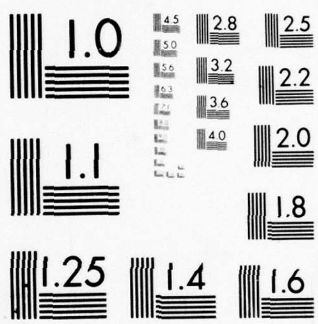
AD-A053 219 ARMY ENVIRONMENTAL HYGIENE AGENCY ABERDEEN PROVING GR--ETC F/G 6/12
MEDICAL FACILITY SOLID WASTE MANAGEMENT, APRIL 1975 - JUNE 1976--ETC(U)
JUN 76 K P STACHIW

UNCLASSIFIED USAEHA-26-0406-78 NL

1 OF 2
AD A053219



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

12
B. S.

SOLID WASTE SPECIAL STUDY NO. 26-0406-78
MEDICAL FACILITY SOLID WASTE MANAGEMENT
APRIL 1975 - JUNE 1976

Approved for public release; distribution unlimited

SERVING THE ARMY IN ITS HEALTH AND ENVIRONMENT PROGRAM

SENTINEL of HEALTH

US ARMY
ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MD 21010

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
Solid Waste Special Study No. 26-0406-78

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
6 Medical Facility Solid Waste Management, April 1975 - June 1976,

5. TYPE OF REPORT & PERIOD COVERED
Final, Apr 75 - Jun 76

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
10 Kenneth P. Stachiw

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
USA Environmental Hygiene Agency, Solid Waste Management Division, Aberdeen Proving Ground, MD 21010

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Commander
USA Health Services Command
Fort Sam Houston, TX 78234

12. REPORT DATE
11 ~~Apr 75 -~~ Jun 76

13. NUMBER OF PAGES
126 12 125 p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
9 Final rept. Apr 75 - Jun 76

18. SUPPLEMENTARY NOTES
14 USAEHA-26-0406-78

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Solid waste management; infectious waste; Army hospitals; landfilling, waste storage, collection, processing and disposal techniques.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The report discusses, evaluates and recommends various waste storage, collection, transportation, processing and disposal techniques. A set of guidelines for selecting, designing, operating and maintaining waste handling and disposal techniques will be provided in future supplemental reports.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

038 150

DEPARTMENT OF THE ARMY
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010

Mr. Stachiw/smt/584-2024

HSE-ES

21 APR 1978

SUBJECT: Solid Waste Special Study No. 26-0406-78, Medical Facility Solid Waste Management, April 1975 - June 1976

HQDA (DASG-PSP)
WASH DC 20310

1. Attached study was performed to determine the best hospital solid waste handling and disposal practices available and to provide guidance for implementing these practices in planned and existing US Army medical facilities. The study included a literature review, a query of Army practices through a questionnaire, visits to civilian hospitals, telephone communications with civilian and military hospitals, and visits and telephone communication with equipment manufacturers.

2. Failure to consider solid waste management during the planning phase was a primary reason for inefficient unsanitary systems found in many hospitals. The practice of infectious waste segregation was found inefficient, unnecessary and usually unsuccessful in achieving its intended purpose. Techniques are available, however, which would provide sanitary inhouse transport of mixed waste. Burial of mixed waste at properly operated and located landfills was found to be a practical disposal technique.

3. The report discusses, evaluates and recommends various waste storage, collection, transportation, processing and disposal techniques. A set of guidelines for selecting, designing, operating and maintaining waste handling and disposal techniques, based on the report's recommendations, is being prepared.

FOR THE COMMANDER:

John P. Piercy

1 Incl
as (10 cys)

JOHN P. PIERCY, P.E.
COL, MSC
Director, Environmental Quality

CF:
HQDA (DAEN-ZCE)
Cdr, HSC (HSPA-H)
Supt, AHS (HSA-IHE)
C, USAEHA-Rgn Div North
C, USAEHA-Rgn Div South
C, USAEHA-Rgn Div West

CONTENTS

DEPARTMENT OF THE ARMY
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010

HSE-ES/WP

SOLID WASTE SPECIAL STUDY NO. 26-0406-78
MEDICAL FACILITY SOLID WASTE MANAGEMENT
APRIL 1975 - JUNE 1976

1. AUTHORITY. Letter, DASG-HCL, Office of The Surgeon General, 10 October 1974, subject: Medical Facility Solid Waste Management and indorsement thereto.

2. REFERENCES.

a. AR 40-5, Health and Environment, 25 September 1974.

b. AR 200-1, Environmental Protection and Enhancement, 7 December 1973.

c. Letter, HSE-ES, this Agency, 24 September 1975, subject: Preliminary Report, Solid Waste Special Study No. 99-014-75/76, Solid Waste Management Program of Active US Army Medical and Veterinary Facilities in CONUS, November 1974 - July 1975.

3. PURPOSE. The purposes of this study are to determine the best solid waste handling and disposal practices available and to provide guidance for implementing these practices in planned and existing US Army medical facilities.

4. BACKGROUND.

a. See Appendix A for a list of definitions.

b. The Office of The Surgeon General has requested that this Agency study and evaluate current hospital solid waste management practices and determine the best practices available to US Army medical treatment facilities. The information would be incorporated in criteria for construction, alterations, additions and replacement of medical facilities where feasible. To accomplish this task a 5-step plan was devised. It included:

(1) Investigation of literature to determine the major problems involved with waste management in hospitals and the waste handling and disposal techniques best suited to solve these problems.

(2) Queries of Army hospitals by questionnaire (Appendices B and C) to determine the state-of-the-art of solid waste management in Army hospitals and the basic circumstances confronting Army hospitals which might influence the selection of waste management techniques and equipment.

(3) Investigation and evaluation of promising waste handling and disposal techniques by onsite inspection of the technique and interviews with personnel directly involved with them.

(4) Correlation of all data obtained to determine waste management equipment and techniques most appropriate for Army medical facilities.

(5) Development of guidelines for putting the recommended techniques into use.

5. FINDINGS AND DISCUSSION.

a. General.

(1) Observations of Nationwide Waste Management Problems. Onsite visits (see Appendix D) and literature reviews reveal that hospital waste management practices are usually characterized by inefficiency, needless complexity and poor sanitation. These characteristics are due primarily to the following:

(a) Poor Planning. In general, most hospital waste handling systems are not planned until the hospital is well under construction. Thus, the hospital is limited to either a manual system or an automated/semiautomated system severely hampered by architectural constraints. Ross Hoffman[1] reports that in 1974, of the 200 hospitals in the country having automated waste handling systems, only a small number of these utilized professional consultants or in-depth studies in selecting these systems. Information developed in this study has verified this statement. None of the hospitals surveyed based selection of their present system on an in-depth study of systems available. Some hospitals did perform studies, but these were usually conducted after their system was in operation and only presented comparison of their existing system to a poorly organized manual system. Finally, hospitals were generally satisfied with their system as long as it removed waste regularly from the building without breakdown. Such factors as cost, poor sanitation and poor use of manpower are essentially ignored as long as the job is accomplished. Only when the system presented continual maintenance problems or complaints from health authorities did hospital administrators begin to investigate other methods.

(b) Poor Waste Handling Practices.

- Waste Rehandling. Esco Greenleaf[2] reports that labor currently represents 90 percent of the hospital solid waste management cost. This is due largely to the inefficient practice of rehandling waste. For example, a typical system might include collection of waste from each room by a custodian; transportation of this waste in a cart to a central storage container on the floor; reloading waste into a cart by another employee; vertical and horizontal transportation of this waste to a central storage location within the building; collection and reloading of the waste at this location and transportation to outdoor storage. In this procedure, waste was handled three times by as many as three different people primarily because of the two interim storage points. Wastes should move directly from generation point storage to the point of final storage or processing without stops. Although unusual situations sometimes make it necessary, interim storage promotes the possibility of cross contamination and squanders valuable man-hours. Elimination of waste rehandling is one of the major aims for improving waste management.

- Quality of Labor. Potential health hazards, social stigma and the unattractiveness of the waste collecting job have resulted in an overall lack of quality labor. These factors have produced a trend in which poorly trained, unskilled individuals are hired to do the job for a relatively high salary. Hence, hospitals often receive unsanitary solid waste handling programs for high costs.

- Misdirected Waste Handling Technology. A possible solution to the labor problem is to replace it as much as possible with automated waste removal systems. However, Esco Greenleaf[2] indicates that 90 percent* of the labor involved in waste handling occurs on the floor level. This statement is important since technology today is essentially focused on facilitating movement of waste away from the floor. Therefore, if these findings are accurate, virtually all waste handling facilities available today (such as pneumatic conveyors, compactors and chutes), while indirectly improving movement of wastes on the floor, are primarily directed at eliminating only 10 percent of the labor. Since the majority of the labor is involved with actual collection of materials from patient rooms, laboratories and offices, an ideal system would automatically move waste directly from the point of generation to final storage (similar to a toilet/sanitary sewer system). Present technology does not provide a facility that can economically accomplish this. Thus, waste storage at the point of generation with manual collection by a custodian are currently unavoidable handling steps.

---

* Although it is not specifically stated, this 90 percent also may include labor involved with removing bed linen and food service trays.

(c) Waste Segregation. Much of the complexity of hospital waste handling systems stems from the practice of segregation of waste into clean and infectious (contaminated). The basic thinking behind this practice is that infectious waste may cause a health hazard if it is not handled and disposed in a special manner. Since special handling and disposal is considered too expensive for all the waste, infectious waste is separated from general waste. However, in reality, the practice results in two or more waste handling systems instead of one as special storage containers, collection routes and disposal systems must be added to accommodate this practice. The practice inevitably results in unnecessary confusion and an intermixture of general and infectious waste, thus defeating the initial purpose of the action. Waste segregation is now being seriously questioned by health authorities and noted hospital consultants. Esco Greenleaf indicates that "* * * separate collection channels for contaminated and noncontaminated wastes cannot be practically or economically enforced in the conventional hospital facility."[2] The Mid-Ohio Health Planning Federation[3] states that "* * * the waste generated in patient care areas could not be segregated from contaminated waste no matter how desirable this might be." Past surveys accomplished by this Agency have revealed the same frequent failure of the waste segregation system to adequately separate waste. Finally, it is this Agency's opinion that all waste coming from patient care areas is <u>potentially</u> dangerous and should be given special consideration. Thus, a system in which all waste is collected and handled together with equal care is preferred and should benefit the hospital both with better sanitation and less cost. {NOTE: Because of aesthetic and religious reasons pathological waste, particularly anatomical waste, must be stored, collected, transported and disposed separately. However, the generation rate is so small [paragraph 5b(3)(c)] and the sources so few that it should have little impact on the overall Solid Waste Management Program. Wastes from patients having rare, dangerous diseases, such as anthrax, also should be excluded.}

(d) Waste Disposal Problems. Hospital administrators generally lack the expertise to select proper waste disposal methods. State restrictions on infectious waste burial have prevented some hospitals from burying all their wastes. Air pollution requirements and overall costs inhibit hospitals from incinerating all their waste. As a result, hospitals resorted to either a disposal system using incineration for infectious waste and landfilling for the rest, thus increasing the complexity of the handling system, or attempting to use an unproven method of waste disposal such as pulping with sanitary sewer disposal. Both practices are still causing numerous problems.

(2) Solid Waste Management Practices in Department of the Army Hospitals.

(a) General. Information concerning US Army hospital solid waste management practices was obtained by sending a questionnaire (see Appendix B) to each hospital. The results, presented in Appendix C, demonstrate a basic pattern for waste management practices in Army hospitals. Waste is usually separated at the point of generation into infectious and clean wastes. Clean waste is stored at the source in containers lined with plastic bags, collected from the source by medical personnel, and brought to a central storage point on the floor. Then the wastes are collected from this point by refuse collection personnel or orderlies and transported by cart to dumpster containers. Infectious waste is collected separately in plastic bags and handcarried to the incinerator for disposal.

(b) Problem Areas. The data shown in Appendix C demonstrate that Army hospitals have many of the problems mentioned in the previous section. Problems involving waste segregation practices have long been a nuisance to Army health officials. Item 12c, Appendix C, indicates that one-third of the Army hospitals responding are having or have had problems with their infectious waste incinerator. Item 4, Appendix C, shows that 61 percent of the hospitals responding use unnecessary interim storage, thus increasing labor costs and potential health hazards. The exclusive use of manual systems in Army hospitals is a good indication that waste management is not considered in the design stages. The manual systems themselves are in all probability haphazardly arranged. The Appendix also shows several potential problem areas not discussed in paragraph 5a(1) including excessive collection frequency (Item 11, Appendix C, indicates a minimum collection frequency of once per day for all hospitals) and improper infectious waste handling (Items 12, 3, 5 and 6, Appendix C, indicate that infectious waste contained only in plastic bags is transported by hand through corridors and patient elevators). All in all, waste management programs in Army hospitals should be upgraded.

(c) Positive Aspects. Although the internal solid waste management programs of Army hospitals have all the pitfalls plaguing the hospitals country wide, the external situations surrounding most Army hospitals are very conducive to upgrading the entire waste management process. A good example is the landfilling of hospital waste. Some States have strict standards for landfill disposal of infectious waste. Notable consulting firms, in reports published for the US Environmental Protection Agency (EPA) and other Federal agencies, speak against the landfilling of even general hospital waste without prior decontamination. The objections generally presented against landfilling are twofold.

- The hospital has no control over the collection practices of refuse collectors. Thus, the collection crew and the community along their collection route may be subject to health hazards.

- The hospital has no control over sanitary landfill practices. Their waste may be subject to scavenging, exposed to potential disease organism transmitters such as rodents and insects, and leached out of the landfill into drinking water sources.

In most cases, however, Army installations have close control over all these practices. Therefore, collection schemes can easily be devised to provide separate, enclosed transportation of hospital waste over special routes. Immediate burial of waste at a landfill properly selected, operated and monitored by the installation will eliminate scavenging, leaching and disease organism transmitter problems. For these reasons, many Army installations could use landfills for disposal of infectious as well as general hospital waste. This possibility can positively influence the internal hospital waste system. If infectious and general wastes can be disposed together at the landfill, they no longer need to be separated within the hospital. All waste could be handled together as potentially contaminated. This would not only reduce the complexity found in waste handling systems but also decrease cost and improve the overall sanitation.

(3) Objectives. If the purpose of this study is to be achieved, the waste handling and disposal systems selected should eliminate, avoid or minimize the problems mentioned in paragraphs 5a(1) and 5a(2). Thus, the following study objectives were formulated which would provide solutions to each of these problems.

(a) Determine storage techniques which would provide sufficient volume and adequate enclosure for mixed, clean and infectious waste for a 24-hour period at the source of generation, facilitate collection procedures and eliminate any need for interim storage on the floor.

(b) Determine the waste collection techniques which require no rehandling of waste, provide adequate measures to prevent cross contamination when both clean and infectious wastes are collected and minimize labor requirements.

(c) Determine the waste transportation techniques which provide sanitary removal of all waste from the floor directly to point of final storage or disposal with minimal manual labor, provide compatibility with collection and final storage or disposal systems and accomplish the above at reasonable costs.

(d) Determine the waste processing and disposal techniques which provide sanitary disposal of all hospital waste at reasonable costs and without producing environmental hazards.

(e) Establish hospital waste management planning, operational and maintenance guides. These would include guides for the selection of waste handling, processing and disposal methods and equipment for specific hospitals, and guides for operating and maintaining these techniques once selected.

The remainder of this report will present and discuss solutions to objectives 5a(3)(a) through 5a(3)(d). These solutions will be incorporated in a supplementary report, Solid Waste Management Design Guidelines: Proposed Revisions for TM 5-838-2, and additional TM's for operation and maintenance.

b. Waste Characteristics. The properties of waste such as quantities, composition and associated hazards must be clearly defined before one can attempt to develop adequate techniques for its storage, collection, transportation and disposal. This section provides a description of these properties for each type of waste generated in the hospital environment.

(1) General Waste.

(a) Definition. General waste is all solid waste generated in the hospital, other than infectious waste, waste drugs, biologicals and reagents, and pathological waste. Common examples include materials packaging, soft drink cans and newspapers.

(b) Sources. Table 1 presents a qualitative and quantitative guide of the sources of all solid waste in a given hospital. The Table demonstrates that the majority of general waste is generated by the dining facilities and the nursing stations.

