man-day will be available from urine and food waste. If desiccation is employed as the agent for deactivating the waste, the resultant water vapor can be condensed for reuse. The two concepts presented are the Static Water Vapor Condenser and the Rotary Water Vapor Condenser.

Static Water Vapor Condenser (Figure 4-3)

This concept employs the "Marangoni" effect, i.e., theory of flow caused by surface tension gradients. By passing coolant over the walls of the condenser, a temperature gradient will exist causing the vapor to condense on the walls. The condensed water will be driven along the wall from regions of low surface tension to regions of high surface tension, or from warmer to colder regions. These surface tension forces will also drive the liquid to the corner of a cone or wedge. By employing hydrophilic and hydrophobic surfaces, efficient collection of condensed water vapor will occur at the apex of the cone. The water can then be pumped to a reclamation point.

Condenser area versus pounds per day of waste desiccated is presented in Figure 4-4.

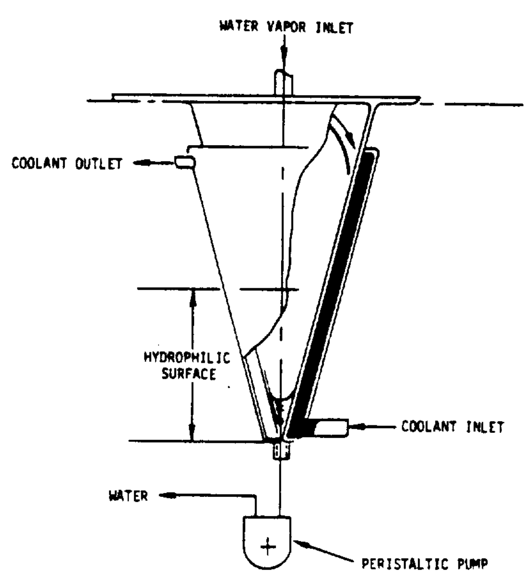

Figure 4-3. Static Water Vapor Condenser

Rotary Water Vapor Condenser

The condenser will receive water vapor that has been oxidized in the presence of a catalyst to remove impurities. Approximately 0.007 pound of oxygen per pound of recovered water will be required for the oxidation process. The purified water vapor will be condensed on a cooled surface within the condenser unit and the condensate will be wiped from the surface and centrifugally forced to a sump within the outer rotating shell. A stationary pitot tube within the sump will be utilized to discharge the condensate to a water manifold.

Ignoring thermal losses, the condenser must reject approximately 100 Btu of heat for each pound of water recovered. The condensing area required for a rotary condenser is shown in Figure 4-4.

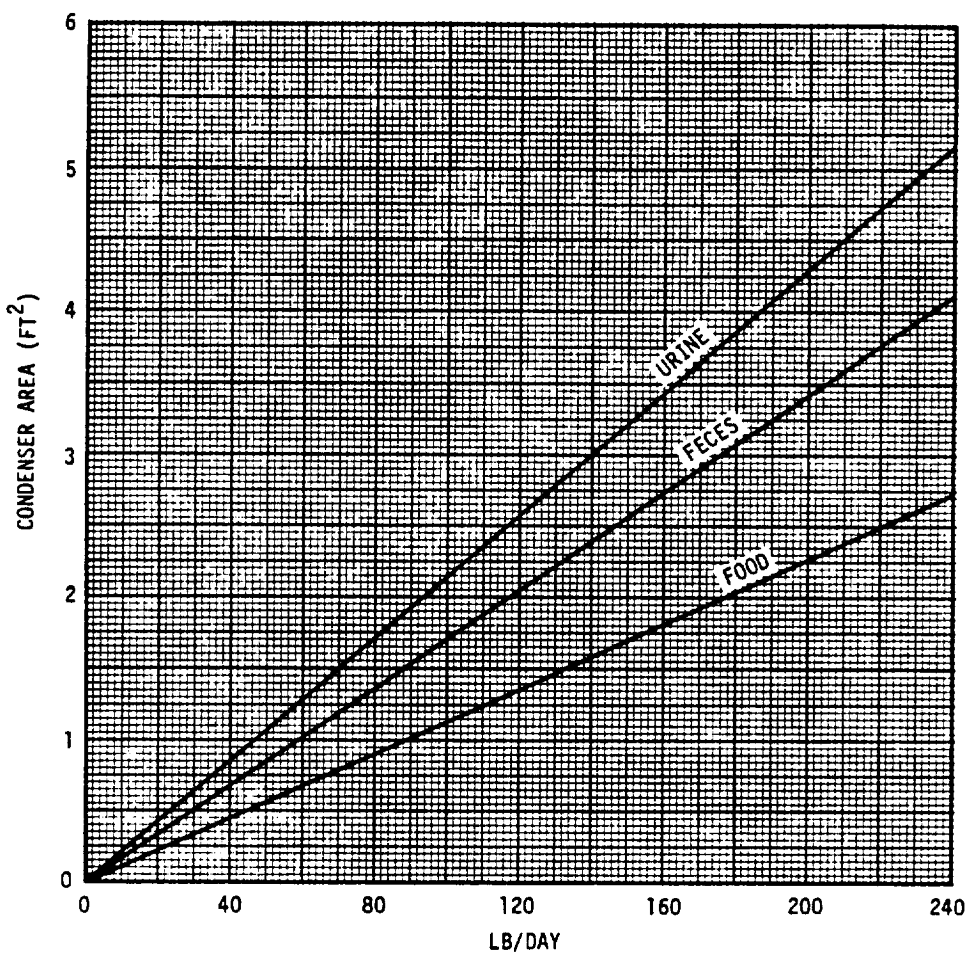

Figure 4-4. Condenser Area vs Pounds/Day Desiccated Waste

4.3.1.3 Refrigeration. Waste material which would deteriorate and produce harmful micro-organisms at room temperature may be kept in a dormant state at temperatures between 34° and 38°F. By decreasing the pressure atmosphere, the inherent free moisture within the waste will cool the waste by evaporation and/or sublimation. A pressure regulating valve on a vacuum line may be used to decrease the temperature to the desired level.

The relationship between the waste temperature and the required weight of water that must be evaporated or sublimated to obtain this temperature is shown in Figure 4-5. The enthalpy of the waste is taken to be that of water and heat loss through the insulation is assumed negligible. Approximately 0.032 pound of water per pound of waste would cool the waste from 70°F to a storage temperature of 36°F.

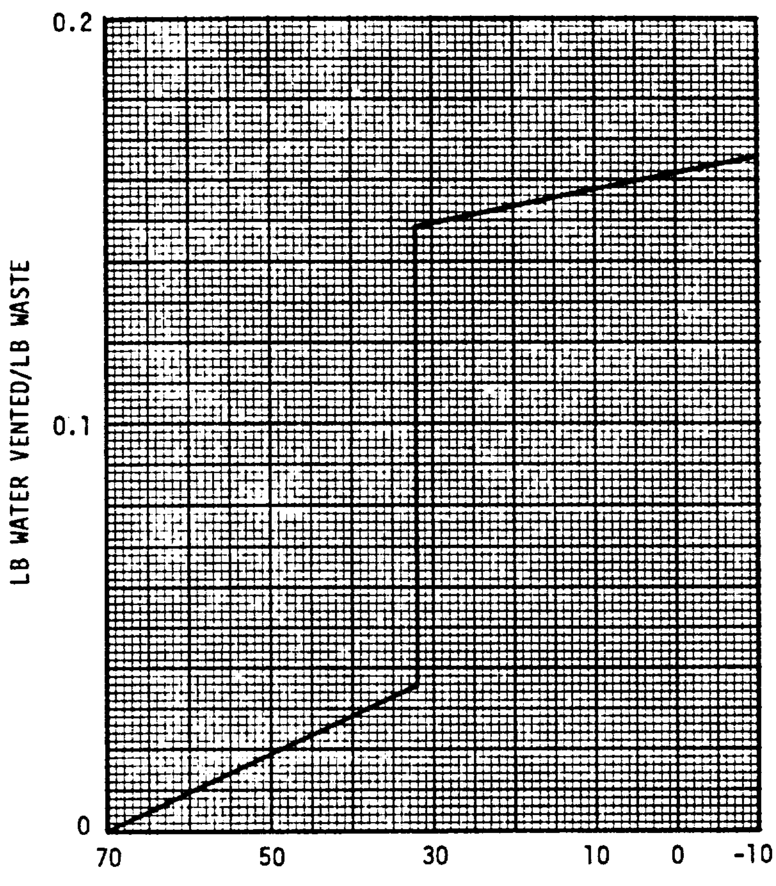

Figure 4-5. Pounds of Water Vented/Pounds of Waste vs Waste Temperature

4.3.1.4 Radiation. The use of sterilization by radiation to control microorganisms in waste may be worthy of consideration in large space vehicles. Both beta and gamma rays can be used to sterilize any living organism without producing lasting radioactivity. Gamma radiation is emitted from certain radioisotopes such as cobalt 60 and cesium 137. Application for radiation sterilization includes such items as sutures, catheters, dressings, bandages, petri dishes, food preservation and animal wastes. Ionizing radiation provides a means of sterilizing at low temperatures. A sterilizing dose of 2.5 megarad is equivalent to 6 calories of heat. The sterilizer should be located in a remote area of the spacecraft so it would not impose a hazard to crewmen. This unit would contain no moving parts and should not require attention. A design concept for a gamma-ray sterilizer is shown in Figure 4-6. The waste (in liquid or slurry form) would be pumped through the unit where it is bombarded with cesium ions and sterilized.

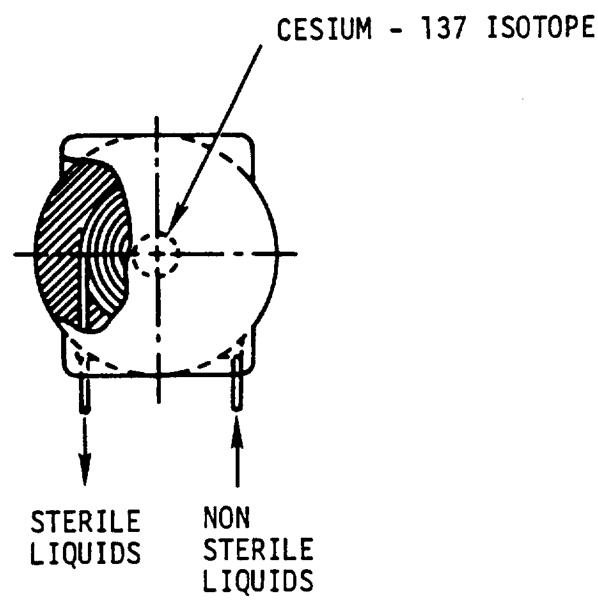

Figure 4-6. Gamma Ray Sterilizer for Liquids

Example:

Determine size of a gamma-ray sterilizer for a 100-man vehicle with a central fecal and urinal waste collection system. The daily waste slurry output from a 100-man vehicle would be 633 pounds or 26.4 pounds/hour if processed on a continual basis. To impact a 2.5 megarad sterilizing dose to this waste, a 208-watt isotope source would be required, assuming an absorption efficiency of 40 percent.