(c) Quantities. Accurate waste generation data are essential to adequately plan for waste handling and disposal, equipment and personnel. An easy method for estimating it would be to research the average daily waste generation rate. Unfortunately, literature provides a wide range of waste generation rates (ranging from 4.3 lbs/patient/day[4] to 30 lbs/patient/day[5]). One reason for this diversity is the variable use of disposable linen and food service items. Use of disposable trays, knives, forks, plates and bed sheets can increase waste production by 250 percent. (Because of this potential increase, it is recommended that disposable linens and food service utensils not be used except where significant reduction in cross contamination has been proven.) Another reason is the diversity of activity in a given hospital. For example, a 300-patient hospital with a research center or nursing school will generate more waste than a 300-patient hospital without these activities. Three methods for waste generation rate determination have been formulated which account for these factors and other considerations and are presented in Appendix E, along with the relative advantages and disadvantages of each. All three methods are recommended as each provides special information which the other two do not. Further, use of all three is encouraged for cross checking. Appendix F provides sample calculations to illustrate their use. Finally, if planning is being done on an existing facility, the best method for generation rate determination is to weigh all refuse for a given period of time. The planner must decide how important accuracy is to his plans since weighing can be time-consuming and costly.

TABLE 1. SOURCES OF SOLID WASTE WITHIN A HOSPITAL

Generating Sources	Type of Wastes Generated: General Waste	Infectious	Pathological	Hazardous	Percent Contribution to Overall Waste Generation (Percent by Weight)
Administrative Offices	X				1.60
Central Supply	X				0.84
Teaching Facilities	X		X		0.03
Construction & Demolition	X				0.22
Dietary Facilities	X				49.00
Emergency	X	X	X		0.82
Extended Care	X	X			0.54
Grounds	X				0.36
Hospitality Shop	X				0.94
Housekeeping	X				0.13
Intensive Care	X	X			0.46
Isolation	X	X			0.26
Laboratories	X	X	X	X	2.10
Laundry	X				0.46
Maintenance	X				0.34
Maternity	X	X	X		3.80
Morgue	X	X	X	X	0.04
General Nursing Stations	X	X			20.00
Outpatient Department	X	X			0.24
Pediatric Care	X	X			0.85
Pharmacy	X			X	0.74
Physical Therapy	X				0.05
Psychiatric Care	X				0.20
Public Areas	X				0.29
Residences	X				0.76
Storerooms	X				1.20
Surgery	X	X	X	X	4.50
X-Ray	X			X	1.10
Mixed, Other & Unknown	X				8.30

Table made from information found in "Hospital Solid Waste Disposal in Community Facilities," School of Public Health, University of Minnesota, May 1971. [18306, SWIRS]

(d) Composition. General waste composition is particularly important for selecting waste processing and disposal equipment. For example, if the waste contains a high concentration of noncombustibles, incineration would not be effective. Also, it would be unwise to use floor compactors with waste having high moisture content. Composition data also are needed for specific design considerations. For example, accurate Btu values obtained from waste composition are necessary to design incinerators to meet increasingly strict air pollution requirements. Unfortunately, most composition data presented in the literature (examples in Table 2) are not specific enough for design purposes. Combustibles could have a Btu value of 6,000 Btu/lb or 14,000 Btu/lb dependent upon the plastic concentration. Another example of information omitted by this type of data is whether the items listed, such as noncombustibles, are compactible or pulpable. If the majority of the noncombustibles were made of metals, they would not possess these characteristics. Data must be broken down into more basic components for disposal systems to be properly selected and designed. More usable data are presented in Table 3. The two sets of composition data compare well with one notable exception, the concentration of plastics. Although the data can be used for processing/disposal design purposes, design should be based on data from actual sampling, particularly if incineration is planned. If this is impossible, this Agency should be contacted for assistance in incinerator design.

(e) Hazards. Currently, there are two schools of thought concerning hazards of general hospital waste - one indicating that hospital waste presents no greater hazard than domestic solid waste; the other saying that all hospital waste is a potential carrier of hazardous microbiological organisms and should be handled with appropriate care. Findings of this study indicate that, because of the impossibility of separating infectious from general waste, general hospital waste will normally be contaminated with waste considered infectious. Even if infectious waste could be accurately defined and scrupulously separated, general waste is still likely to be contaminated simply because the infectiousness of many patients is unknown. Any patient, particularly those whose ailments have not been completely diagnosed, could generate waste which is contaminated with infectious microorganisms, but classified as general. Therefore, the health hazards associated with general waste can often be the same as those associated with infectious waste. Thus, it is probably best to handle both in the same manner.

TABLE 2. TYPICAL COMPONENTS OF HOSPITAL WASTE PRESENTED IN LITERATURE

1. Components from EPA "Solid Waste Handling and Disposal in Multistory Buildings and Hospitals.[2]*

   Sharps, Needles, Blades
   Surgical, Pathological
   Soiled Linen
   Rubbish or Mixed Refuse
   Patient Care Items
   Noncombustibles
   Garbage
   Food Service Items

2. Components from "Hospital Solid Waste Management in Community Facilities:"[6]

   Garbage
   Combustible Rubbish
   Construction Waste
   Biological Waste
   Noncombustibles
   Yard Waste
   Mixed Unknown

* This report was sponsored and approved by EPA.

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE 3. GENERAL WASTE COMPOSITION DATA

Waste Component	Source A[1] (Percent by Weight)	Source B[3] (Percent by Weight)
Paper and Cardboard	60.0	66
Plastics	21.0	6
Rubber	0.5	Included with Plastics
Textiles, Cotton, Synthetics	7.5	0
Animal Products	0.5	Trace
Wood Products	1.5	0
Food Products	1.0	16
Glass, Metals, Noncombustibles	8.0	10
Miscellaneous	0	2

(2) Infectious Waste.

(a) Definition. Numerous definitions for infectious waste (also called contaminated, biological or medical waste and many other names) appear in the literature. The confusion resulting from so many definitions has contributed greatly to the problems in separation practices. Appendix G lists several of these definitions. The following definition was chosen because it was simple and it best fit the needs of the report. "Waste originating from the diagnosis, care and treatment of a person or animal which has been or may have been exposed to a contagious or infectious disease."[7] Note that this definition includes wastes from the clinical laboratory since waste generated here is often related to disease diagnosis. It also implies that any waste related directly to patient care is considered infectious since all patients in a hospital may have been exposed to contagious disease.

(b) Sources. A significant number of sources generating infectious waste are provided in Table 1. The number of sources help demonstrate the problem involved with providing special storage and collection for this type of waste.

(c) Quantities. Infectious waste quantities are only important when a hospital plans to dispose of it separately from general waste. In this case, quantities are necessary for planning storage and collection requirements and are indispensable for incinerator design. Infectious waste quantities are usually expressed in the literature as percentages of total solid waste generation. Although the percentages reported generally range from 4 to 10 percent, estimates as low as 1 percent and as high as 50 percent also have been published. This wide range of percentages is due, at least, in part to these three variables: the type of facility sampled (i.e., university hospitals tend to do more research and hence generate more infectious waste than municipal hospitals); the definition of infectious waste used; and the adherence of the staff to that definition in the actual practice of infectious waste storage and removal. Unlike the variables associated with general waste, these do not conform to a particular predictable pattern. There is no way of predicting what definition a planned hospital will use and how well it will adhere to it. If an existing hospital already has a definition and a plan of separation, waste generations are easily and more accurately measured by weighing. Thus, if infectious waste must be source separated, generation rates should be determined by actual weighing. If this is impossible, planning officers should contact the Solid Waste Management Division, US Army Environmental Hygiene Agency, for technical assistance.

(d) Composition. Composition of infectious waste is important only if these wastes are to be separated and disposed by incineration. In this case, for reasons listed in paragraph 5b(2)(d), accurate data is needed to properly select and design it. Because this waste is considered harmful and obnoxious, few composition studies have been performed in which the components were actually measured. To date only one source, Brewer,[8] has been found which presents specific useable composition data for infectious waste. Composition data from a study completed recently at General Leonard Wood Army Hospital, Fort Leonard Wood, Missouri, are presented with Brewer's data in Table 4. Although the data compare extremely well for most items, plastics have somewhat divergent data. Since plastics will have the greatest Btu input as well as air pollution potential, an accurate fix on its concentration is essential for incinerator design. Thus, if plastic concentration is needed for design purposes, data in Table 4 are not helpful. Actual sampling is necessary to obtain it.

TABLE 4. INFECTIOUS WASTE COMPOSITION DATA

Component	Source A[8] (Percent by Weight)	Source B* (Percent by Weight)
Glass	17.93	20
Metal	2.63	1
Paper	35.85	36
Plastic	18.51	29
Organic	6.68	9
Rubber	Included in Misc	1
Cloth	10.33	4
Wood	1.53	0
Miscellaneous	6.64	0

* Letter, HSE-ES, this Agency, 19 September 1975, subject: Infectious Waste Characterization - General Leonard Wood Army Hospital

(e) Hazards. The hazardous nature of infectious waste is also in question. Some private hospitals surveyed do not have any special handling or disposal considerations for infectious wastes. However, many major hospital engineering consultants and Federal agencies confirm that infectious wastes have significant disease transmission potential and should be considered a biological hazard. Ross Hoffman Associates[1] report that "* * * due to the nature of the waste and their generation points, they contain proven pathogenic organisms present in high concentrations, particularly if an organic substrate is present. Tests of waste sampled have shown Bacillus* organisms are most prevalent, particularly streptococci and staphylococci." They also say "the recorded biological hazardous nature of hospital wastes indicate that housekeeping practices used in collecting, transporting, centralizing, reducing and removing these materials off-site must be excellent at all times." The EPA publication "Hospital Wastes"[9] also has indicated that pathogens may be found in the wastes in high concentrations. Additionally, virus survival studies quoted in the same publication demonstrated that almost all materials found in hospital waste can become vehicles for transmission. Until infectious waste can be conclusively proven nonhazardous, it should be given special treatment for handling and disposal. In like manner, since general waste is likely to be contaminated with infectious waste, all patient-care waste should be given the same special treatment for handling and disposal.

* Streptococci and staphylococci are not bacillus organisms. This statement is in error. However, the point is still conveyed as streptococci and staphylococci are still pathogenic microorganisms.

(3) Pathological Waste.

(a) Definition. Pathological waste for the purposes of this report refers to high moisture content waste (70 percent water by weight or greater) such as animal carcasses or body parts.

(b) Source. Sources of pathological waste are listed in Table 1. These are much fewer in number than infectious waste sources.

(c) Quantities. Pathological waste contains materials such as human body parts which are frequently required by State law to be disposed by incineration. Hence knowledge of this waste generation rate is important for planning, since this material will have to be separated and incinerated. Data found in reports by Ross Hoffman[1] and the Mid-Ohio Health Planning Commission[3] indicate pathological wastes generally form less than 1 percent of the overall waste load. One percent of the general waste load should provide an adequate generation rate for planning purposes.

(d) Composition. See definition, paragraph 5b(3)(a).

(e) Hazards. Pathological waste provides excellent substrate for microorganisms regardless of what it was previously in contact with. Thus, pathogenic organisms may be present there at any given time and the material should be given the same special treatment or more extensive treatment as infectious waste.

(4) Drugs, Biologicals and Reagents.

(a) Examples. A listing of chemicals commonly found is presented below.

Boric Acid	Chloroform
Hydrochloric Acid	Copper Sulfate
Nitric Acid	Iodine Crystals
Orthophosphoric Acid	Mercury
Phosphoric Acid	Phenol
Potassium Hydroxide	Potassium Dichromate
Sodium Hydroxide	Potassium Permanganate
Sulfosalicyclic Acid	Silver Nitrate
Sulfuric Acid	Sodium Dichromate
Trichloroacetic Acid	Sodium Fluoride
Benzene	Toluene
Carbon Disulfide	Xylene
Carbon Tetrachloride	Zinc Chloride

(b) Sources. Sources of this waste are limited primarily to the laboratory and pharmacy.

(c) Quantities. Since this classification is made up largely of chemicals with differing shelf lifes and uses, generation rates are highly variable and are not found in the literature.

(d) Composition. Self-explanatory.

(e) Hazard. A variety of hazards are presented here depending upon the chemical being considered. Some common hazards presented by these chemicals are explosion, fire and poisoning.

c. Storage.

(1) General. Storage of wastes is defined as "the interim containment of accumulated materials in either loose, compacted or other processed form prior to subsequent handling, processing or disposal."[10] This section will deal with storage practices for the floor (see definition, Appendix A) or unit level including both storage techniques as well as storage equipment available. Final storage of hospital waste in bulk containers will be addressed in the processing and disposal section.

(2) Description and Evaluation of Storage Practices.

(a) Generally, containers are provided at the source of waste generation. Container sizes are governed by the quantity of refuse generated at each source (with high generating sources such as nurses' stations provided large 32-gallon containers and low generating sources such as patient rooms provided wastepaper baskets). Containers are usually lined with plastic or paper bags. The practice provides a number of benefits including storage of infectious waste without fear of cross contamination, easier collection, reduced cleaning frequency, reduction of cleaning time by a factor of five[6] and reduced wear on the containers. Containers without liners are not good for storage of infectious waste. Even when they are used for general waste, they will require daily cleaning for aesthetic and sanitation purposes. Although this practice eliminates the cost of the bags, additional cost for separate storage of infectious waste and manpower required for frequent cleaning nullifies this benefit. Lined containers are clearly preferred.

(b) Another common practice is to gather waste from generation point storage and restore it on the floor (secondary storage) usually in large 55-gallon containers, floor compactors, or uncontainerized. This practice, discussed in paragraph 5a(1)(b), is clearly inefficient, uneconomical and sometimes unsanitary, and should not be used. A case may be raised for secondary storage in floor compactors since volume reduction is achieved. This is discussed in detail in paragraph 5c(3).

(3) Floor Compactors.

(a) A floor compactor (or mobile compactor) is a machine that reduces the volume of solid waste by forcing it into a disposable container. It is designed small for internal office or hospital use and produce refuse cubes ranging in weight from 75 to 175 pounds. In hospitals, it is frequently found on each floor for secondary storage of wastes.

(b) The use of mobile compactors, however, is currently of questionable value. Unpublished hospital surveys conducted by this Agency have indicated that mobile compactors can present the following problems:

- Cost. Compactors have high initial cost and require additional funds for maintenance and the purchase of cartons or plastic bags to house refuse cubes.

- Manpower. Due to added tasks (compactor loading, unloading and cleaning), waste handling systems employing compactors ultimately can consume more man-hours than simple manual systems (see Table 5).

- Sanitation. Compactors require daily emptying and cleaning to keep them sanitized and free of noxious odors. Cleaning times as high as 1 hour per unit have been reported.

The three most publicized advantages of floor compactors are reduction in central storage volume requirements, reduction in time required to transport refuse from the floor to the central storage area, and reduction of floor waste storage space requirements. Stationary compactors, however, can render an equally effective means of reducing central storage volume and collection requirements. Table 5, presents a good illustration of how compactors actually add to the tasks and the total time of the overall waste handling system. The table also shows that the system becomes more inefficient as more compactors are added. Finally, a good solid waste system minimizes the number of rehandling steps. Waste should move directly to the point of final storage with few, if any, stops. For this reason, secondary storage of waste on each hospital floor is undesirable and should be eliminated, not reduced. Compactors may indeed prove useful where centralized storage of waste on each floor is necessary and access through the hospital to the final storage area is limited. However, this equipment, in general, is not recommended and a thorough study should be done to justify their use before they are implemented.

TABLE 5. COMPARISON OF ESTIMATED DAILY TIME* REQUIREMENTS FOR FLOOR SOLID WASTE SYSTEMS WITH AND WITHOUT COMPACTORS

Description of Time Requirements (Unless Otherwise Indicated)	None	Compactors (per floor) 1	3
Collect refuse from each room	50 min	50 min	50 min
Pack bags in compactor (assuming) 30 s per cycle, 50 bags per floor)	-	5 min	5 min
Unload compactor (assuming 1-1/2 mins to unload compactor)	-	3 min	4-1/2 min
Clean compactors (assuming daily cleaning taking approximately 20 mins each, although greater time requirements have been recorded)		20 min	60 min
Number of trips to outdoor storage (assuming carts hold 75 lbs of refuse. Compactors create 100-lb cubes with a typical floor generating approximately 200 lbs/day)	3	1 to 2†	1 to 3†
Bring loads down to stationary compactors (assuming 10 min round-trip)	30 min	10 to 20 min	10 to 30 min
Total daily time required per floor	80 min	88 to 98 min	129-1/2 to 149-1/2 min

* No actual measurement was used to obtain the data; the data presented are estimated.

† Good sanitary practice will require removal of waste material from compactors at least once per day. Thus, the numbers listed are the daily trips required for combined and individual transporation of refuse cubes to outside storage respectively. Note, however, that cart requirements, cube storage requirements and the difficulties presented in handling dense cubes may eliminate combined transportation of refuse cubes.