P = (sterilizing dose) (rate of waste sterilized) = Power @ 100% absorption efficiency

$$P = (2.5 \times 10^6 \text{ rad} \times 10^2 \frac{\text{dyne-cm}}{\text{gm rad}} \times 454 \frac{\text{gm}}{\text{lb}} \times \frac{\text{kw-sec}}{10^{10} \text{ dyne-cm}} \times \frac{\text{hr}}{3600 \text{ sec}}) \times (26.4 \frac{\text{lb}}{\text{hr}}) = 83.2 \text{ watts}$$

P' = P/absorption efficiency = power actually required

$$P' = \frac{83.2}{.40} = 208 \text{ watts}$$

4.3.1.5 Germicidal Detergents. Many laundry detergents may be used for microbial control and are discussed in Volume 5, Garments and Ancillary Equipment.

4.3.1.6 Sterilization. The three concepts discussed are: a) the Moist Heat Sterilizer, b) the Dry Heat Sterilizer, and c) Gaseous Sterilization - Ethyl Oxide.

Moist Heat Sterilizer - Autoclave

The autoclave is a sterilizer designed to use 250°F to 270°F saturated steam under regulated pressure to kill microbial cells. High-temperature saturated steam is a dependable agent for sterilization. It has the advantages of rapid heating, penetration and moisture, which facilitate the coagulation of proteins - the mechanism by which the organisms are destroyed. The most resistant microbial forms, bacterial spores, are killed at a much lower temperature and in a shorter period of time by moist heat than by dry heat. The time required to sterilize a material is a function of the nature of the material, its volume, and the type container it is in. A common sterilizing period for an autoclave is 15 minutes at 250°F. The regulated chamber pressure, corresponding to a 250°F saturated steam temperature, is 30 psia. To attain this temperature, air within the chamber must be completely replaced by saturated steam. The effect of a partial pressure of air is to reduce the saturated chamber pressure to that corresponding to the partial pressure of the water vapor. In addition, any air entrainment within the material being sterilized will produce an insulating effect, which would tend to protect the more resistant bacterial spore.

The parameters upon which this concept is based are as follows:

- Incorporate provision for a selection of exposure times at a minimum saturated steam temperature of 205°F
- Eliminate air from the steam chamber
- Provide a capability for sterilizing liquid materials without excessive loss during depressurization
- Provide a means for drying and cooling the chamber and its contents after sterilization (condensate will not drain in zero-g)
- Prevent the steam chamber door from being opened while the chamber is pressurized and prevent the vacuum valve from being opened until the chamber door is closed and locked
- Automate the sterilizing cycle.

The autoclave is capable of sterilizing both solid and liquid material, e.g., surgical instruments, rubber gloves, syringes, flasked solutions, glassware and contaminated linen. Materials immiscible in water and materials adversely affected by 250°F steam, such as oils and powders, are not suitable for autoclaving. The power required to operate an autoclave is essentially that associated with vaporizing the quantity of water required to pressurize the chamber to the degree selected and that required to raise the temperature of the chamber and its contents to the sterilizing temperature. Approximately 0.153 pound of water and 378 watt-hours of energy will be required to heat and pressurize a 1.78 cubic foot chamber to 260°F (35.4 psia). The additional energy required to heat various materials is as follows: water requires 56 watt-hours/pound; aluminum, 15 watt-hours/pound; and glass, 11 watt-hours/pound.

Dry Heat Sterilizer

Dry heat is a good agent for sterilization; however, it requires much higher temperatures and much longer exposure times than does moist heat. For laboratory glassware, a period of two hours exposure at 320°F is required for sterilization. Dry heat destroys organisms through oxidation of their intercellular constituents; i.e., it denatures the organism. Dry heat is ideal for sterilizing oils, petroleum jelly, powders, glassware, utensils, space approved fabrics and any other solid and fluid materials not adversely affected by the high temperatures involved. Aqueous materials would not be sterilized with dry heat due to their low vapor pressure.

The power required to operate a dry heat sterilizer is essentially that associated with raising the temperature of the chamber and its contents to the sterilizing temperature selected. Approximately 207 watt-hours of energy will be required to heat a 1.78 cubic foot chamber to 320°F. The additional energy required to heat a pound of representative non-aqueous material would be 20 watt-hours.

Gaseous Sterilization - Ethylene Oxide

Ethylene oxide gas is a powerful chemical sterilizing agent. Bacterial spores show little resistance to destruction by this agent. It is the most widely accepted alternative to moist or dry heat, being particularly suitable for sterilizing heat or moisture sensitive materials. Ethylene oxide has great penetrating power and is capable of passing through and sterilizing large packages of materials and bundles of cloth. It can also be used for sterilizing a variety of other materials, including biological preparations, soil, plastics, and contaminated laboratory and hospital equipment. Liquid materials would not be sterilized with ethylene oxide. On the negative side, pure ethylene oxide is extremely flammable in air. This condition is circumvented by using mixtures of 88 percent Freon 12 and 12 percent ethylene oxide, or 90 percent CO_2 and 10 percent ethylene oxide. Ethylene oxide sterilant mixtures are also toxic and corrosive.

The sterilization treatment must be strictly supervised since variables such as gas concentration, humidity, temperature and process time can appreciably affect the efficiency of the treatment.

A bottle of sterilant mixture is used for charging the ethylene oxide chamber. Approximately 0.003 pound of water per charge will be required for humidifying a 1.78 cubic foot chamber at a gas pressure of 22 psia to obtain a relative humidity of 40 percent. The chamber should operate at 130°F. Space vacuum may be used to exhaust the chamber air prior to sterilization, and to expel the sterilant gas after sterilization.

4.3.1.7 Isolation. Certain biological waste such as laboratory animal carcasses will take special handling if treated by any of the concepts described in this section. An alternative would be to seal the waste in specially designed high pressure containers and store the containers until final disposal.

4.3.2 Physical Separation.

4.3.2.1 Multifiltration. Multifiltration is a process for the recovery of either constituent of a fluid-particle mixture. The process consists of filtering the liquid through various materials such as charcoal and ion exchange resins to remove contaminants. Candidate materials for this process are acids, alkalis, oils, colloids, suspensions, slurries, and other fluids. The prime current uses are water reclamation from urine, wash water, and environmental condensate.

The consumables required for this process are:

- Carbon filters including activated charcoal in canisters
- Ion exchange resin canisters
- Bacteria filters.

This process may be utilized for:

- Closure of the water cycle loop
- Generation of potable water
- Separation and isolation of contaminants
- Reclamation of applicable fluids other than water.

4.3.2.2 Centrifugation. Centrifugation is a process for the separation of liquid/liquid, liquid/solid, or liquid/gas mixtures. The separation is accomplished by creating a centrifugal force which tends to push liquids or particles of greater density farther away from the axis of rotation. By imparting tangential momentum to the constituents and strategically placing collection tubes within the separator, any particular part of the mixture can be collected.

This type of process will require no consumables other than the power required to pump mixtures and drive the device. This process may be utilized to:

- Close the water cycle loop
- Prepare liquid/gas discharges from water and reclaim any fluid which has been contaminated with nonsoluble contaminants of different densities
- Remove excess moisture from air prior to recirculation
- Separate immiscible fluids of different densities.

4.3.2.3 Distillation. Distillation is the volatilization or evaporation and subsequent condensation of a selected liquid for the purification or concentration of that liquid. The practical distillation systems include various forms of vacuum distillation and humidification which vary by pressure and carrier gas. The candidate materials for this separation process are easily volatilized hydrocarbons and contaminated water. For water reclamation, the distillation process will be used in conjunction with filtration, various chemical pretreatments and posttreatments, vapor compression, and/or vapor pyrolysis. Table 4-2 shows these associated processes, their purpose, and the requirements for implementation.

The distillation process will require no consumables other than electrical power to drive the pumps and heaters. This process may be utilized to:

- Close the water cycle loop
- Recover contaminated fluids
- Recover dissolved solids.

4.3.2.4 Sorption. Sorption is the binding of one substance by another, by any mechanism such as absorption (one substance into another), adsorption (one substance onto another), or persorption (a liquid selectively entering a solid matrix, e.g., sponge). This process may be utilized to purify and recover contaminated media.

Table 4-2. Distillation Processes for Water Reclamation

Process	Purpose	Functions/Characteristics
Evaporation	To separate water from dissolved solids through heat addition, lowering pressure, or both	• Surface boiling in artificial gravity • Flash evaporation across expansion valve • Humidification of circulating gas stream • Humidification of stagnant gas stream
Vapor filtration	To stop bacterial and some organic contaminants	• Vapor permeable membrane
Heat of condensation recovery	To recover heat of condensation by increasing vapor's temperature (and pressure) or by using heat pump	• Vapor compression • Thermoelectric heat pump
Vapor pyrolysis	To oxidize organic vapors and incinerate bacteria	• High temperature catalytic oxidation
Condensation	To recover processed vapor in liquid form	• Surface condensation in artificial gravity • Porous plate condenser-separator • Condensing heat exchanger - porous plate separator • Condensing heat exchanger - rotating separator

Candidate applications for this process are:

- Gas mixtures for the selective removal of contaminants
  - desiccants - silica gel for removal of water vapor
  - molecular sieve - zeolite for removal of CO_2
  - activated charcoal for trace contaminant removal
  - bacteria filters
- Liquids
  - clean contaminated water or other fluids
  - separation of fluid mixtures

The consumables this process will require are the particular sorption agents used and the power to circulate the medium through the agent.

4.3.3 Water Electrolysis. Water electrolysis is a process by which water and/or water constituents, i.e., H_2 and O_2, may be recovered from contaminated water. All water electrolysis processes carry out the electro-chemical process:

$$2H_2O \longrightarrow 2H_2 + O_2$$

Various concepts can be used to accomplish this process. These concepts are distinguished by: source of contaminated water, state of the water in the electrolysis cell, physical and chemical nature of the electrolyte, and system configuration. Table 4-3 provides water electrolysis concepts and associated characteristics.

The primary sources of water to be treated by electrolysis will be from the water management system and vapor in the cabin air. The only constraint on the feedwater will be that it must be relatively free of electrolytes and impurities that could alter the process or products of the process. The only consumables of this process will be water and electrical power. The process will produce H_2 and O_2 as end products which may then be used for other consumables within the vehicle.

4.3.4 Oxidation. Oxidation is a process in which oxygen is chemically united with another element to form a compound with desired properties.

Table 4-3. Classification of Water Electrolysis Concepts

Concept	Feed Water Source	State of Water in Cell	Chemical Nature of Electrolyte	Physical Nature of Electrolyte	System Configuration
Cabin air	Water vapor in cabin air	Vapor	Acid	Liquid immobilized in matrix	Cabin air processed in single pass
Gas Circulation	Water management system	Vapor	Acid or base	Liquid immobilized in matrix	Oxygen or hydrogen recirculated through humidifier and cell modules
Wick feed	Water management system	Vapor	Base	Liquid immobilized in matrix	Liquid water wicked into cell where it evaporates
Ion exchange electrolyte	Water management system	Liquid	Base	Solid	Liquid water supplied directly to cell
Ion exchange membrane	Water management system	Liquid	Acid	Free liquid	Feed water mixes with free liquid electrolyte

4.3.4.1 Incineration. Incineration is the complete oxidation of wastes, using either pure oxygen or oxygen diluted with an inert gas (such as nitrogen), to produce a dry powder-type residue. The incineration process consists of two steps. The first step, after the wastes are sealed in a vacuum chamber, will be to apply heat for a specific time. This time will be dependent on the internal pressure desired (usually about 30 psia). The heating is performed to ensure vaporization and sterilization of the gas and vapor to be exhausted to space vacuum, and to dry the waste so that combustion can follow.