(4) Based on the information presented in the preceding paragraphs, containers lined with plastic or paper bags and located at the point of generation is the recommended method for storage of general and infectious wastes on the unit or floor level. Since the unit level of operation is essentially the same for storage purposes in all sizes and shapes of hospitals, the storage recommendation for existing, planned, small and large hospitals is the same.

(5) Additional Considerations.

(a) Pathological Waste. Storage of pathological waste using methods recommended for general and infectious waste would result in aesthetic and odor problems. For this reason, pathological waste should be packaged in leakproof cardboard boxes or refuse containers lined with thick (3 mil or greater) plastic bags and stored under refrigeration.

(b) Laboratory Waste. Although storage in lined containers is adequate for all infectious waste, waste sterilization prior to initial storage is desirable if this is already done routinely and does not cause inconvenience to hospital workers. This situation is normally true for laboratory waste, and thus infectious waste generated in laboratories should continue to be autoclaved prior to storage in lined containers.

(c) Needles and Syringes. Needles must be encased in a rigid container. Once encased, it may be handled with the rest of the waste.

(d) Drugs, Biologicals and Reagents. Waste chemicals should be stored in their original container pending treatment or disposal.

(6) Implementation Guidelines. Guidelines for implementing the recommended storage techniques including equipment specifications, guidelines for the selection of equipment and instructions for storage procedure implementation will be presented in supplemental publications.

d. <u>Collection</u>.

(1) General. For the purposes of this report, collection is the pickup of wastes from patient rooms, nurses' stations, laboratories, reception rooms and all other waste generating sources in the hospital. As mentioned in the general observations, there is a variety of ways to automatically remove wastes away from the floor; but there is now and for the foreseeable future, only one way to gather wastes from individual sources on the floor - it must be done manually. This section will discuss and evaluate the various techniques used to manually collect waste from waste generation points.

(2) Description and Evaluation of Available Collection Techniques.

(a) Random Method. In this system, the job of waste collection and removal is not specifically assigned to anyone. Waste is collected, as needed, by any of the ward staff. This system might appear economical since no one must be hired to do the job. Studies have shown, however, that random systems ultimately utilize more man-hours than the more regulated practices.[1] Another major drawback of this system is in the area of health and safety. Since the entire staff is involved in collection, the job of keeping all informed on proper waste handling techniques is impossible. Consequently, individuals usually mishandle refuse and create a cross contamination hazard throughout the hospital. Additionally, since carts are not needed with this system, refuse is carried by hand through the corridors and elevators in the container liner. Thus, the chances of spillage and of puncture wounds from protruding sharp objects is greater.

(b) Structured System. In this system, waste is collected by a designated group of employees, usually the maids, housekeepers or porters. The system offers much tighter control over the waste handling practices since there are fewer people to instruct and a clear cut responsibility exists.

(c) Specialized System. In this system, employees are hired specifically for the job of waste collection. This system offers greater control than the structured system and minimizes chances of cross contamination since only one to four individuals in the entire hospital handle the waste. This aspect is particularly desirable if the waste handled will be mixed general and infectious waste. Additionally, time and cost studies have revealed that specialization considerably reduces the overall cost.[1]

(3) Comparison of Collection Systems. The structured system and specialized system are both adequate for collection of wastes from hospital floors. The random system has too many problems to seriously consider. Table 6, presents the relative advantages and disadvantages of the two systems. The structured system with or without carts would fit well into a system of automated waste removal from the floor. The specialized system, however, appears best where waste must be manually removed from the floor. Thus, the type of collection system used will depend upon the type of waste transportation system adopted.

TABLE 6. RELATIVE ADVANTAGES AND DISADVANTAGES OF THE RECOMMENDED COLLECTION TECHNIQUES

METHOD 1 (Structured System)	METHOD 2 (Special System)
ADVANTAGES	
Can be used well in conjunction with automatic or conveyor cart system	Aids in preventing cross contamination as only one or two men in the entire hospital handle the waste after initial storage
Requires no backup system	Can provide stimulus for creative employees to develop truly efficient handling system
	Facilitates handling of infectious waste materials since only one man and one cart is used. (Also waste can be more efficiently routed to minimize cross contamination)
DISADVANTAGES	
There may be no place to store carts when not in use	Requires backup system if trash man is sick
Divided responsibility for solid waste handling	Possibility of cross contamination if same cart is used throughout the hospital
Carts must be cleaned on a regular basis	Carts must be cleaned on a regular basis

(4) Additional Considerations.

(a) Pathological Waste. Either of the two recommended systems can be easily modified for collection of pathological waste. A special collection can be scheduled at regular time intervals to pickup pathological waste from the generation point and cart it directly to the disposal point.

(b) Needles and Syringes. Destroyed needles and syringes can be collected along with pathological waste or with the rest of medical waste to eliminate a second special collection.

(c) Drugs, Biologicals and Reagents. Treated chemicals (i.e., stabilized, neutralized, detoxified) in solid form which may be disposed with normal refuse can be collected with medical waste. Specific information for transportation of chemicals prior to treatment or treated chemicals requiring special disposal considerations can be obtained from the Hospital Safety Officer. In general, this should not be handled by refuse collection personnel, but by individuals appropriately trained for the task.

(d) Special Infectious Waste. Waste resulting from treatment of patients with exceptionally dangerous infectious disease, such as anthrax, will be collected separately according to procedures prescribed in the infection control officer.

(5) Implementation Guidelines. Information concerning selection and maintenance of carts, selection and implementation of a waste collection system, selection and training of personnel for a specialized waste collection system, and guidelines for proper handling of the waste will be presented in supplemental publications.

e. Transportation.

(1) General.

(a) For the purpose of this report, hospital waste transportation refers to the movement of mixed general and infectious waste from floor to the disposal/processing center or final storage outside the hospital. Although most of the hospital solid waste technology is devoted to waste transportation, it represents only 10 percent of the labor required.[2] Most of the labor occurs in the collection of wastes from rooms and stations. Hence, automated transportation systems used solely for solid waste are rarely justifiable economically. However, other benefits such as clean and safe transport of waste and the ability to move other materials may make their purchase worthwhile.

(b) Several of the automated systems evaluated are conceived primarily for movement of food and supplies. Hence, to be totally fair, comparison should evaluate each system by its ability to move all materials (i.e., meal trays, clean linen, soiled linen, central material supplies, pharmacy, mail and documents, general and infectious wastes, general supplies). Since overall materials movement is beyond the scope and intent of this study, each system will be evaluated primarily for its ability to move solid waste safely and efficiently. Ability to move other materials will be considered only as an added extra even if it is the systems primary function.

(2) Description and Evaluation of Available Systems.

(a) Manual System (with cart).

- In this system, mixed general and infectious waste is collected in carts by a designated individual and transported to final storage or processing/disposal. Bulky, pathological, and some chemical wastes also are collected by this individual in the cart on separate trips and brought to their respective processing/disposal points.

- It is quite common to consider this system antiquated. Since the collection of waste is usually accomplished in carts regardless of the transportation mode, the only difference between this system and "modern" systems is that the waste must be manually taken down to the final storage area. For many small hospitals, however, the seemingly inconvenient practice of manually escorting the waste to final storage is much more economical, reliable and flexible than sending it automatically.

- Because manual cart systems are often poorly planned and highly disorganized, they have earned a bad reputation. Good planning can easily correct this situation. For example, a common problem for manual systems is frequent trips to outdoor storage. In the publication, "Hospital Solid Waste Disposal in Community Facilities,"[6] it is indicated that 75 percent of the hospitals surveyed had a mean cart load of less than 50 pounds of refuse. Since carts with 100 to 150 pound capacities are available, this represents an inexcusable waste of time. If 1 cubic yard carts were used to full capacity, trips could be reduced by a factor of at least two, possibly three. Hiring competent enthusiastic personnel, training personnel on correct waste handling procedures, purchase of properly sized and constructed equipment and careful planning of routes will result in a manual system which is clean, safe and efficient.

(b) Gravity Chutes.

- In this system, waste is collected in bags or carts, brought to the chute and sent directly through the chute to final storage or processing/disposal without further handling. The system also includes a sister chute for handling laundry and hand carts for transporting pathological, bulky and hazardous chemical waste to their respective disposal points.

- Chutes usually consist of vertical cylindrical tubes, 12 inches to 36 inches in diameter, fabricated of stainless steel or aluminum. They are usually built into the building, but can be built on the side of the structure. The tube is vented at the top and can be equipped with an explosion vent. Charging stations for both linen and waste are located in a separate room and access to the tubes can be operated by hand or foot. Often, keys are required to open the refuse chute so that only authorized personnel can have access. This aids greatly in preventing deposition of laundry in trash chutes and vice-versa.

- In the past, gravity chutes were condemned as both a fire and health hazard. Health officials were concerned with the health hazards from cross contamination caused by aerosols generated by wastes falling through and coating the sides of the chutes. Fires were common occurrence in chutes, particularly those which fed into incinerators. It was not unusual for fire prevention officials to board chutes up and forbid their use. Recent developments in technology have, for the most part, eliminated these problems. Sprinkler systems and separate fire rated chute charging rooms have minimized fire hazards. Self-cleaning/sanitizing equipment and negative pressure are usually installed to minimize potential of health hazards. Chute blockage is one common problem which has not been solved. The problem is only minor and becomes quite tolerable if the chute is properly sized and designed to permit access to the tube at frequent intervals.

- Gravity chutes, designed to eliminate fire and health hazards and to funnel waste directly into final storage or waste processing, appear to provide an efficient, economical and sanitary means for waste transportation.

(c) Pneumatic Tubes.

- In this system, waste is collected in large plastic bags or carts, brought to the chute and sent through a pneumatic conveyance tube directly into disposal/processing without further handling. Also included in this system is a sister chute for laundry and handcart transportation of pathological, bulky and hazardous chemical wastes.

- The pneumatic conveying method employs stainless steel tubes (usually about 12 to 20 inches in diameter) in which air, under positive or negative pressure, is used to suspend and carry wastes or laundry at speeds of approximately 60 mph. Numerous variations and combinations of pneumatic systems are employed. Some examples include a single tube system in which one tube is used for both laundry and trash (with a push button diverter used to regulate the final destination); a dual chute system in which separate chutes are used for laundry and refuse; a gravity pneumatic system in which dual gravity chutes are used for vertical transport of refuse and laundry into a dual pneumatic tube system for horizontal transportation.

- Charging stations are located in separate rooms. Once in the room, access to the chute is provided by two doors, an outer door into which waste or laundry is deposited and an inner door which provides closure between the charging station and the tube when the outer door is open. The outer door can only be opened when the inner door is closed. Once waste is deposited in the outer door, it is closed and the destination button is pushed. This both opens the inner door allowing refuse into the tube and programs the diverter tube to send the refuse to the right destination. Since only one item can be moved in the tube at a time, the opening of the inner door cannot occur until the entire system is not in use. The system is usually designed to release stored refuse into the tube as soon as the previous cycle of operation is complete.

- The major problem with the use of this equipment is that hospitals tend to under-utilize them. A study of three hospitals employing pneumatics revealed that only 25 percent, 39 percent and 60 percent (by weight) of the waste, respectively, were transported via the tubes.[1] The rest was usually transported manually. Reasons given for this under-utilization include mechanical failures, high maintenance, limitations in tube diameter size, management decision to exclude materials for noise or sanitation purposes, preferences for handcart by management, and restricted hours of operations. Ross Hoffman Associates[1] indicate that "assuming a hospital elects to use an automated pneumatic transport system, then it must do so to the point where virtually no waste is transported outside the system. No hospital, no matter how large, can justify automation (at present installed costs) unless it is used to the maximum extent possible." They eventually indicate that surveys of other hospitals have shown that use of the system for total waste removal is possible provided it is designed and installed correctly.

- Although expensive, pneumatic conveyors provide a sanitary means of transporting mixed waste to almost any location in the hospital. Its flexibility makes its use in existing facilities a distinct possibility. Because of these factors, pneumatics are quite frequently recommended by many of the notable hospital engineering consultants.

(d) Automatic Carts.

- In this system, waste is collected from each room and placed in an automatic self-propelled cart. Then the cart is directed to the central processing area where the waste is unloaded by hand and put into final storage or the disposal/processing unit. Pathological and bulky wastes are transported in the same manner but simply programmed to go to a different destination for disposal. Hazardous waste is still transported manually.

- The key feature in this system is the electric, battery-powered, driverless cart which is designed to follow an electronic guidepath of wire concealed in the floor. The cart or power module is essentially a platform which can hold a variety of containers used for food, linen, supply materials and waste handling. Once loaded, the vehicle is dispatched by means of push button controls located on the power module. The operator programs the destination on the control panel, puts it over the wires and then the unit proceeds to the programmed destination. A central station for controlling and monitoring the progress of the carts also is provided. Vertical transport is provided by four elevators, one set of two for outgoing and the other set for returning to minimize cross contamination. Used carts return to the central cart cleaning and sterilizing area where carts are unloaded, sterilized and dispatched to supply for further use.

- Many major problems are noted with the system. First and foremost is a large dependency on the power modules. If a module is not available, materials cannot be moved. The number of modules will be limited because of the high unit cost (approximately $10,000 for each). Consequently, movement of materials must be scrupulously timed or there will be much delay. Another noteworthy drawback is that waste must be rehandled (unloaded by hand from the cart) once it reaches central processing.† Although it does not necessarily pose a cross contamination problem, a significant amount of labor not present in other automated systems is required. Finally, the modules require a large amount of preventive maintenance to keep them running properly. Most systems require a large inventory of spare parts. Thus, the benefit of having the system is questionable.

(e) Overhead Chain Conveyor.

- In this system, carts containing waste are attached to an overhead chain conveyor and carried approximately 2 inches off the ground to its programmed destination. The system is capable of moving almost any material in the hospital including pathological, bulky and hazardous chemical waste.

- The system's primary units are the chain conveyor and a special trolley carrier. The chain conveyor pulls the special trolley carrier to a given destination and the carrier in turn physically supports any of a wide assortment of carts and baskets which may be attached to it. Central heads are mounted on the carrier for programming the route of both the carrier and the supported carts. Carts can be attached to the carrier by either a section of nonpowered track which can be raised or lowered or by a section of track sufficiently below the level of the operating track to allow the wheels of a cart to touch the floor. Two separate elevators are provided for vertical transportation, one for movement of clean supplies and the other for return of refuse and soiled items. An important aspect provided by the manufacturer for waste removal are refuse carts with the access doors on the bottom. The cart can be automatically opened as it passes over the final storage container thus depositing refuse in the container without need of manual unloading. Elimination of this gives it a distinct advantage over automatic carts. Although it is dependent on carrier carts, the carts are much less expensive ($300/cart) allowing a given hospital to have an adequate number on hand. All carts are cycled through a decontamination area before reuse.

---

† Automatic unloading may have been developed for this cart by the time this report is published.

- Informal surveys of hospitals using the system have indicated a number of initial problems in implementing the system including construction problems in existing hospitals, defective parts, improper use by personnel and design imperfections. However, the ones installed most recently have reported much less difficulty than the ones installed 7 years ago, as manufacturers through experience have eliminated imperfections and problems with parts. Further, once the "kinks" are worked out, operation appears quite smooth. No hospital reported a total breakdown lasting more than several hours, but an extensive preventive maintenance program was always needed to ensure continued operation. No hospital surveyed used these carts for waste removal so specific information as how this functioned for solid waste could not be obtained. Significant problems are not anticipated.

(f) Conveyor Belts.

- In this system, waste is collected in carts or bags, put onto a conveyor belt which transports the waste into the final storage or disposal/processing area. Also, conveyors are used for general materials handling. Pathological waste, bulky materials and hazardous chemicals must be transported by handcart.

- The system offers a variety of ways for waste movement. One of the more common is to place material in a box and to transport the box on the conveyor. This adds numerous steps to the process as waste must be collected, loaded into boxes then manually unloaded into final storage. Another method is to put waste contained in sealed plastic bags directly on the conveyor belt. This poses a possible health hazard as the belt is likely to be contaminated from contents of broken bags. Another major difficulty is that several conveyors are usually needed and, thus, a tremendous amount of space must be dedicated for that purpose. All in all, it does not seem as effective or as versatile as the overhead chain conveyor.

(g) Comparison. A comparison of all the aforementioned systems is presented in Table 7.

(3) Selection of Best Alternatives.

(a) Unlike storage and collection, selection of the best transportation alternatives is complicated by a large number of selection criteria. For this reason, a mathematical rating technique (Albert Klee's Dare Technique) was used to facilitate the decision making process and to provide a consistent technique in which each system could be evaluated. The publication is presented in Appendix H to familiarize the reader with its development and use. In Appendix I, the process is applied to the various transportation alternatives presented in this section.