The second step will be to apply heat to bring the incineration chamber temperature to 1000°F, while a controlled flow of oxygen is continuously supplied to the chamber. The incineration process will result in a 97 to 99 percent reduction in the processed waste. The residue remaining will be a dry powder which can be vacuumed from the chamber after a cooldown period.

The waste materials which can be treated by this process must be oxidizable such as plastics, textiles, paper, urine, feces, and food waste. The process consumes oxygen (or diluted gas when used) and power for heating. This process may be utilized for:

- Deactivating complex organic wastes (including biological)
- Waste reduction and disposal
- Producing material for closing the nutrition loop
- Producing fertilizer and minerals.

4.3.4.2 Wet Oxidation. Wet oxidation is a moderate temperature, high-pressure process used commercially on a large scale in industrial sewage treatment plants. The wet oxidation process (known as the Zimmerman process) employs a chamber similar to the incineration and decomposition processes. Waste treatment is accomplished by charging the chamber with 500 psia oxygen at ambient temperature and applying heat to bring the chamber up to oxidation temperature. A study on the feasibility of small scale wet oxidation systems has shown that the use of a base metal oxide catalyst affects not only the rate of reaction, but also the quality of the end products, and is thus highly desirable. The process effluent consists of a dark organic ash and a liquid consisting mostly of carbon dioxide and water with traces of acetone vapor, carbon monoxide, hydrogen, and nitrogen. The oxygen required (approximately 0.05 pound per pound of wet waste) can be obtained by electrolyzing the product water. Solid residue is expected to be approximately twenty percent of the total waste from the effluent. The remainder of effluent, consisting primarily of carbon dioxide and water, may be delivered to the carbon dioxide concentrator for separation. The water portion of the effluent may be delivered to the water management system for processing. The waste materials to be treated by this process are raw urine, feces, cellulose, sucrose, proteins, and amino acid. The process will consume oxygen and power for heating. The nominal process temperature will be 500°F at 2000 psi. Thermal requirements will be approximately 250 Btu per pound of waste treated. The process may be utilized for:

- Deactivation of complex organic wastes (including biological)
- Closure of carbon balance (in conjunction with CO_2 reduction)
- Generation of plant nutrition media through lower level (partial) oxidation.

4.3.5 Decomposition.

4.3.5.1 Thermal-Pyrolysis. Thermal decomposition is a process using high temperature in the absence of oxidizing agents to decompose and volatize organic compounds. The chamber is a pressure vessel with electrically heated insulated walls. The approximate weight of this incinerator versus its internal volume is shown in Figure 4-7. The power required to decompose waste (pounds per hour) is shown in Figure 4-8.

The pyrolysis process will initially use heating (at 250°F and 30 psia) to sterilize contaminated waste. The chamber will then be vented to space vacuum and heating will continue until the waste temperature reaches 1500°F. This will cause approximately 88 percent of the original waste to be vented as vapor. The residue will be loose particulate matter. This residue may be reduced from 12 percent to approximately 3 percent by subsequent oxidation incineration. This additional incineration would require 0.20 pound of oxygen per pound of waste.

Testing has shown that vaporization and pyrolysis of plastics in the wastes results in the formation of solidifying fractions. If these materials are