TABLE 7. ADVANTAGES AND DISADVANTAGES OF WASTE TRANSPORTATION SYSTEMS

Advantages	Disadvantages
MANUAL	
Effective, clean removal of mixed wastes Simple mechanically Low capital cost Can be used for all types of waste Flexible	High labor cost Increased traffic and congestion on floors and elevators Greatest cross contamination possibility of systems considered
CHUTE	
Effective, clean removal of mixed wastes Low capital cost Mechanically simple Readily available Low manpower cost	Cannot be used for bulky or pathological waste Subject to frequent blocking
PNEUMATIC	
Effective, clean removal of mixed wastes Low labor cost Readily available Provides automatic horizontal transport	Requires backup system High capital cost Considerable maintenance cost Subject to frequent blocking High degree of mechanical complexity Cannot be used for bulky or pathological waste
AUTOMATIC CARTS	
Effective, clean removal of mixed wastes Can be used for materials movement Provides automatic horizontal and vertical transport Can be used for all types of waste	Complex to operate Mechanically complex Requires backup system Waste must be unloaded by hand High capital cost Requires highly trained personnel to keep in good working order High maintenance cost
OVERHEAD CHAIN CONVEYORS	
Effective, clean removal of mixed wastes Can be used for material movement Low labor cost Can be used for all types of waste Provides automatic horizontal and vertical transport Can send waste to a variety of locations	Complex to operate Mechnically complex Requires backup system High maintenance cost High capital cost Requires trained personnel to keep in good working order
BELT CONVEYORS	
Can be used for materials movement Provides automatic horizontal and vertical transport	Requires backup system High capital cost High degree of mechanical complexity Possible cross contamination hazard High maintenance cost

(b) Unlike storage and collection, selection of the best transportation alternatives is further complicated by the following factors: hospital capacity, structure of the hospital building, and whether the hospital is planned or existing. A transportation alternative which is good for a small hospital may not be good for a large one, or one that is good for a multistoried structure may not be good for a single storied structure. Hence, the mathematical procedure was applied six times; once each for existing hospitals with capacities of 200, 400 and 600 beds; and once each for planned hospitals with capacities of 200, 400 and 600 beds.

(c) Referring to Appendix I, it is important to note that the criterion "total cost" was the only one to vary for the six situations addressed in the previous paragraph. However, since cost was one of the most heavily weighted factors, the variations in cost noted for each situation produced differing transportation recommendations for each.

(d) Although each decision (rating a criterion or transportation system greater than another) is based on objective facts, the degree to which one is rated better than another is subjective. The method, however, clearly and definitively outlines the rationale used in making the conclusions about to be presented. The reader is invited to use the same method in his specific circumstances to select a transportation system for his hospital.

(4) Discussion of Conclusions.

(a) General. The results of the analysis as determined in Appendix I are as follows:

EXISTING FACILITIES

200 beds and under	Chute System, Manual System
Over 200 beds	Chute System, Manual System, Pneumatic System

PLANNED FACILITIES

200 beds and under	Manual System, Chute System
200 to 400 beds	Chute System, Manual System, Pneumatic System, Overhead Chain Conveyor
Over 400 beds	Overhead Chain Conveyor, Pneumatic System, Manual System, Chute System

Each of the recommended systems represents a practical alternative for that type and size of facility. The planner should decide which would best fit the needs of his hospital. The following paragraphs describe the decision making process for each type of facility in more detail. Table 8, presents an aid to planners for choosing among the recommended transportation systems.

(b) Existing Facilities Under 200 Beds. The scoring system used left two systems, chutes and manual, clearly superior to the rest. Although overhead chain conveyors and pneumatics also rated highly, they are not recommended for facilities this size. In fact, overhead chain conveyors are not even recommended by manufacturers for facilities this size. The chute system is recommended with conditions. The chute must feed directly into final storage or disposal/processing for the system to be effective. Consequently, if building constraints prevent this or if the building is two stories or less, a manual system should be adopted.

(c) Existing Facilities Over 200 Beds. Four transportation systems, manual, chute, pneumatic and overhead chain conveyors, are clearly shown as preferential by the calculations. However, only the first three are recommended since it is felt that putting a chain conveyor system into an existing facility is a risky proposition as architectural constraints could skyrocket costs and limit its overall effectiveness. Chutes should be investigated first. If the hospital has less than three floors or the chute cannot be designed to feed directly into final storage or processing/disposal, the manual and pneumatic systems should be compared economically. If the building is a multistory building, but has constraints against direct chute feed into final storage or disposal/processing, a combined system of gravity chute for vertical movement and pneumatic tube for horizontal movement could be designed to accomplish this. If the hospital is two stories or less, a totally pneumatic system should be evaluated against a manual system.

(d) Planned Facilities 200 to 400 Beds. The calculation clearly indicates gravity chutes as the prime choice for this size hospital. If the building is to be multistory, chutes should be installed. If the building is not multistory, manual, pneumatic and overhead chain conveyor systems should be compared economically for overall materials movement. In this case, it is likely that manual systems will be optimum for hospitals with capacities near 200 beds and the automatic system optimum in hospitals with capacities near 400 beds.

(e) Planned Facilities Over 400 Beds. Four systems scored very closely for this situation. For this case, serious consideration should be given to the overhead chain conveyor system for the following reasons: it can be easily incorporated in design stages, and it provides greater overall support to the hospital than the other transportation systems. It should be compared economically with the other systems for overall materials handling. Thus, additional manpower costs must be added to the other three alternatives for movement of the materials.

TABLE 8. WASTE TRANSPORTATION SYSTEM SELECTION GUIDANCE

Type of Facility	Recommendations From Appendix I	Structural or Miscellaneous Constraint	Recommendation
Existing Facility Under 200 Beds	Chute Manual	Three floors or more, plus direct feed into final storage.	Chute
		Less than three floors above ground.	Manual
		Direct chute feed into final storage - impossible.	Manual
Existing Facility Over 200 Beds	Chute Manual Pneumatic	Three floors or more, plus direct feed into final storage.	Chute
		Three floors or more; direct feed impossible.	Chute and pneumatic
		Less than three floors.	Manual or pneumatic
Planned Facility Under 200 Beds	Chute Manual	Three floors or more.	Chute
		Less than three floors.	Manual
Planned Facility 200 - 400 Beds	Chute Manual Pneumatic Overhead chain conveyor	Three floors or more.	Chute
		Less than three floors.	Manual or pneumatic or overhead chain conveyor
Planned Facility Over 400 Beds	Chute Manual Pneumatic Overhead chain conveyor	Three floors or more.	Consider all four recommendations.
		Less than three floors.	Consider manual, pneumatic, overhead chain conveyor

(5) Implementation Guidelines. Guidance on the selection of recommended transportation equipment will be provided in a supplemental report entitled "Solid Waste Management Design Guidelines: Proposed Revisions for TM 5-838-2, Medical Facilities Design - Army." Operation and maintenance of the four primary recommended systems will be provided in other supplemental reports.

f. Processing and Disposal.

(1) General.

(a) In this section, a variety of processing and disposal techniques are combined and treated as one function. This is done primarily because of the influence processing has on disposal; namely, the way waste is processed will dictate the disposal procedure.

(b) Disposal is the most crucial step in the solid waste management plan. It must be able to adequately dispose mixed general and infectious waste since elimination of dual waste transport, collection and storage systems is a major objective of this study.

(2) Discussion and Evaluation of Processing and Disposal Alternatives.

(a) Unprocessed Waste Hauled to the Landfill.

- This method includes the hauling of mixed general and infectious waste to a sanitary landfill and incineration of pathological wastes.

- As mentioned previously, EPA and notable consulting firms object to landfilling potentially infectious waste because the hospital has no control over the collection and landfilling practices. Thus, sloppy operation in either will result in health hazards and pollution problems to the surrounding community. However, most consultants agree that burial of waste is possible at landfills which meet EPA criteria and provide special considerations for the waste such as immediate cover and compaction. The major problems listed with landfilling of infectious waste are that wastes may be subject to scavenging, exposed to potential disease carriers such as rodents and insects, and leached out of the landfill into drinking water sources. A landfill which meets EPA criteria and provides the special considerations mentioned should eliminate the scavenging and vector problems. Several authors do not feel that burial of infectious waste will pose a threat to the ground-water system. DeRoos[11] indicates:

> "* * * another significant factor when dealing with pathogenic microorganisms in sanitary landfills is whether or not they percolate into ground waters. If landfills are constructed with the bottom a few feet above the highest ground-water table

fluctuation (approximately 10 feet) and are underlain by well compacted fine sand or silty material, there is evidence from experiments with irrigation of sewage that viruses will not penetrate through the aerated zone.

"Similarly, bacteria in the aerated zone above the table rarely move more than 5 feet downward through homogeneous soil. When bacteria in unconsolidated formations do enter the saturated zone, they travel in a fairly narrow band a few feet wide and normally disappear completely after traveling about 100 feet downstream. Therefore, solid wastes deposited in a properly constructed sanitary landfill should pose little hazard of contamination of ground waters with pathogenic organisms."

Also, the University of Southern California at Los Angeles[12] recommends burial of all hospital wastes in a sanitary landfill indicating "* * * yet until any study proves contrary, landfill disposal of all hospital wastes does not seem any more hazardous than disposal of public wastes into landfills." They go on to state "* * * questions of the time of survival of pathogens would not be of much significance if special precautions were taken to avoid burial of hospital waste in the top layer of a sanitary landfill and to restrict such burial to a reasonable distance from the fill face." For these reasons and because the landfill provides a hostile environment to microorganisms (high temperature, low pH), mixed hospital waste, if given special treatment, can be safely disposed in a properly operated sanitary landfill.

- Although landfilling is acceptable, major problems are anticipated for the unprocessed storage and hauling provided in this disposal technique. Waste stored in multiple or open top containers is not compatible with automatic feeding with chutes or conveyor carts. Also, waste stored in this manner is easily accessible to scavengers. Collection of unprocessed hospital waste is expensive when collected as part of the normal route and will be very costly when provided the necessary separate collection to prevent hazards to collection personnel and the local community. The method does not appear very effective.

(b) Waste Processed in Stationary Compactors and Buried in a Sanitary Landfill. This method includes compaction of all refuse in a stationary compactor, hauling of the refuse in a totally enclosed leakproof container to the sanitary landfill for immediate compaction and cover. Pathological waste is incinerated.

- Stationary compactors differ considerably from the mobile compactors mentioned in the storage section. In these, waste is compacted in large reusable containers ranging in volume from 2 to 50 cubic yards. This container is lifted by a tilt-frame vehicle, hauled to the landfill for waste disposal, cleaned and then returned to the hospital. There are two types of stationary compactors, one in which both the compactor ram and the storage container are contained in one unit and one in which they are two completely separate units. The latter has the advantage of less wear and tear on the actual compactor mechanism which always remains behind when waste is transported to the landfill. The former has the advantage of being considerably more leakproof and for this reason is preferred for hospitals. Compaction ratios of 5 to 1 are often claimed by manufacturers but 3.5 to 1 or 2.5 to 1 are more realistic ratios to expect.

- Stationary compactors present several key advantages to hospitals. They provide a sealed container for sanitary transportation of mixed hospital waste to the landfill. Since the container can only be used to service the hospital, separate transportation of hospital waste is inherent to the system minimizing cross contamination possibilities in community areas. The compactors take up less area and reduce collection frequency for relatively low capital and maintenance costs. Two significant problems are noted for the system; a problem with littering and leakage and the problem of purchasing a tilt-frame vehicle just to service the hospital. The first problem can be avoided by purchase of the self-contained compactor which does not experience the leakage and litter problems encountered with the other more commonly used mechanism. The second problem has several solutions. Since purchase of a truck just for hospital pickup is not recommended, stationary compactor services can be either contracted for or provided by a dual purpose truck which can be used either as a tilt-frame vehicle or a front-end loader. Additionally, some small compactor containers (10-cubic yard capacity or less) can be serviced by hoist and haul vehicles.

- All in all, the overall system is considered promising for most hospitals.

(c) Sterilization by Steam Retort, Stationary Compaction/Landfill.

- This method includes sterilization of all patient-care wastes followed by compaction of waste in a stationary compactor and hauling waste to the landfill for burial. Pathological waste is incinerated.

- Sterilization of wastes would be accomplished in waste sterilizers, also known as retorts. These mechanisms are designed specifically for solid waste sterilization, have capacities up to 500 pounds per hour and are fully automated requiring no monitoring. Like an autoclave, it uses steam under pressure; however, unlike autoclaves, it does not use vacuum for drawing out dead air and steam and for introducing cooling air.[13] The waste sterilization process begins by containerizing wastes in 55-gallon porous paper bags. These bags are loaded into the sterilizer and the machine is started. When the process is complete, bags are collected and manually taken to the stationary compactor.

- The main advantage is that the sterilizers render the waste innocuous, thus permitting burial in sanitary landfills without special treatment or burial in locations where States forbid infectious waste disposal. The equipment used has relatively low capital and maintenance cost, requires no skilled labor, has insignificant fuel consumption and poses no apparent threat to the environment. The main objection is that it is difficult to automate loading and unloading. Loading waste into paper bags on the floor level along with creative design could allow direct feed through a chute/bin system. But this does not solve the problem of unloading as the paper bags, once sterilized, are wet and tear easily when lifted. This problem can be alleviated by containing the waste during the sterilization process in large porous metal boxes (provided by the manufacturer), but only at the sacrifice of 20 percent of the useful sterilizing volume.

- Although this concept appears troublesome, it provides a valid alternative particularly where landfill of infectious waste is prohibited or not practical.

(d) Incineration.

- This system involves incineration of all waste followed by burial of the residue in a sanitary landfill.

- This technique is by far the most frequently recommended of all the processing/disposal techniques. Syska and Hennessy,[14] Ross Hoffman,[1] Esco Greenleaf,[2] and others[15] have wholeheartedly recommended incineration of all solid waste indicating it is the best all around method. The method of incineration most frequently mentioned is controlled air incineration. This method consists of three fundamental steps; i.e., evaporation of free moisture, pyrolysis of the volatile fraction, combustion of fixed carbon. Lewis and Rinker[16] provide the following discussion of the process: "While the free moisture is being evaporated the temperature of the material stays constant at approximately 212°F. Combustion cannot take place at this temperature. When evaporation is complete, pyrolysis of the volatile fraction takes place. The dense white smoke that issues from a fire ignited from the bottom is an example of pyrolysis. This white smoke is in reality an extremely fine mist of liquid aerosols. These aerosols are burned to completion in the secondary combustion chamber (afterburner) under the proper conditions, temperature and turbulence. The final phase of the controlled air incineration process is the combustion of the fixed carbon. The glowing embers that remain in a fire when the blaze has died down is an example of fixed carbon combustion." The manufacturers claim that total control of the system can be done automatically. The system also requires a large storage bin and some means of automatic feed of materials into the incinerator. Storage within waste chutes is not recommended.

- The overall system offers the advantage of both reduced volume and weight. All general and contaminated waste can be incinerated.† The combustion process leaves a sterile residue which allows transportation in refuse vehicles and burial at sanitary landfills normally without special considerations. The large volume reduction greatly reduces hauling costs. Additionally, the heat generated in the combustion of this high Btu content waste can be recovered and used in the hospital. As impressive as these advantages may seem, however, the disadvantages are equally pronounced. Capital cost to include cost for air pollution control devices is the largest of all processing equipment. Incinerators must be designed specifically for the waste they are to burn, if composition data are inaccurate, mechanical and air pollution problems will result. Although manufacturers claim no need for air pollution control devices, increasingly strict particulate emissions requirements and new gaseous emissions requirements will require addition of wet scrubbers for emissions removal. The water from the scrubbers also will require onsite treatment prior to being discharged to the sanitary sewer. Regardless of manufacturer claims of automation, a competent operator is always necessary to ensure continued acceptable operation; thus, labor costs also must be considered. Incinerators are subject to breakdown, hence a backup incinerator or disposal system must be provided. The sterility of both the residue and the stack effluent has even been questioned.[17] One report[12] has indicated high concentrations of live microbes in residue of incinerators operating at 1700°F. Finally, additional labor for loading the incinerator and containers for interim storage of waste are necessary.

- Because of all the significant pros and cons of incineration, it should be carefully studied in the light of specific situations before it is adopted.

(e) Pulping with Discharge to Sanitary Sewer.

- This method includes hydropulping all waste except pathological waste and nonpulpable materials and flushing the resulting pulp into the sanitary sewer. Pathological waste would be incinerated and nonpulpable waste would be buried in a sanitary landfill.

- The key mechanism in this system is the pulping apparatus which usually consists of a pulping bowl, an impeller plate studded with teeth and a waste-sizing ring. Waste is introduced into the pulping bowl which is half filled with water. The violent action of the impeller rotating in the bowl at high speeds tears and abrades the waste reducing it to a finely suspended slurry. This process continues until the slurry is fine enough to pass through the waste-sizing ring at the bottom of the bowl. Once out of the bowl, the waste is discharged into the sanitary sewer at a controlled rate to prevent settling in the sewer system. The pulper usually will not accept metals or other hard objects, certain plastics, wood and cloth.

---

† Pathological waste also may be incinerated if the percentage of pathological waste in the incinerator is low (less than 10 percent).

- The overall method appears advantageous as the majority of waste is disposed in-house, in an economical manner. Additionally, outside storage requirements and waste hauling requirements are greatly reduced. There is no need to worry about proper burial of waste as the sanitary sewer provides a safe means of conveyance of the contaminated slurry to the sewage treatment plant, which can be designed to safely treat waste water with high pathogen counts with a final disinfection step.

- This system, however, presents the possibility of overloading of the sewage treatment plant. Many municipal sewage treatment plants simply cannot handle the load of solids that the addition of hospital waste would provide. Since Army operated sewage treatment plants are usually significantly underloaded, it is difficult to determine the overall effect on Army installations. Facilities engineers may simply not permit discharge of this material into the sewer as it may have negative psychological effect on treatment plant operators. Although solids removal may not be a problem, low flow in the sewer lines may result in the settling of pulp in and the eventual clogging of the sewer lines. Further, the pulped hospital waste will increase the concentration of enteric viruses in the flow. Since the sewage treatment process does little to eliminate these viruses, they will ultimately end up as pollutants in surface streams. Another negative factor is the required sorting of nonpulpable waste. This requirement is in conflict with this study's goal of handling all waste in the same manner. This system also has a history marred by major breakdowns and lengthy downtime due to difficulty in obtaining replacement parts.

- Overall the system shows some promise. It could be a practical processing/disposal method particularly for Army installations once technology removes the aforementioned problems.

(f) Pulping, Dewatering, and Burial in a Sanitary Landfill.

- This method includes passing of waste (except nonpulpable and pathological) through a pulper. The pulp is pumped by pipe to a dewatering press. The water is recycled back to the pulper. The dewatered pulp is extruded into a container and hauled to the landfill along with nonpulpable waste for burial. Pathological wastes are incinerated.

- Like the previous system, the major component of this processing/ disposal system is the pulper. There are two key differences, however, in the overall operation. First, chemicals are introduced into the pulping bowl during the process to disinfect the pulp. Second, once the slurry passes through the waste-sizing ring, it is pumped to a water press where it is dewatered into a homogeneous moist pulp and deposited in a container pending removal to the landfill. These two alterations eliminate the problems with disposal in the sanitary sewer. The process results in a waste which is disinfected and 25 percent of its original volume. It also reportedly will not attract insects or rodents. However, waste sorting is still necessary and mechanical breakdowns and long downtime are common problems for this system. Further, the pulping process results in an overall increase in the weight of the solid waste, a disadvantage if hauling costs are based on weight.

- When this system is working properly, it is an impressively clean and efficient method of waste processing/disposal. If the system is made more reliable and technology improves it such that it can process virtually all hospital waste, it could become a very practical method for Army hospitals.

(g) Shredding and Landfilling.

- In this process as much waste as possible is shredded, stored in large dumpster containers and hauled separately to the sanitary landfill where the waste is buried immediately. Pathological waste is incinerated; nonshreddable waste is simply sorted prior to shredding and taken separately to the dumpster. Waste also can be compacted immediately after shredding.

- Shredding is the process of reducing waste to small particle size by cutters, choppers, hammers or other mechanisms designed to continually shear whatever is put into it. Unlike pulpers, shredders require no water and have the power to shred almost all types of hospital waste. Shredding, by itself, is usually preparatory for some other process such as incineration or compaction. Quite often shredders are used with compactors to produce small briquettes of shredded waste. Manufacturers using this combination of processes claim as much as a 15 to 1 volume reduction ratio.

- This system offers several advantages including volume reduction, reduction of the possibility of aerosol can explosion and the creation of a homogeneous mix for incineration. But, these qualities are either not of sufficient importance or not accomplished to a significant degree to warrant its use. The process is very noisy and generates hazardous aerosols. Further, the end product of shredding still requires special attention since the process does nothing to decontaminate the waste. Finally, the system requires significant operational expense particularly for power to run it and labor for monitoring and operating. For these reasons, shredders are not often recommended for use in hospitals.

(h) Comparison. A comparison of all disposal alternatives listed is provided in Table 9.

(4) Selection of Best Alternatives.

(a) The Dare technique used for rating the transportation methods was used to rate the waste processing/disposal systems. The calculations were simplified by the fact that processing/disposal systems are not affected

TABLE 9. ADVANTAGES AND DISADVANTAGES OF PROCESSING/DISPOSAL SYSTEMS

Advantages	Disadvantages
	UNPROCESSED
Low labor cost	High hauling cost
Low capital cost	High cross contamination possibilities in hauling and landfilling
Low maintenance cost	Possibility of water pollution problems at the landfill
No air pollution problems	Large number of outside storage containers required
	STATIONARY COMPACTION
Low labor cost	Need to separate pathological waste
Low capital cost	Possible problem in obtaining a vehicle to haul the container
Reduced hauling cost	Remote opportunity for water pollution at sanitary landfill
Sealed container for separate sanitary hauling of potentially contaminated waste	
Little need for waste separation	
Low maintenance cost	
Easily amenable to automatic feed	
No air pollution problems	
Available for use any time - day or night	
	RETORT STERILIZATION
Moderate capital investment	Labor cost may be high
Low cost disinfection of waste	Need to separate pathological waste
Elimination of special burial requirements	Difficult to automate as waste must be removed by hand
Low operational cost	Requires special bagging of waste
No air pollution problems	Limited to operation during daily hours
No water pollution problems	
Little need for waste separation	
Highly reliable	

Advantages	Disadvantages
INCINERATION	
Reduced hauling cost	High operational cost
No water pollution problems	High labor cost
No special burial requirements	High initial cost
Effective disinfection of waste	Potential air pollution problems
No need for waste separation	Requires backup system
Fairly reliable	Difficult to feed automatically
Reduced outside storage	
PULPING/WASTE TREATMENT PLANT	
Reduced hauling cost	Requires separation of nonpulpables
No water pollution problems	May result in water pollution problems if chlorine at the waste treatment plant is not enough to kill viruses
Effective removal of potentially infectious materials from hospital	
Reduced outside storage	History of severe maintenance problems; frequent breakdowns
	High labor cost
PULPING/LANDFILL	
Reduced hauling cost	Requires separation of nonpulpables
No air pollution problems	May increase hauling cost, if cost is based on weight
Effective disinfection of waste	History of service maintenance problems
	High labor cost
SHREDDING	
Reduced hauling cost	Waste is not disinfected
Low maintenance cost	High capital cost
	Generates hazardous aerosols and noise

greatly by externals such as shape and state (planned or existing) of the building. The only criterion which varied was total cost which changed considerably with the size of the hospital. Thus, the calculations were done for hospitals with 200, 400 and 600 bed capacities.

(b) The method involves subjective decisions and is presented just to clearly outline the rationale used in making the recommendations. Once again the reader is invited to use the same method in his specific circumstances to make a decision.

(5) Discussion of Conclusions.

(a) General. The results of the analysis as determined in Appendix J are as follows:

HOSPITALS WITH CAPACITIES OF 0 TO 200 BEDS

Stationary Compaction/Landfill

Sterilization/Stationary Compaction/Landfill

Incineration

HOSPITALS WITH CAPACITIES OF OVER 200 BEDS

Sterilization/Stationary Compaction/Landfill

Stationary Compaction/Landfill

Incineration

Once again, the systems scoring highest were listed as the recommended alternatives. In this case, the same three processing/disposal methods were clearly highlighted by the mathematical selection procedure for each hospital size investigated. Of the three methods recommended, the calculations clearly favor compaction with and without sterilization. All three methods are good for disposal, however, and hospital planners should evaluate and compare all three before making a selection.

(b) Circumstances at a given installation or in a given State may limit the number of recommended alternatives available. Table 10, provides some of the major limitations and the disposal possibilities available. This listing should aid planners in selecting one of the recommended alternatives for their hospitals.

TABLE 10. SPECIFIC PROCESSING/DISPOSAL RECOMMENDATIONS FOR LOCAL CONSTRAINTS

Situation	Waste Processing Recommendation
Landfill meeting EPA requirements located on the installation.	Stationary Compactor
No landfill available on the installation. Incineration permitted by State.	Retort Sterilization* or Incineration*
No landfill available on the installation. Incineration not permitted by State.	Retort Sterilization
EPA approved landfill available; State laws against burial of infectious waste.	Retort Sterilization* or Incineration*

* These two should be compared economically.

(6) Implementation Guidelines. Guidance on the selection of the recommended disposal/processing procedures is presented in a supplemental report entitled "Solid Waste Management Design Guidelines: Proposed Revision for TM 5-838-2, Medical Facilities Design Army." Implementation, operation and maintenance of the three recommended systems is provided in a forthcoming supplemental report.

(7) Processing/Disposal of Hazardous Materials.

(a) Pathological Waste. State laws usually require incineration of body parts, animal carcasses and other pathological waste. For this reason, hospitals will have to employ pathological incinerators even if they choose to landfill the rest of their waste. However, since the composition is known and fairly consistent, incineration usually can be accomplished in a Type 4 waste incinerator without major problems if no other waste is burned with it.

(b) Hazardous Waste. Disposal guidance for Class 6505 items is available in SB8-75-9, 4 March 1977, and should be used where applicable. Disposal guidance for Class 6505 items not listed in this publication, and for other pharmaceutical stocks and hazardous chemicals, can be obtained by following instructions provided in paragraphs 6-15 and 6-11e, respectively, AR 200-1.

(c) Special Infectious Waste. Waste resulting from the treatment of patients with exceptionally dangerous infectious disease, such as anthrax, should be sterilized or incinerated prior to landfilling. This should make up a small percentage of medical waste, if it is present at all.

6. CONCLUSIONS.

a. <u>General</u>.

(1) The root causes of poor solid waste management practices in hospitals include poor planning, poor organization and a lack of awareness of the proper waste handling and disposal practices available.

(2) Effective separation of infectious waste from general waste is impractical.

(3) Waste management systems designed to contain transport and dispose of medical waste are more practical and sanitary than separate systems for segregated general and infectious waste.

(4) The nature of Army installations provides Army hospitals with numerous handling and disposal options not available to civilian hospitals.

b. <u>Waste Characteristics</u>.

(1) Waste Generation Rates.

(a) Accurate waste generation data are essential for planning hospital waste management requirements.

(b) Since waste management systems should be designed to handle general and infectious waste combined, knowledge of specific infectious waste generation rates is unnecessary.

(c) Waste generation rates are most accurately determined by actual weighing.

(2) Waste Composition.

(a) Waste composition data are often necessary for proper selection and design of waste processing/disposal equipment.

(b) Waste composition is most accurately determined by actual sampling and analysis of the refuse.

(c) Because of the fairly consistent makeup of pathological waste, composition determination is not necessary for design of pathological waste processing and disposal equipment.

(3) Waste Hazards.

(a) Infectious waste is a hazardous material and requires special handling and disposal.

(b) Since general waste is frequently contaminated with infectious waste, it is considered hazardous and requires the same handling and disposal as infectious waste.

(c) Pathological waste is considered a hazardous material. Because of State laws and its composition, it requires separate storage, handling and disposal.

c. Waste Storage.

(1) Storage of waste at the source in lined containers minimizes handling and cross contamination and provides both adequate capacity and easy collection in an aesthetic, economical manner.

(2) Secondary storage of solid waste on the floor in either containers or mobile compactors adds to the overall labor required for solid waste handling and poses a health threat through aerosol generation and cross contamination during waste transfer and storage.

(3) Storage of pathological waste in lined containers would result in aesthetic and odor problems; hence, it requires refrigerated storage.

(4) Autoclaving infectious waste generated in laboratories (such as cultures and petri dishes) adds an extra safety factor to waste handling practices without significantly affecting the overall flow of waste.

d. Waste Collection. Collection systems with well defined responsibilities and tasks provide the most efficient and sanitary means of waste collection.

e. Waste Transportation.

(1) Although automated transportation systems used primarily for solid waste are rarely justifiable economically, other benefits provided such as clean and safe transport of waste and the ability to move other materials may make their purchase worthwhile.

(2) Manual systems which are carefully planned and performed enthusiastically by competent employees provide flexible, clean and efficient means of waste transportation.

(3) Gravity chutes, designed to eliminate fire and health hazards and to funnel waste directly into final storage or waste processing and disposal, provide an efficient, economical and sanitary means for waste transportation.

(4) Although expensive, pneumatic conveyors provide a sanitary, efficient and flexible means of transporting waste to almost any location in the hospital.

(5) Pneumatic conveyors must be used for all the waste generated for benefits to be derived from its use.

(6) Because of high costs and a lack of flexibility and responsiveness, automatic carts are not currently considered a practical alternative for waste handling in hospitals.

(7) Although expensive, the overall waste and materials handling benefits provided by overhead chain conveyors make it a practical waste and materials handling alternative for large hospitals in the planning stages.

(8) Because of likely sanitation problems and a lack of flexibility, conveyor belts are not considered a practical alternative for hospital waste handling.

f. Waste Processing and Disposal.

(1) Mixed infectious and general waste can be buried in sanitary landfills meeting EPA criteria without harm to health and environment.

(2) Waste processing and disposal methods selected by planners must be able to effectively dispose of infectious as well as general waste.

(3) Because of potential health problems in collecting and hauling unprocessed waste and high hauling costs, sanitary landfilling of unprocessed waste is not encouraged.

(4) Processing of refuse in leakproof self contained stationary compactors, followed by burial in a sanitary landfilling is an acceptable processing and disposal technique.

(5) Waste sterilizers provide an acceptable alternative for waste disposal particularly where landfill of untreated infectious waste is prohibited.

(6) Incineration of wastes offers both significant benefits and drawbacks and, therefore, requires thorough evaluation before it is adopted.

(7) Because of numerous operational problems and the requirement to separate waste, pulping systems are not considered practical at this time.

(8) Because of sanitation problems, shredding is not considered a practical processing mode for hospital waste.

7. RECOMMENDATIONS.

a. Plan all solid waste management considerations during the design phase of medical treatment facilities construction or modification. Use "Solid Waste Management Design Guidelines: Proposed Revisions for TM 5-838-2, Medical Facilities Design - Army" as a basis for design.

b. Use subsequent proposed TM's based on the findings of this report for operating and maintaining solid waste management systems in medical treatment facilities.

c. Consider implementing the following in existing hospitals.

(1) Eliminate segregation of infectious and general waste while continuing to separate pathological waste and to autoclave laboratory waste.

(2) Collect all medical waste in one waste collection system. The system should be characterized by well-defined tasks and responsibilities.

(3) Use a manual, gravity chute or pneumatic tube waste transportation system.

(4) Use leakproof containers to store medical waste outside the medical facility and to transport it to the sanitary landfill.

(5) Landfill medical waste (providing immediate cover) if the landfill complies with Federal, State and local requirements. Incinerate or sterilize it if the available landfills do not comply and cannot be improved to comply.

(6) Contact this Agency for specific details in accomplishing these steps.

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

d. Consult with this Agency before purchasing mobile compactors.

Kenneth P. Stachiw

KENNETH P. STACHIW
Sanitary Engineer
Solid Waste Management Division

APPROVED:

Robert G. Grodt

ROBERT G. GRODT, P.E.
LTC, MSC
Chief, Solid Waste Management Division

APPENDIX A

DEFINITIONS

Clean Waste - See General Waste.

Collection - The act of gathering waste from a number of storage locations. It is usually done with a cart or a large plastic bag.

Compactor - Any power-driven mechanical equipment designed to compress and thereby reduce the volume of waste materials.

Contaminated Waste - Waste originating from the diagnosis, care and treatment of a person or an animal which has been or may have been exposed to a contagious or infectious disease.

Final Storage - For purposes of this study, the term refers to holding waste in containers outside the hospital awaiting pickup for disposal away from the hospital.

Floor - For the purposes of this study, floor refers to a single basic health care unit consisting of patient rooms, utility rooms and a nursing station.

Floor Compactor (Mobile Compactor) - A compactor producing refuse cubes of approximately 75 to 150 pounds in disposable containers. They are normally used in offices or patient care units in hospitals.

General Waste - All waste generated in a medical care facility, excluding infectious waste, needles and syringes, pathological waste and drugs, biologicals and reagent waste. It includes waste generated in patient care, food service, supply maintenance and commercial operations, and administrative activities.

Hazardous Waste - Drugs, biologicals and reagents.