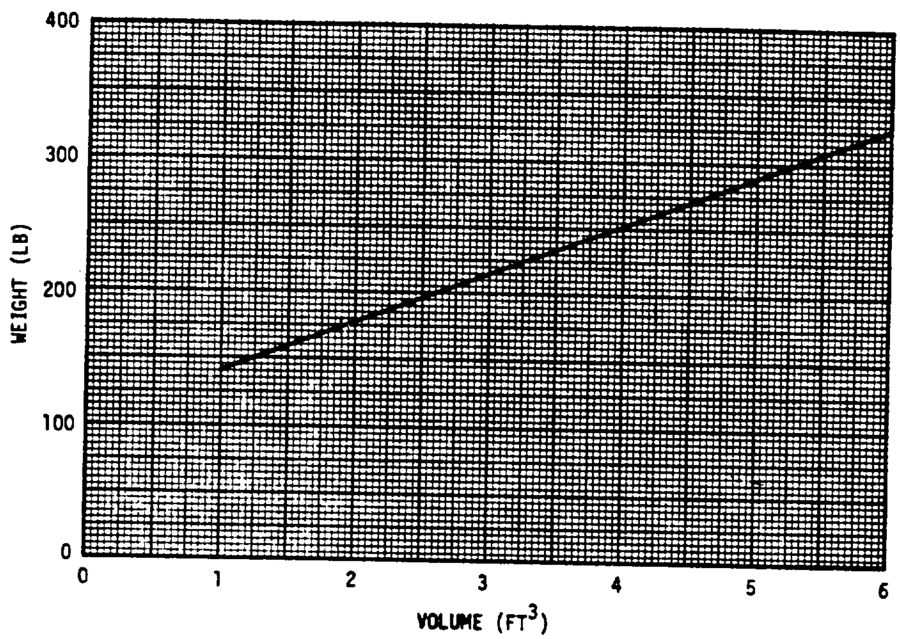

Figure 4-7. Incinerator Weight vs Internal Volume

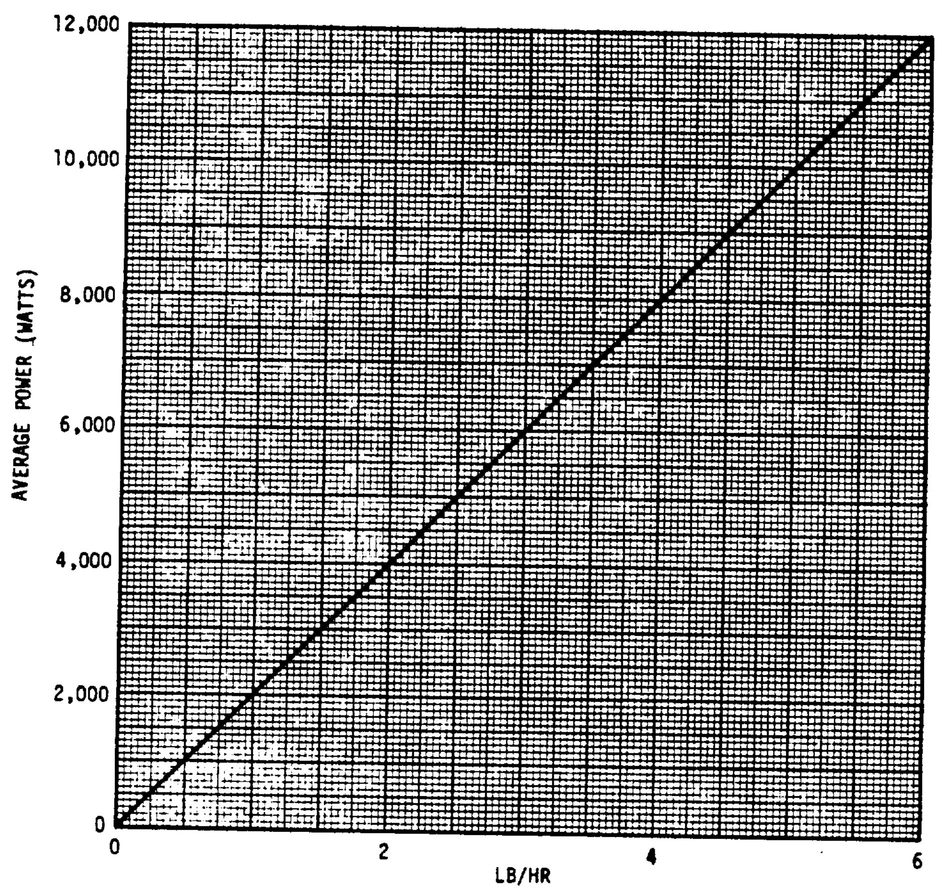

Figure 4-8. Average Power vs Pounds per Hour Decomposed

allowed to condense, the chamber exhaust tubes will clog. Thus, the gases must be ejected at a high temperature and the vent line should be heated. This process will consume only power for heating. The process may be used for any organic wastes.

4.3.5.2 Anaerobic and Aerobic Biodegradation. The biodegradation concept is a biological process in which organic waste compounds are used up by biota in supporting microbial metabolism either in the absence (anaerobic biota) or presence (aerobic biota) of free oxygen. The anaerobic (waste digestion) process results in the production of noxious gases such as H_2S and CO, and pyrimidines and pathogens tend to survive the process; thus, the use of the anaerobic process is questionable for safety considerations.

The aerobic method utilizes an external oxygen supply, is relatively rapid, and results in the production of end products (mostly CO_2) which are not noxious and do not support pathogens. Two principal aerobic processes are available, the activated sludge and the trickling filter processes. While both of these processes are used commercially in sewage treatment plants, little development effort has been encountered in adapting these processes to workable flight systems for spacecraft use. This process may be utilized for:

- Decomposition of human wastes and contaminated organic debris without the need of pretreatment, i.e., sterilization or dehydration
- Production of raw materials and/or biomass for use in closing of food loops.

4.3.6 Waste Compaction. The waste compaction unit will provide high-density compression of wastes, including the waste containers and liners, by utilizing a pressure plate capable of exerting large forces. The pressure plate will force the waste against the opposite end of the compactor. Hardness sensors and self-limiting controls could be incorporated to determine the degree of compaction.

This process will reduce waste volume to about 25 percent of its original volume. The compacted waste package can be utilized as radioactive or meteorite shielding, or possibly some form of thermal barrier if binding agents are added to the debris. The binding agents will stabilize the geometry of the compressed block, inhibit bacteria growth, and provide uniform surfaces.

4.3.7 Waste Shredding. Dry waste could be more efficiently compacted if previously shredded. Candidate wastes include food containers, plastic bottles, and disposable clothing.

4.3.8 Food Preparation.

4.3.8.1 Physiochemical. The physiochemical process is one by which carbohydrates, or particularly monosaccharides, are synthesized from the waste products of humans. This process consumes human wastes and electrical power and produces carbohydrates that can be utilized for production of food.

4.3.8.2 Bioenergetic Photosynthesis. The photosynthetic process of food production is one by which a carbohydrate (saccharoglucose) is formed by exiting H_2O and CO_2 through a chain of energy levels using light energy of visible wavelength. This process consumes light energy and water to produce saccharoglucose, oxygen, and biomass.

4.3.8.3 Bioenergetic Non-Photosynthesis. The bioenergetic non-photosynthetic process is one by which carbohydrates are formed using a bacterium. The bacterium is hydrogenomonas eutrophia and is capable of reducing CO_2 to water in the presence of hydrogen and oxygen. The bacteria has a concentrated high quality protein content and will grow in the dark using salts, hydrogen, oxygen, and nitrogen. The process consumes CO_2, N_2 and metabolic waste to produce water, carbohydrates and protein.

5.0 WASTE UTILIZATION/DISPOSAL

After processing, the waste package requires further handling to remove it to the appropriate area according to the planned waste control function. This waste handling should be accomplished in accordance with the concepts described in Section 3.

5.1 UTILIZATION

The utilization concept must interface with food management, personal hygiene, and other areas using the products of utilization processes. These interfaces will require sorting, packaging, and delivering to the proper place (i.e., refrigeration, storage, and water management).

5.2 DISPOSAL

The disposal concept consists of two methods for final disposition of wastes. These are: (1) removal to a storage area or another vehicle, and (2) direct jettison to space. The first requires only personnel and equipment to transfer the waste package to a predetermined area. Direct jettison to space has been presented as a means for disposing of vapors produced during processing. This method of disposal involves venting condensable vapors which could coat the surfaces of windows, optics, solar arrays, and other special exposed areas causing possible degradation of operating performance. This problem may be partially solved by incorporating a condenser in the vent system to remove these degrading vapors.