Incineration - The controlled process in which combustible solid, liquid or gaseous wastes are burned and changed into noncombustible gases and solids.

Incinerator - A facility consisting of one or more furnaces in which wastes are burned.

Infectious Waste - Same as Contaminated Waste.

Interim Storage - The action of holding waste in a container but not at the point of generation. It represents at least the second container the waste has been stored in within the hospital.

Leachate - Liquid that has percolated through solid waste and has extracted dissolved or suspended materials from it.

Lined Containers - Refers to plastic or metal refuse containers, ranging in size from 10 to 55 gallons, containing a plastic or paper bag. The purpose of the bag is to keep the container clean as refuse of all sorts is placed in it.

Medical Waste - Solid waste resulting from operating a medical care facility. For the purposes of this study, it includes general waste, infectious waste, needles and syringes, and laboratory waste. It does not include soiled reusable linen, waste drugs, biologicals and reagents, or pathological waste.

Mixed Waste - Same as Medical Waste.

Noncontaminated Waste - Same as Clean Waste.

Pathological Waste - Anatomical parts of humans or animals.

Processing - Action performed on waste to make it more amenable to transportation (i.e., compaction, shredding) or to prepare it for disposal (i.e., sterilization, incineration).

Pulper - A mechanical device which mixes waste with water, then tears and abrades the waste into a finely suspended slurry.

Refuse - For the purposes of this report, the same as medical waste.

Retort - Mechanisms designed specifically for solid waste sterilization using steam under pressure for the sterilization process (see Item B in Bibliography).

Sanitary Landfill - A land disposal site employing an engineered method of disposing of solid wastes on land in a manner that minimizes environmental hazards by spreading the solid wastes in thin layers, compacting the solid wastes to the smallest practical volume, and applying and compacting cover material at the end of each operating day.

Sanitation - The science and practice of affecting healthful hygienic conditions.

Scavenging - Uncontrolled removal of solid waste materials by unauthorized personnel.

Shredder - A mechanical device used to break or cut waste materials into smaller pieces by tearing and impact action.

Solid Waste - Useless, unwanted or discarded materials with insufficient liquid content to be free-flowing.

Solid Waste Handling - The combined actions of storing, collecting and transporting waste.

Special Waste - Pathological waste, drugs, biologicals and reagents.

Stationary Compactor - A compactor which compresses refuse into a reusable container. It is normally located outside the building and has a container volume ranging from 2-40 cubic yards.

Storage - The action of holding waste in a container, such as a waste paper or 32-gallon can, pending pickup by collection personnel. For the purposes of this study, storage normally refers to this holding action at the point of generation.

Transportation - The act of transporting collected waste to the point of final storage or disposal.

Vertical Transport - Transportation of waste among various levels of the hospital building.

Waste Handling System - For the purposes of this study, a waste handling system is all actions performed to get waste from the point of generation to the point of final storage or disposal.

Waste Management System - For the purposes of this study, a waste management system is the actions performed on waste from the point of generation to final disposal. It encompasses waste handling systems.

Waste Segregation - The practice of separate storage, collection, transportation and disposal of general and infectious waste.

APPENDIX B

HOSPITAL SOLID WASTE MANAGEMENT QUESTIONNAIRE

The following questionnaire was sent to all 41 US Army Medical Department Activities. Thirty-eight responded, and the results are expressed in Appendix C as percentages of the 38 responses. The questionnaire was normally filled out by the Medical Activity Environmental Science Officer.

INSTRUCTIONS: Please fill in the blank or circle the appropriate response (or responses where more than one method is used).

1. NAME AND LOCATION OF HOSPITAL: ______________________________________

____

NOTE: Questions 2 thru 11 pertain to noninfectious wastes.

2. HOW ARE WASTES STORED IN PATIENT OR SOURCE-GENERATING AREAS: a. Plastic-lined wastebaskets. b. Nonlined wastebaskets. c. 32-gallon cans. d. Other. _____

3. WHO COLLECTS WASTES FROM PATIENT OR SOURCE-GENERATING AREAS: a. Housekeeper who also cleans rooms. b. Porter whose only job is to collect refuse. c. Other. _____

4. HOW ARE WASTES COLLECTED FROM PATIENT OR SOURCE-GENERATING AREAS: a. Placed in a larger bag, then handcarried. b. Placed in carts. c. Other. _____

5. IF WASTES ARE STORED ON THE FLOOR PRIOR TO TRANSPORT TO FINAL STORAGE OR DISPOSAL, DESCRIBE STORAGE METHOD: a. Stored uncompacted in utility or soiled linen room. b. Stored in a compactor located in the utility or soiled linen room. c. Other. _____

6. HOW ARE WASTES COLLECTED FROM THE FLOOR: a. Covered carts. b. Uncovered carts. c. Gravity chutes. d. Other. _____

7. ARE WASTES TRANSPORTED IN: a. Patient elevators. b. Service elevators. _____

8. HOW ARE WASTES STORED PRIOR TO FINAL DISPOSAL OR PICK UP: a. In a large stationary compactor. b. In a Dempster-Dumpster type container. c. Other. _____

9. INDICATE FINAL DISPOSAL METHOD: a. Grinding and discharge to the sanitary sewer. b. Incineration. c. Onpost sanitary landfill. d. Contractor operated sanitary landfill. e. Other. ____

10. LIST FREQUENCY OF COLLECTION FROM: a. Patient or source-generating areas ____. b. Interim (on-floor) storage ____. c. Final storage prior to disposal ____.

11. DESCRIBE ANY SPECIALIZED EQUIPMENT, INCLUDE MANUFACTURER, MODEL NUMBER, AGE (e.g. 4 years old, 14 cubic yard, Dempster Bros. stationary compactor):

12. BRIEFLY DESCRIBE COLLECTION SYSTEM FOR SOILED LINENS:

13. BRIEFLY DESCRIBE STORAGE, COLLECTION AND DISPOSAL OF INFECTIOUS WASTES. Use questions 2 through 11 as an outline.

14. IF AVAILABLE AND IF BASED ON ACTUAL MEASUREMENTS, LIST THE AMOUNT OF SOLID WASTES GENERATED:

NONINFECTIOUS ____________ INFECTIOUS ____________

15. DOES YOUR FACILITY HAVE ANY PLANS TO IMPROVE THE SOLID WASTE MANAGEMENT SYSTEM? EXPLAIN. DO YOU FEEL IMPROVEMENT IS NECESSARY?

16. DESCRIBE HOSPITAL CONFIGURATION (e.g. cantonment, 8 story, 3 wing building):

17. IF AN INCINERATOR IS OPERATED, HAS IT BEEN CITED BY A GOVERNMENTAL AGENCY AS AN AIR POLLUTION SOURCE? IF SO, WHAT CORRECTIVE ACTIONS ARE PLANNED.

18. AVERAGE NUMBER OF IN-PATIENT/DAY ________. AVERAGE NUMBER OF OUT-PATIENTS/DAY ________. TOTAL NUMBER OF HOSPITAL EMPLOYEES, MILITARY AND CIVILIAN, ALL SHIFTS ________.

19. NAME AND AUTOVON NUMBER OF INDIVIDUAL FILLING OUT FORM: ______________
____.

APPENDIX C

RESULTS OF HOSPITAL SOLID WASTE MANAGEMENT QUESTIONNAIRE
(Numbers in percent of responses received)

1. STORAGE OF CLEAN WASTE AT THE POINT OF GENERATION	
Plastic lined wastebaskets	76
Nonlined wastebaskets	3
Plastic lined wastebaskets and 32-gallon cans	18
Plastic lined wastebaskets and other sized containers	3
2. WASTE IS COLLECTED BY	
Housekeeper who also collects from other rooms	47
Porter whose only job is to collect waste	22
Both porters and housekeepers	3
By health care personnel, such as nurses' aides	28
3. WASTE IS TRANSPORTED BY	
Handcarried in a large plastic bag	38.5
Carts	38.5
Both large bags and carts	13
Randomly transported to outside container by generator	5
Handcarried in 32-gallon containers	5
4. CENTRAL STORAGE OF WASTES ON THE FLOOR	
Stored uncompacted in a utility room	36
Stored in a floor compactor	19
Not stored on floor	39
Stored somewhere on floor, not in utility room	6

5. TRANSPORTATION FROM FLOOR (where waste is either stored or not stored on floor)

Covered cart	26
Uncovered cart	40
Handcarried in plastic bags	31
Compactor box	3

6. ELEVATOR TRANSPORTATION

Patient elevators	37
Service elevators	40
Do not use elevators	23

7. FINAL STORAGE

Stationary compactor	24
Dumpster containers	71
32-gallon cans	5

8. DISPOSAL

Incineration	13
Post-operated sanitary landfill	66
Contract operated sanitary landfill	21

9. FREQUENCY OF COLLECTION FROM EACH SOURCE

Once per day	44
More than once per day	56

10. FREQUENCY OF COLLECTION FROM EACH SOURCE (for those who use interim storage - 20 hospitals)

Once per day	55
More than once per day	45

11. FREQUENCY OF COLLECTION FROM FINAL STORAGE

Once per day	41
More than once	25
Less than once	34*

12. INFECTIOUS WASTE HANDLING

a. Segregation Practices

Use waste segregation	100
Do not use waste segregation	0

b. Collection Practices.

Collected separately, double bagged, handcarried, incinerated	76
Collected separately, double bagged, transported in carts to incinerator	20
Collected separately, double bagged, transported in carts to autoclave	4

c. Disposal Problems.

Percent of hospitals reporting incinerator problems	33

* Majority of these hospitals compacted their waste.

APPENDIX D

LISTING OF CONTACTS

1. US ARMY HOSPITALS VISITED.*

   a. Lyster Army Hospital, Fort Rucker, AL.

   b. Madigan Army Medical Center, Fort Lewis, WA.

   c. Tripler Army Medical Center, HI.

   d. Brooke Army Medical Center, Fort Sam Houston, TX.

   e. Walson Army Hospital, Fort Dix, NJ.

   f. Patterson Army Hospital, Fort Monmouth, NJ.

   g. Martin Army Hospital, Fort Benning, GA.

   h. Eisenhower Army Hospital, Fort Gordon, GA.

   i. US Army Hospital, Fort Stewart, GA.

   j. US Army Medical Department Activity, West Point, NY.

   k. Walter Reed Army Medical Center, Washington, DC.

   l. Kirk Army Hospital, Aberdeen Proving Ground, MD.

2. CIVILIAN HOSPITALS VISITED.

   a. Riverside Hospital, Boonton, NJ.

   b. US Public Health Service Hospital, Baltimore, MD.

   c. Johns Hopkins Hospital, Baltimore, MD.

   d. Fairfax Hospital, Falls Church, VA.

   e. Anne Arundel Hospital, Annapolis, MD.

   f. Union Memorial Hospital, Baltimore, MD.

   g. Sinai Hospital, Baltimore, MD.

---

* These hospitals were visited on solid waste management general surveys, not on visits specifically made for this study.

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

APPENDIX E

WASTE GENERATION RATE FORMULAS

FIGURE 1.

Formula 1: Equivalent Population. These equations are based upon data presented in "Solid Waste Handling and Disposal in Multistory Buildings," by Esco Greenleaf and approved by EPA.

a. For hospitals using reusable linens and food services items:

3.6 x Equivalent Population = Generation rate in lbs/day

b. For hospitals using reusable linens and totally disposable food service items:

6.5 x Equivalent Population = Generation rate in lbs/day

c. For hospitals using disposable linen and food service items:

12.7 x Equivalent Population = Generation rate in lbs/day

Where:

Equivalent Population = 5/7 (Avg shift population; Monday - Friday) + 2/7 (Avg shift population; Saturday - Sunday) and

$$\text{Average shift population} = \frac{\text{T.E.H.P. 1st Shift} + \text{T.E.H.P. 2d Shift} + \text{T.E.H.P. 3rd Shift}}{3}$$

Where T.E.H.P. = Total Estimated Hospital Population

ADVANTAGES

Information based on data from seven different hospitals.

Presents equations for waste estimation for situations in which disposable food services items and/or linens are used.

DISADVANTAGE

Does not provide generation information for specific areas of the hospital.

FIGURE 2.

Formula 2. This formula was developed by the University of Minnesota, School of Public Health taken from "Hospital Solid Waste Disposal in Community Facilities," page 207.[6]

$Y_3 = 6.7 - 0.0057X_1 + 0.85X_3 + 0.0051X_7 + 0.015X_8 + 0.010X_9 + 1.7X_{10} + 0.00028X_{11}$ and $Y_3 \cdot$ Inpatient Census = Generation rate lbs/day

Where:

Y_3 = lbs of solid waste per day per patient

X_1 = bed capacity, including newborn bassinets

X_3 = one if there is laboratory research at the hospital and zero if there is not

X_7 = number of trainees

X_8 = number of trainees residing at the hospital

X_9 = number of outpatient visits per year, in thousands

X_{10} = one if the hospital possesses a current State license and is accredited by the Joint Commission; zero otherwise

X_{11} = number of surgical procedures per year

ADVANTAGES

Most comprehensive equation; takes more into account than the others.

Based on measured information from numerous hospitals.

DISADVANTAGES

Does not provide specific generation information for particular areas of the hospital.

Does not account for use of disposable linens or food service items.

FIGURE 3.

Formula 3. This formula was developed by the University of West Virginia and presented in the EPA publication "Hospital Wastes," page 13.[9]

HOSPITAL FACILITY	EXPECTED POUNDS PER DAY ARE EQUAL TO:
HEAVY-CARE UNITS	
General surgery, neurosurgery, cardiovascular, urology, eye, chest, burns, maternity-newborn, orthopedics, operating room, intensive care, recovery	4.47 times the total number of paid staff for that unit, excluding doctors
LIGHT-CARE UNITS	
Metabolic, psychiatric, general medicine, pediatrics, gynecology, neurology, ear-nose-throat	2.77 times the total number of paid staff for that unit, excluding doctors
SUPPORT UNITS	
Administrative offices, gift shop, dietary offices, laundry, pharmacy, receiving, regional medical program, Appalachian Respiratory Diseases Lab	2.21 times the total number of paid staff for that unit, excluding supervisors or administrators
SPECIAL UNITS	
X-ray, radiation therapy, emergency room, central supply	0.48 times the number of patients treated or orders filled
Clinical laboratories, outpatient clinic	0.19 times the number of tests run or patients treated
Kitchen, cafeteria	1.5 times the number of patient meals served

The sum of the generation rates for each unit will yield the generation rate in lbs per day for the entire hospital.

ADVANTAGE

Provides generation rates for each source; thus enhancing the overall planning.

DISADVANTAGES

Based on data from only one hospital.

Does not address disposable linens for food service items.

APPENDIX F

SAMPLE WASTE GENERATION RATE CALCULATION

The following is a sample calculation of waste generation rate to demonstrate the use of each equation presented in Appendix E.

1. Given 65 bed hospital with:

   a. Staff (Personnel, Monday through Friday):

Department	Shift 1	Shift 2	Shift 3
Department of Medicine (1)	3	1	1
Dental Activity (4)	13	3	3
Department of Pediatrics (2)	8	3	0
Pharmacy Service (1)	3	1	1
Department of Radiology	4	0	0
Ophthalmology and Otolaryngology Services (4)	6	3	0
Clinical Investigation Service (2)	6	4	0
Department of Pathology (4)	6	4	0
General Medical Service	7	3	3
Patient Accountability Branch (1)	8	2	2
Logistics Division (6)	22	18	5
Food Service Division	15	15	3
Department of Obstetrics and Gynecology (5)	10	4	3
Patient Affairs Branch (5)	7	3	3
Medical Records Branch (3)	3	2	2
Command (6)	6	2	1
Department of Surgery (4)	10	0	0
Intensive Care (3)	6	2	2
Nursery (1)	3	1	1
Coffee Shop	3	2	1
General Surgical Service (3)	10	9	6
TOTAL	159	82	37

NOTE: Numbers in parentheses indicate number of doctors or administrators in the department.

b. Staff (Saturday and Sunday):

Department	Shift 1	Shift 2	Shift 3
Department of Medicine (1)	2	1	1
Dental Activity	0	0	0
Department of Pediatrics (1)	5	0	0
Pharmacy Service	1	1	1
Department of Radiology	0	0	0
Ophthalmology and Otolaryngology Services (1)	3	0	0
Clinical Investigation Service	2	2	0
Department of Pathology	0	0	0
General Medical Service	3	3	0
Patient Accountability Branch (1)	2	2	2
Logistics Division (3)	7	5	4
Food Service Division	9	9	2
Department of Obstetrics and Gynecology (2)	5	5	3
Patient Affairs Branch (3)	3	2	0
Medical Records Branch (1)	2	2	2
Command (2)	2	1	1
Department of Surgery	0	0	0
Intensive Care (1)	2	2	2
Coffee Shop	1	1	1
General Surgical Service (2)	9	9	9
TOTAL	58	45	28

TOTAL STAFF = 411

NOTE: Numbers in parenthesis indicate doctors or administrators.

c. The Following Activities or Characteristics:

(1) Bed capacity including newborn bassinettes = 68.