6.0 WASTE DEFINITION

This section presents a comprehensive listing of waste items that will be produced aboard a space vehicle. The waste items are listed according to architectural area and functions of a space vehicle. The list includes average weights and densities of the waste items where applicable and the physical characteristics of each item. The rationale for the rate of production of the waste item is presented where there is significant contribution to the gross waste product.

To apply this data to the design of a waste control system, the designer should:

(1) Choose applicable architectural areas for a particular mission, vehicle and crew size

(2) Choose the functions to be performed in that area from those given in the list

(3) Use the waste items listed under that function and the associated data.

Procedure:

To find what waste items are produced in a particular architectural area, turn to the page indicated below. Under the area name, find the function(s) to be performed. The applicable waste items and the data pertinent to the waste items are listed under this function.

The following architectural areas are considered in these lists:

WASTE LIST

Architectural Area: Personal Quarters

Function Performed: Clean or Dispose of Furnishings

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Soiled sheet	1.0	15.0	Fabric	Sheets per day = crew size ÷ 6
2. Soiled blanket	1.0	5.0	Fabric	1 per 180 man-days
3. Soiled pillow case	0.1	15.0	Fabric	Pillow cases per day = crew size ÷ 6
4. Soiled mattress cover	0.7	5.0	Fabric	1 per 180 man-days
5. Pillow	1.0	3.0	Sponge	1 per 90 man-days
6. Mattress	13.5	3.0	Sponge	1 per 90 man-days
7. Lounge cover	1.0	20.0	Fabric	1 per man-year

WASTE LIST

Architectural Area: Personal Quarters

Function Performed: Clean or Dispose of Clothing

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Soiled shirt	0.3	17.0	Textile	0.1 lb per man-day
2. Soiled trousers	1.0	17.0	Textile	0.2 lb per man-day
3. Soiled undershorts	0.2	18.0	Textile	0.1 lb per man-day
4. Soiled undershirt	0.2	18.0	Textile	0.1 lb per man-day
5. Soiled socks (pair)	0.04	12.0	Textile	0.02 lb per man-day
6. Soiled shoes (pair)	1.5	65.0	Plastic	1.5 lb per 180 man-days
7. Soiled jacket	1.0	19.0	Textile	1.01 lb per 90 man-days

WASTE LIST

Architectural Area: Dining Room

Function Performed: Clean Dining Area Facilities

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Uneaten food	N/A	50.0	Food	TBD
2. Spilled food	N/A	50.0	Food	0.5% of total food
3. Soiled napkin	0.05	20.0	Linen	3 per man-day
4. Meal tray	0.8	50.0	Plastic	1 per man per meal
5. Soiled utensils (set)	0.156	70.0	Aluminum and plastic	1 set per man per meal
6. Disinfectant sol	N/A	64.0	Liquid chemical	52.0 lb per 12 man-years
7. Wipe	0.04	6.0	Paper	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Lounge

Function Performed: Provide for Off-Duty Activities

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Paper, writing	N/A	11.0	Paper	5 sheets per man-day
2. Book	N/A	50.0	Paper	*
3. Magnetic tape	N/A	80.0	Plastic	*
4. Micro film	N/A	80.0	Acetate	*
5. Battery	TBD	TBD	TBD	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Galley

Function Performed: Assemble Meals

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Wipe	0.25	20.0	Cloth	4 per 12 men per day
2. Spilled food	N/A	50.0	Food	3% of total food
3. Packaging	N/A	60.0	Aluminum, plastic	0.7 lb per man-day
4. Spilled rehydration water	N/A	62.4	H_2O	0.661 gal per man-day
5. Spoiled food	N/A	50.0	Food	1% of total food

WASTE LIST

Architectural Area: Galley

Function Performed: Clean Utensils

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Food debris	N/A	50.0	Food	TBD
2. Detergent	N/A	N/A	Liquid dissolved in H_2O	0.38 lb per 80.0 lb water
3. Water	N/A	62.4	H_2O	8.0 lb per lb equipment washed
4. Packaging, soap	N/A	12.0	Plastic	5% of soap weight
5. Wipe	0.04	6.0	Paper	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Bathroom

Function Performed: Groom and Clean Body (Local Cleaning)

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Absorbant wipe	0.04	6.0	Paper	22 per man-day
2. Waste water	N/A	62.4	H_2O and impurities	4.5 lb per man-day
3. Empty toothpaste tube	0.2	85.0	Metal and plastic	*
4. Used toothbrush	0.07	35.0	Plastic and nylon	*
5. Razor blade	0.002	250.0	Steel	*
6. Towels, bath	0.25	20.0	Fabric	1 per man-day
7. Soap	N/A	N/A	Dissolved in H_2O	0.004 lb per usage
8. Odor control cartridge	0.92	50.0	Carbon	1 per 500 sink usages
9. Packaging for wipes	0.002	85.0	Aluminum	22 per man-day

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Bathroom

Function Performed: Clean Body (Bath or Shower)

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Dirty water	N/A	62.4	H_2O and impurities	10.0 lb per man-day
2. Filter and trap	0.5	20.0	Plastic and glass	9.0 lb per 6 months
3. Towel	0.25	20.0	Fabric	1 per bath
4. Wash cloth	0.08	20.0	Fabric	1 per bath
5. Soap	N/A	N/A	Dissolved in H_2O	*
6. Soap packaging	N/A	12.0	Plastic	5% of soap weight

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Bathroom				
Function Performed: Collect and Process Urine				
Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Odor control filter	TBD	26.4	Metallic	0.033 lb per man-day
2. Waste water	N/A	62.4	H_2O, urine, chemicals	TBD
3. Bacteria control filter	TBD	66.0	Metallic	0.0011 lb per man-day
4. Penis seal diaphragm	TBD	87.0	Rubber	0.0083 lb per man-day