(2) No research facilities or operations.

(3) No trainee program.

(4) Approximately 89,000 outpatient visits per year = 244 per day.

(5) Hospital has a State license and is accredited.

(6) Approximately 1,300 surgical procedures are performed annually.

(7) Radiology performs approximately 20 x-rays per day.

2. Waste Generation Rate by Method 1.

Monday - Friday Estimated Population	Staff	Inpatient	Outpatient	Total
First Shift Population	159	65	244	468
Second Shift Population	82	65		147
Third Shift Population	37	65		102
TOTAL				717 people

Average Shift Population = Total 1/3 or 239

Similar calculations for Saturday - Sunday yield an average shift population of 190.

Equivalent Population = 5/7(239) + 2/7(190) = 224 people

Generation rate = 3.6 x equivalent population = 3.6(224) ~ 800 lbs/day of refuse.

3. Waste Generation by Method 2.

$Y_3 = 6.7 - 0.0057X_1 + 0.85X_3 + 0.0051X_7 + 0.015X_8 + 0.010X_9 + 1.7X_{10} + 0.00028X_{11}$

From data listed in paragraph 1b we have:

$X_1 = 68$, $X_3 = 0$, $X_8 = 0$, $X_7 = 0$, $X_9 = 89$, $X_{10} = 1$, $X_{11} = 1300$

Our equation becomes:

$Y_3 = 6.7 - 0.0057(68) + 0.85(0) + 0.0051(0) + 0.015(0) + 0.010(89) + 1.7(1) + 0.00028(1300)$

$Y_3 = 9.3$ lbs/inpatient/day, considering a maximum of 65 inpatients.

Generation rate = 9.3 · (65) = 600 lbs/day.

4. Calculation by Method 3 (based on typical midweek day, Monday - Friday).

a. Heavy Care.

Includes	Number of personnel
Ophthalmology and Otolaryngology Service	5
Department of Surgery	6
Intensive Care	7
Department of Obstetrics and Gynecology (Labor Delivery)	6
TOTAL	24

From equation 3, 24 · 4.47 = 107 lbs/day

b. Light Care.

Includes	Number of Personnel
Dental Activity	6
Department of Pediatrics	9
Department of Pathology	6
Department of Obstetrics and Gynecology (General Care)	9
General Surgical Service	22
TOTAL	52

From equation 3, 52 · 2.77 = 144 lbs/day

c. Support.

Includes	Number of Personnel
Department of Medicine	4
Pharmacy Service	4
Clinical Investigation Service	11
Logistics Division	38
Patient Affairs Branch	8
Medical Records Branch	4
Command	3
Nursery	4
Coffee Shop	6
TOTAL	82

From equation 3, 2.21 x 82 = 181 lbs/day

d. Special Units (From Equation 3).

Radiology = 0.48 x 20 x-rays/day = 10 lbs/day.

Clinic = 244 tests run x .19 = 46 lbs/day.

Meals = 65 patients x 3 meals/day x 1.5 = 290 lbs/day

TOTAL = 346 lbs/day.

TOTAL GENERATION = heavy care + light care + support + special units = 780 lbs/day

APPENDIX G

DEFINITIONS OF INFECTIOUS WASTE

1. Definition adopted by the Hospital Council of Southern California published by Brewer, John B., "A Case History," presented at AHA Institute on Hospital Waste Management, Chicago, IL (May 1972).[8]

Infectious waste from a general hospital shall be defined as:

a. Significant laboratory wastes including pathologic specimens and disposable fomites attendant thereto.

(1) Pathologic specimens shall include all tissues, specimens of blood elements, excreta and secretions obtained from patients.

(2) Fomites shall include any substance which may harbor or transmit pathogenic organisms.

b. Surgical operating room pathologic specimens and disposable fomites attendant thereto.

c. Similar disposable materials from outpatient areas and emergency rooms.

d. Equipment, instruments, utensils and fomites of a disposable nature from the rooms of patients with suspected or diagnosed communicable disease, which by the nature of the disease is required to be isolated by public health agencies. Nothing in this section shall be construed to limit the authority of the local health officer to require waste to be treated as infectious, when he determined it necessary and declares such waste to be infectious.

2. Definition proposed by Frank Arnold in "Defining Categories of Solid Waste," presented at AHA Institute on Hospital Waste Management, Chicago, IL (May 1972).[7]

INFECTIOUS WASTE. Waste originating from the diagnosis, care or treatment of a person or animal which has been or may have been exposed to a contagious or infectious disease.

3. EPA definitions as appears in Title 40, Code of Federal Regulations, 1976 ed., Part 240, Guidelines for the Thermal Processing of Solid Wastes.

Infectious waste means: (1) Equipment, instruments, utensils and fomites of a disposable nature from the rooms of patients who are suspected to have or have been diagnosed as having a communicable disease and must therefore be isolated as required by public health agencies; (2) laboratory wastes such as pathological specimens (e.g., all tissues, specimens of blood elements, excreta and secretions) obtained from patients or laboratory animals and disposable fomites (any substance that may harbor or transmit pathogenic organisms) attendant thereto; (3) surgical operating room pathologic specimens and disposable fomites attendant thereto and similar disposable materials from outpatient areas and emergency rooms.

4. Definitions of biological wastes taken from "Hospital Solid Waste Management in Community Facilities," published by School of Public Health, University of Minnesota, May 1971.[6]

Resulting directly from patient care activities, such as diagnostic procedures and treatment, includes materials of medical, surgical, autopsy and laboratory origin are listed as follows:

a. Medical waste, which is considered to include such items as gauze dressing and bandages, swabs, cartons and plastic casts as well as sputum cups and paper bags containing paper tissues soaked with secretions of the nose or throat from tuberculosis and other infectious disease cases.

b. Surgical and autopsy waste, which was considered to include amputated limbs, tissues and organs, placenta and similar types of material.

5. Department of the Army definition found in AR 40-5, paragraph 5-9b.

*Infectious Waste. Wastes contaminated with disease organisms, and/or offensive materials (bandages, sacrificed animal carcasses, laboratory tissue specimens, dressings, surgical wastes, food service wastes from infectious disease wards, used disposable needles and syringes, materials contaminated with blood, body exudates or excreta, infectious wastes incident to hospital and laboratory operation) * * *.*

6. Hospital Infection Control Program, this Agency, proposed definition.

Waste contaminated with body fluids, secretions and/or excreta from humans or animals undergoing medical diagnosis, care and/or treatment; waste incident to the operation of a laboratory, handling materials which are obviously or potentially contaminated *with microorganisms; and certain medical waste which require special handling. Typical examples of infectious waste are:*

a. Patient waste such as bandages, dressing and disposable material used for collection of body fluids.

b. All solid waste originating from patients placed on strict isolation procedures for control of infection.

c. All laboratory refuse of a potentially infectious nature such as sputum, stool or urine specimen cups and microbiological cultures.

d. Medical wastes requiring special handling such as pathological waste, disposable needles and syringes and other hazardous materials.

7. Definition by Frank L. Cross presented in Hospital Waste Management Course Handbook.* The definition is broken down into two parts:

PATHOLOGICAL. Certain biological waste is hazardous due to contamination with pathogens. Tubercular lungs are particularly hazardous due to possibility of airborne dissemination of pathogens.

The American Hospital Association has identified as particularly hazardous the organism Mycobacterium tuberculosis, bacteria of the genus <u>Pasteurella</u> and <u>Brucella</u>, and psittacosis group, as well as certain viruses.

Autopsy and surgical waste present pathogenic hazard and also public insult if not correctly handled.

CONTAMINATED. Blood, pus and spittle can contaminate the air with a variety of microbiological agents. Contaminated casts and dressings are potentially equally hazardous.

Sharp wastes such as scalpels and hypodermic needles are potentially disease and accident hazards. Discarded hypodermic needles also may be stolen for drug abuse.

---

* Course presented at George Washington University, October 1972.

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

APPENDIX H

ALBERT KLEE'S DARE TECHNIQUE

Reprinted Courtesy of Morgan-Granpian Publishing Co., Berkshire Common, Pittsfield, MA 01201.

Let DARE make your solid-waste decisions

Engineers discover a new method of decision making and apply it to the solid-waste problem

By **Albert J. Klee**

Evaluating the alternative solutions to solid-waste problems is a complicated task. It is often difficult to determine:

- the factors used to evaluate these alternatives,
- the evaluator's view of the importance of the factors,
- the worth of each alternative with respect to each factor.

To introduce a rational, orderly process to score alternatives, we found it necessary to examine the entire category of decision-weighing models. As a consequence, we developed a helpful new technique that produces meaningful scores, is simple to use, and which minimizes the number of decisions required of the decision-maker. This technique is DARE, an acronym for Decision Alternative Ration Evaluation.

Mr. Klee of the Bureau of Solid Waste Management was instrumental in developing the DARE technique. This bureau is a function of the U.S. Department of Health, Education and Welfare in Washington, D.C.

To explain how it works we must first review the concepts of scoring models and their use. Let us assume that there are three proposals for the disposal of municipal solid wastes: sanitary landfill, composting and incineration. Suppose that the factors (which are simply decision criteria) that will help evaluate these alternatives are:

1. Capital cost of the facility,
2. Ability of the process to salvage certain of the wastes,
3. Time needed to develop the process,
4. Contribution to air pollution of the process,
5. Operating cost of the facility.

Simple scores

One simple evaluation technique would be to consider one alternative and to assign a subscore to it for every factor selected. The sum of these subscores could constitute a "score" for the alternative, repeating the practice until all alternatives have been scored. Algebraically, the model would look like this:

$$A = S_1 + S_2 + S_3 + S_4 + S_5$$

where A is the score of the alternative being evaluated and the S values (known as "factor subscores") are the subscores assigned to this alternative for each of the five factors used to make the evaluation. However, factors are rarely of equal importance. In this example, for instance, an evaluator may feel that the air-pollution factor is of far greater importance than the salvage-value factor. Accordingly, he is able to construct a better model, one which weights each of the subscores:

$$A = S_1W_1 + S_2W_2 + S_3W_3 + S_4W_4 + S_5W_5$$

where the W-values (known as "factor weights") are numbers reflecting the relative importance of the factors used in the evaluation process. This model is a simple linear, additive one. It is satisfactory provided the factors are independent of each other (that they do not constitute optional means of satisfying the same objectives). For example, assume that one of the objectives of the disposal project is to provide a means for returning the metals in the waste to the economy as a useful by-product, and that two criteria (factors) are established. One is the feasibility of salvaging

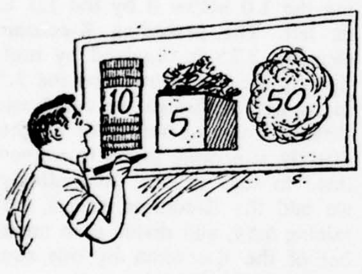
This paper proposes a new method of decision making as an offspring of the complicated problems encountered in solid waste research. It is applicable however, to any field where one must evaluate complicated sets of competing alternatives. This new method, DARE, produces cardinally weighted scores, is simple to use, and minimizes the number of decisions required of the decision-maker. The conclusions reached in the example given in this article are for illustration only and should not be applied to specific situations without considering local conditions.

metals in the form of pellets, and the second is the feasibility of salvaging metals in the form of irregular pieces.

These criteria are *not* independent with regard to utility; either will satisfy the same objective. In this example, the decision-maker might well have considered the dollar value of the metal returned to the economy as well as the tonnage of the metal so returned as basic criteria.

Little dependence

These criteria, of course, constitute different means of satisfying the stated objective. The remaining discussion (and the DARE technique) assume that the decision-



maker has selected and refined his decision on criteria in such a way as to minimize dependence among them.

Now we must determine both the factor weights, W, and factor subscores, S. One method, termed "rating" assigns numbers on an arbitrary scale directly. For example, with regard to the factor weights in our problem we might, after a great deal of pondering, assign a weight of 10 to capital cost, 5 to salvage, 50 to air pollution, and so on. In addition to its somewhat arbitrary flavor, this method poses great difficulties to the decision-maker. It does have one distinct advantage, however, the factors produced are cardinal ones and we are able to determine almost at a glance just *how much more important* one factor is than any other.

An easier way

We could instead adopt a procedure which places much less strain on the decision-maker, simply ordering ("ranking") the items under consideration. With regard to factor subscores, for example, in the case of the capital-cost factor we might rank landfilling as the least expensive, incineration the next cheapest, and composting the most expensive alternative. Ranking, however, suffers from a serious drawback. It permits no indication of the *size* of a difference, as does rating.

If the number of items to be ranked or ordered is large, however, even this task might prove formidable for the evaluator. Consequently, a third procedure in which evaluators pair up and compare alternatives has attracted some interest. In value engineering, this technique is termed "forced decisions".

Evaluators then decide which item of each pair is more important or which scores higher. The "winner" receives a score of 1 (a "positive" decision), the loser a 0. For example, in comparing capital cost to salvage possibilities, we might consider capital cost more important. Capital cost scores 1 on this comparison, and salvage scores 0. Next, capital cost is compared with the air-pollution factor. If air pollution is more important, it scores 1. The total number of positive decisions for each factor then determines factor weights. A similar method derives factor subscores.

Mathematics can prove that the pairwise comparison procedure simply produces a rank ordering, although it appears at first glance to be a cardinal procedure. However, the method has the advantage that the decisions required of the decision-maker are simple. He need

compare at any one step just two items. With rating or ranking he might be confronted with dozens or even hundreds of items at one time. However, the pairwise-decision technique suffers from the fact that evaluators must make a tremendous number of comparisons when many factors are involved. For example, if a problem involved ten alternatives evaluated on the basis of 20 factors, the evaluator must make 1,090 comparisons, and each comparison requires a decision upon the part of the evaluator. Clearly, this asks too much of the decision maker.

Studies assessing the evaluation procedures described have found evaluators, for example, to consider ranking the easiest to use and rating among the hardest. Although most assume that pairwise-comparison techniques could be found highly

acceptable, they were judged to be equally as difficult as rating, primarily because of the large number of comparisons usually necessitated by the technique. Oddly enough, no significant differences appeared in the scores produced by these methods when applied to the same problems. However, if the evaluators were knowledgeable about the systems they were evaluating, they tended to *believe* that ranking systems were less reliable than rating systems for recording their judgments in spite of the fact that the improvement in reliability is more apparent than real. The psychological needs of the decision-maker, nonetheless, cannot be ignored. In experiments involving pairwise comparisons, for example, we found that subjects balked at awarding a simple 1 and 0 when the items were almost equally matched.

Our new method, DARE, draws from the strengths of these methods and minimizes their weaknesses. It is simple to use, cardinal in

Table I

Sample Problem: Derivation of Factor Weights, W

Factor	R	K	W
Capital cost	2.0	0.66	0.10
Salvage	0.1	0.33	0.05
Air pollution	2.5	3.25	0.50
Development time	1.3	1.3	0.20
Operating cost	—	1.0	0.15
		6.54	1.00

nature and, although based upon a pairwise-comparison concept, it drastically restricts the total number of comparisons necessary. To illustrate the technique, we'll apply it to the waste-disposal problem. First we list the factors in arbitrary order (more about this later) as shown in Table I. Of the three columns of numbers in this table, only the first reflects input by the evaluator. Simple calculations yield the balance.

The numbers in the R-column are quantitative ratios, assigned by the evaluator, reflecting a comparison of each factor with the one listed immediately below it. The evaluator considers air pollution to be 2½ times as important as development time, the salvage factor only one-tenth as important as air pollution, and development time 1.3 times as important as operating cost. Since the pairs are made sequentially moving down the list one factor at a time, the evaluator need make only a small number of paired comparisons, merely one less than the number of factors.

The remainder of the calculation proceeds quickly. A 1.0 always goes into the K-column opposite the last factor. Each remaining K-value is formed by the product of its predecessor and the R-value opposite it in a zigzag route up the table. The second-last element, in the K-column, 1.3, results from multiplying the 1.0 below it by the 1.3 to its left. The preceding K-column element, 3.25 is obtained by multiplying the 1.3 below it by the 2.5 to its left. Although we could use these K-values as our factor weights directly, it is more useful to convert them to sum to one. Accordingly, we add the K-column values, obtaining 6.54, and divide each member of the K-column by this sum to obtain the W column.