WASTE LIST

Architectural Area: Bathroom

Function Performed: Collect and Process Feces and Vomitus

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Odor control filter	TBD	40.0	Metallic	0.1 lb per man-day
2. Bacteria control filter	TBD	60.0	Teflon	0.0033 lb per man-day
3. Waste container bags w/feces, vomitus, tissue, chemicals	N/A	64.0	Teflon bag w/cellulose, HCl, H_2O, feces	0.217 lb per man-day
4. Fecal and vomitus collector filters	TBD	5.0	Cellulose	0.0033 lb per man-day

WASTE LIST

Architectural Area: Medical Dispensary

Function Performed: Examine Crew

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Tongue depressor	0.007	15.0	Wood	*
2. Sheet	1.0	15.0	Fabric	Number of sheets per day = crew size ÷ 70
3. Sheet packaging	N/A	12.0	Plastic	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Medical Dispensary

Function Performed: Treat Illness

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Empty medication tube	0.01	5.2	Plastic	*
2. Empty spray bottle	0.04	5.2	Plastic	*
3. Empty pill box	0.01	11.4	Plastic	*
4. Empty medication bottle	0.01	5.2	Plastic	*
5. Disposable face mask	0.01	20.0	Paper	*
6. Band aid	0.001	12.0	Plastic and paper	*
7. Dressings and adhesives	0.02	12.0	Plastic and paper	*
8. Catheter	0.05	20.0	Plastic	*
9. Antiseptic solution container	0.40	30.0	Glass	*
10. Splint	0.1	250.0	Steel	*
11. Gloves	0.02	12.0	Plastic	*
12. Eye patch	0.002	20.0	Paper	*
13. Packaging	N/A	12.0	Paper and plastic	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Medical Dispensary

Function Performed: Clean Dispensary

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Trash hamper	3.0	6.0	Plastic	2 hampers emptied per day
2. Trash hamper bag	0.1	20.0	Plastic	2 bags used per day
3. Wipes with bacteriacide	0.1	20.0	Paper, gauze	Wipes per day = crew size ÷ 3
4. Autoclave cloth	0.2	10.0	Fabric	*
5. Autoclave waste water	N/A	62.4	H_2O and impurities	0.5 lb per cycle
6. Packaging material	N/A	12.0	Plastic and paper	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Dental Dispensary

Function Performed: Examine Crew and Treat Teeth/Gums (No Tooth Drilling and Filling Assumed)

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Dental probe	0.05	250.0	Steel	*
2. Dental mirror	0.10	250.0	Steel	*
3. Extraction pliers	0.20	250.0	Steel	*
4. Scalpel	0.06	250.0	Steel	*
5. Drug bottle	0.30	30.0	Glass	*
6. Anesthetic bottle	0.30	30.0	Glass	*
7. Dressing pad	0.02	12.0	Gauze	*
8. Syringe	0.01	5.6	Plastic	*
9. Head rest covering	0.02	20.0	Paper	*
10. Tooth	Negligible	Negligible	Bone	*
11. Waste water	N/A	62.4	H_2O and impurities	TBD

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Dental Dispensary

Function Performed: Clean Dispensary

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Trash hamper	3.0	6.0	Plastic	1 hamper emptied per day
2. Trash hamper bag	0.1	20.0	Plastic	1 bag per day
3. Wipes w/bacteria-cide	0.1	20.0	Gauze w/bacteriacide	(2 per day) x (crew size ÷ 12)
4. Autoclave cloth	0.2	10.0	Cloth	0.1 lb per day = 5 cloths per day
5. Packaging material	N/A	12.0	Plastic and paper	*
6. Water	N/A	62.4	H_2O and impurities	TBD

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area:	Laundry			
Function Performed:	Process Soiled Articles			
Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Wash water	N/A	62.4	H_2O and impurities	20 times the laundry weight
2. Soap	N/A	N/A	Dissolved in H_2O	1% of laundry weight
3. Soap packaging	N/A	12.0	Plastic	5% of soap weight

WASTE LIST

Architectural Area: Food Storage

Function Performed: Store Stable Food

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Spoiled food in package	N/A	50.0	Food, aluminum	0.1% of total stored

WASTE LIST

Architectural Area: Food Storage

Function Performed: Store Perishable Food

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Spoiled food	N/A	30.0	Food, plastic, aluminum	0.1% of total stored
2. Water (frost)	N/A	60.0	H_2O	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: Photographic Support

Function Performed: Provide Processing Equipment

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Developing solution	N/A	63.0	Liquid, caustic	1.0 lb per lb of film used
2. Empty film cartridge	1.7	24.0	Metal	1.0 lb per lb of film used
3. Discarded pictures	Negligible	80.0	Plastic, caustic	0.1 lb per lb of film used
4. Film scraps	N/A	80.0	Plastic, caustic	0.1 lb per lb of film used
5. Wipe	0.04	6.0	Paper	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

WASTE LIST

Architectural Area: General

Function Performed: Clean Exposed Surfaces

Waste Item	Ave. Weight Per Item (lb)	Ave. Density As Packed (lb/ft^3)	Physical Characteristics	Waste Rate Rationale
1. Dirty sponge head	TBD	3.01	Plastic	*
2. Wash water	N/A	62.4	H_2O, detergent, impurities	2.0 lb per man-week
3. Wipes, towel	0.25	20.0	Textile	*
4. Vacuum cleaner bag w/waste	N/A	60.0	Plastic, waste	*

*Waste rate is negligible but accommodations for the item should be taken into account for overall system design.

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1. "Housekeeping Concepts for Manned Space Systems - Volumes I, IIA and IIB," Fairchild-Hiller Report MS 124 Y0002, 30 October 1970.

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