Table II

Sample Problem: Derivation of Factor Subscores, S

	R	K	S
1. Capital cost			
Sanitary landfill	2.5	1.25	0.46
Incinerator	0.5	0.5	0.18
Compost plant	—	1.0	0.36
		2.75	1.00
2. Salvage			
Sanitary landfill	0.5	0.5	0.20
Incinerator	1.0	1.0	0.40
Compost plant	—	1.0	0.40
		2.5	1.00
3. Air pollution			
Sanitary landfill	2.00	1.00	0.40
Incinerator	0.50	0.50	0.20
Compost plant	—	1.00	0.40
		2.50	1.00
4. Development time			
Sanitary landfill	4.0	2.4	0.60
Incinerator	0.6	0.6	0.15
Compost plant	—	1.0	0.25
		4.0	1.00
5. Operating cost			
Sanitary landfill	2.0	1.4	0.45
Incinerator	0.7	0.7	0.23
Compost plant	—	1.0	0.32
		3.1	1.00

Factor subscores

Next, we evaluate the alternatives in terms of each of the five factors by a perfectly analogous procedure to obtain the factor subscores shown in Table II. The capital cost for landfilling is 2½ times *smaller* than for incineration. Note that, since the higher the score an alternative receives the more desirable the alternative, the ratios for items such as costs and development time are really inverses of the estimated cost and time ratios. The order of listing for the factors must follow that used in Table I. The order of listing the alternatives is arbitrary, except that once determined for the first factor, we must follow it for all the remaining factors.

The final step consists of summing the cross-products of the factor weights and factor subscores to produce the final scores for each of the alternatives. We construct Table III to accomplish this conveniently. The factor weights from Table I form the first column. Then, corresponding factor subscores from Table II go under their appropriate headings. Multiplying the elements

Table III

Sample Problem: Derivation of Alternatives Scores, A

		Sanitary Landfill		Incinerator		Compost Plant	
Factors	Factor weights	Factor subscores	Weighted scores	Factor subscores	Weighted scores	Factor subscores	Weighted scores
1. Capital cost	0.10	0.46	0.0460	0.18	0.0180	0.36	0.0360
2. Salvage	0.05	0.20	0.0100	0.40	0.0200	0.40	0.0200
3. Air pollution	0.50	0.40	0.2000	0.20	0.1000	0.40	0.2000
4. Development time	0.20	0.60	0.1200	0.15	0.0300	0.25	0.0500
5. Operating cost	0.15	0.45	0.0675	0.23	0.0345	0.32	0.0480
	Total Scores		0.4435	—	0.2025	—	0.3540

of the factor-subscore columns by the elements of the factor-weight column and then summing the products, produces the final total scores shown indicating that the sanitary-landfill alternative constitutes the best of the three, about one-fourth better than the runner-up, composting.

Because DARE depends upon a pairwise-comparison concept, the individual decisions which it incorporates are relatively easy to make. The decision-maker simply compares one item with another.

Reverse comparison

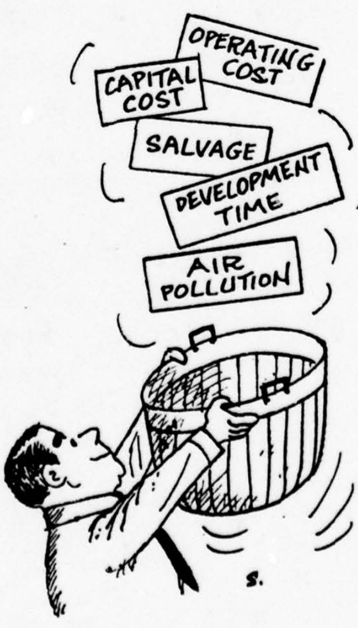
Should the decision-maker find it difficult to determine relative weights less than 1, he could reverse the comparison to arrive at weights such as "3:1 better," "20% better" (i.e., 1.2:1) and so on, remembering only to enter the reciprocal of such reversed relative weights in the R-value columns.

Although the order of listing the factors or alternatives in the tables is arbitrary (except where noted), this assumes that the decision-maker is consistent in his judgments (e.g., if A is 2 times as important as B and if B is 3 times as important as C; then to be consistent, A must be 6 times as important as C).

Experience with the technique, however, suggests that consistency in determining of factor weights improves when the evaluator employs a rough pre-ordering of factors.

A check on consistency can then be obtained by repeating the analysis and rearranging the factors in a random manner to effect a different order.

Occasionally, a factor may be irrelevant with regard to a particular alternative. Since, obviously, the alternative should receive a zero subscore with regard to such a factor, the most convenient procedure is to assign a subscore of zero to the alternative for this factor, and then proceed to determine the subscores for the other



alternatives as if that alternative did not exist.

From data to decision

DARE incorporates both qualitative and quantitative factors. Although the presence of the former increases the subjectivity of the final score, the fact that relative weights serve as inputs to the model insures that the decision-maker's view of the system is clearly and unequivocably stated. Should quantitative data be available, they are easily incorporated in the form of ratios which automatically produce the required relative weights.

Most scoring models permit the utilization of the consensus of the knowledge and judgment of more than one decision-maker. DARE is no exception.

However, it is also useful to compare the results produced by individual decision-makers applying the technique independently, so that it can serve as the basis for a sensitivity analysis concerning the concordance of the decision makers.

Some shortcomings

DARE is basically a technique for cardinally ordering alternatives on the basis of stated criteria. Observers can clearly determine what factors were used in such an evaluation, what the evaluator thought of the importance of these factors, and how each alternative scored. It has some shortcomings, however.

Although it determines the "best" alternative, it does not shed any light on the risk, profitability or utility of this alternative. It is clear that the decision-maker may decline to implement the best of a set of poor alternatives.

The decision to implement or not to implement rests upon other aspects of decision theory. Evaluators who know both the shortcomings and strong points of DARE, however, can employ it to great advantage. ◄◄

APPENDIX I

CALCULATIONS FOR SELECTION OF WASTE TRANSPORTATION SYSTEM

1. The calculations follow the same procedure outlined in Appendix H. Criteria used for evaluation are defined below in paragraph 1a. Transportation systems evaluated in Tables I-2 through I-13 are defined in paragraph 5d(3) of the report. Many of the calculations presented are based on the author's subjective judgments. Thus, the reader is encouraged to attempt calculations choosing factors more applicable to his situation.

a. Transportation System Evaluation Criteria. The following criteria were used to evaluate each waste transportation alternative.

(1) Sanitary Removal of General and Infectious Waste. This criterion evaluates the systems ability to transport mixed general and infectious waste without producing health hazards. Hazards considered include cross contamination potential and insect and rodent problems.

(2) Reduction of People Problems. This is an evaluation of the overall simplicity of the system. For example, does the system provide many opportunities for people to make mistakes in using it or is it designed so that little can go wrong.

(3) Minimization of Annoyance Factors. This criterion evaluates noise, odor and unsightliness caused both directly and indirectly by a given transportation system.

(4) Reliability. This is an evaluation of the past history of the system. For example, does it have a history of frequent prolonged breakdowns or has experience revealed just minor problems.

(5) Responsive to Needs. This criterion evaluates the systems ability to be used any time, day or night, without delay of any sort such as waiting for someone else in the hospital to be done using it.

(6) Total Cost. The estimated total cost of the system is based on capital cost [figures taken from Government Accounting Office (GAO) Study[18] which include equipment, secondary equipment, installation and spatial cost] and labor costs (estimated manpower required to collect and handle solid waste and to run transportation equipment for a 10-year period).

(7) Additional Functions. This is the ability of the system to function in other areas of hospital materials transport such as linen removal and food tray distribution and removal.

(8) Special Waste Removal Capabilities. This is the ability of the system to move special wastes such as pathological, bulky and hazardous chemical waste.

(9) Capability of Moving Wastes to Many Different Locations without the Use of Manpower. Self-explanatory.

(10) Susceptibility. This is an evaluation of inherent weak points in a given system which could result in total shutdown of the system. Note the difference between this factor and reliability. This criterion does not evaluate the systems history. It evaluates its potential for shutdown. Therefore, a given system may be very reliable, having no record of breakdowns, yet susceptible.

(11) Expandability. The capability of the system to be expanded with expansion of the hospital building.

(12) Maintenance and Utility Costs. The cost of keeping the system in good operating order; for example, costs for spare parts, frequent clean up, utility needs and manpower needed to maintain the system.

b. Factor Weight Calculation. Table I-1 presents the calculation of the weights for each factor (criteria) listed in paragraph 1a. Paragraph 1b(1) presents the rationale for each rating of relative importance (R).

(1) Discussion of comparisons found in Table I-1.

(a) Decision A. Sanitary removal of waste is the most important consideration in this study. Although a complex system might induce poor sanitation into the system, it is felt that for the purposes of this study, a system's sanitation is more important than its simplicity.

(b) Decision B. People problems may directly affect health; annoyance factors deal only with aesthetics and should be secondary to a health consideration.

(c) Decision C. A reliable waste removal service is considered much more important than aesthetics.

(d) Decision D. Regardless of how readily available a system is, it is useless if it frequently breaks down. The reliability is considered more important than responsiveness.

TABLE I-1. CALCULATIONS FOR FACTOR WEIGHTS

Decision	Factor	R	K	W
A	Sanitary removal of general and infectious waste	5	3.37	0.27
B	Reduction of people problems	2	0.67	0.05
C	Minimization of annoyance factors	0.25	0.33	0.02
D	Reliability	2	1.35	0.10
E	Responsive to needs	0.20	0.67	0.05
F	Total cost	4	3.37	0.27
G	Additional functions	2	0.84	0.07
H	Special waste removal capabilities	1.5	0.42	0.08
I	Capability of moving waste to many locations	1.5	0.28	0.02
J	Susceptibility to total breakdown	0.75	0.19	0.02
K	System expandability	0.25	0.25	0.02
	Maintenance and utility costs		1.00	0.08
			12.74	1.00

Where:

R is the rating of the relative importance of the given factor as compared to the factor immediately below it. For example, sanitary removal of general and infectious waste is considered five times as important to the author as minimization of people problems and being responsive to needs is considered one-fifth as important as total cost.

K is the factor weight calculated simply by assigning the value one to the K column of the last factor and forming each succeeding (going up the column from the last factor) value by determining the product of the R value of the factor and the K value of the preceding factor (for example, K for system expandability is determined by multiplying 0.25 x 1).

W is the factor weights from K converted to sum to one to facilitate subsequent calculation.

Decisions: This column is used to annotate comparisons to facilitate reference to particular comparison in the text. Therefore, decision A refers to the comparison of sanitary removal of general and infectious waste to minimization of people problems, B refers to the comparison of minimization of people problems to minimization of annoyance factors, etc.

(e) Decision E. No hospital has an unlimited budget for waste removal. Cost is definitely a major consideration and responsiveness to needs (as defined) although important cannot be pursued without giving consideration to cost.

(f) Decision F. Considering the system mentioned solely as solid waste removal systems, the added advantages of being able to move other materials is still subject to cost limitations.

(g) Decision G. Additional functions are considered more important than moving of special wastes because special wastes make up only a fraction (approximately 2 percent of all waste) whereas movement of other materials such as food and supplies can become one of the major functions of this system.

(h) Decision H. Since waste is not usually stored or disposed in a variety of places throughout a hospital, the ability of the system to move all wastes is more important than to move same wastes to a variety of locations.

(i) Decisions I and J. Susceptibility to total breakdown is considered of only minor importance since it does not reflect any problem, but only potential for problems. Thus, they are rated as shown.

(j) Decision K. Necessity of hospital expansion is a relatively infrequent occurrence, whereas maintenance cost is one of the more important considerations.

c. Calculation of Factor Subscores for an Existing Hospital, 200 Beds and Under. Tables I-2 through I-13 present the calculation of factor subscores for each criteria listed in Table I-1.

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE I-2. SANITARY REMOVAL OF GENERAL AND INFECTIOUS WASTE.

System	R	K	S	Rationale
Manual with cart	0.8	2	0.11	Properly operated gravity chutes minimize waste travel through the hospital; thus, cross contamination possibilities are limited.
Gravity Chutes	0.5	2.5	0.14	Both are closed systems, but the pneumatic vacuum system provides continual self-cleaning for the tube.
Pneumatic	2	5	0.28	Waste must be handled a second time when the cart is unloaded; pneumatic chute feeds right into the container providing less opportunity for cross contamination.
Automatic Cart	0.5	2.5	0.14	Cart from chain conveyor can empty itself into final storage; thus eliminating further handling and possible cross contamination; automatic cart systems cannot provide this.
Overhead Chain Conveyor	5	5	0.28	Belt is relatively unsanitary; bags can break contaminating the entire system.
Conveyor Belt	0	1	0.05	
		18	1.00	

TABLE I-3. ENGINEERED TO REDUCE PEOPLE PROBLEMS.

System	R	K	S	Rationale
Manual with Cart	2	4	0.37	Since waste is mixed and is collected by a chosen few, carts provide the simplest system and the fewest opportunities for error; dual chutes for laundry and trash can cause confusion.
Gravity Chutes	1	2	0.18	Both operate with essentially the same problems; i.e., confusion caused by two chutes.
Pneumatics	2	2	0.18	Automatic carts are relatively complex mechanisms; chances for mixups such as sending waste to the wrong location are great.
Automatic Cart	1	1	0.09	Automatic carts and overhead chain conveyors are considered equally complex.
Overhead Chain Conveyor	1	1	0.09	Both are considered equally complex.
Conveyor Belt	0	1	0.09	
		11	1.00	

TABLE I-4. MINIMIZATION OF ANNOYANCE FACTORS.

System	R	K	S	Rationale
Manual with Carts	0.2	0.30	0.03	Since carts can only be used in areas where there is traffic, it provides the most in the way of annoyance factors.
Gravity Chutes	0.5	1.50	0.13	Chutes have greater potential for noise and odor than the pneumatic tubes.
Pneumatic	1.0	3.0	0.26	Both use separate enclosed paths to remove waste; thus considered equal.
Automatic Carts	1.0	3.0	0.25	Same as for pneumatic.
Overhead Chain Conveyor	3.0	3.0	0.25	The greater likelihood of spillage in conveyor belt system would indicate the possibilities of odors.
Conveyor Belt		1.0	0.08	
		11.80	1.00	

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE I-5. RELIABILITY

System	R	K	S	Code	Rationale
Manual with Carts	2	6	0.43	0	Based on code; the code is based on downtime information given by hospital engineers obtained via telephone calls.
Gravity Chutes	2	3	0.21	0	
Pneumatic	1.5	1.5	0.11	*	
Automatic Carts	0.66	1	0.07	†	
Overhead Chain Conveyor	1.5	1.5	0.11	*	
Conveyor Belt		1	0.07	x	
TOTAL		14	1.00		

0 - Experienced only minor problems
* - Experienced somewhat prolonged shutdown, not more than a day
† - Experienced one or more full day's shutdown
x - No data available; used intuitive reasoning

TABLE I-6. RESPONSIVE TO NEEDS

System	R	K	S	Rationale
Manual with Carts	0.3	0.33	0.07	Waste collection personnel can only be so many places at once; chute is readily available to all at all times.
Gravity Chutes	1.2	1.08	0.23	Although similar, pneumatics may require waiting if someone else is already using the system at another station.
Pneumatic	3.0	0.9	0.20	Pneumatics are readily available; automatic carts are highly dependent on the availability of power modules.
Automatic Carts	0.3	0.3	0.06	Again automatic carts power module are expensive and not readily available; overhead chain conveyor power modules are much less expensive and, therefore, much more available.
Overhead Chain Conveyor	1.0	1.0	0.22	Both are continuously available.
Conveyor Belt		1.00	0.22	
		4.61	1.00	

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE I-7. TOTAL COST (CAPITAL AND LABOR)

System	R	K	S		Rationale
Manual with Carts	0.7	1.19	0.22	$162,000	Based on the total costs (for a 10-year period) listed immediately to the left. Cost data come primarily from GAO study.
Gravity Chutes	1.7	1.70	0.31	$120,000	
Pneumatic	4.2	1.00	0.19	$200,000	
Automatic Carts	0.8	0.24	0.04	$840,000	
Overhead Chain Conveyor	0.3	0.30	0.05	$640,000	
Conveyor Belt		1.00	0.19	$190,000	
		5.43	1.00		

TABLE I-8. ABILITY TO BE USED FOR MATERIALS SUPPLY

System	R	K	S	Rationale
Manual with Carts	1	0.0	0	Neither can be used for materials movement other than waste (i.e., you wouldn't use trash carts for linen handling).
Gravity Chutes	1	0.0	0	Neither can be used for supply purposes.
Pneumatic	0.001	0.0	0	Pneumatics simply cannot be used for supply, while it is one of the main functions of the automatic cart.
Automatic Carts	0.5	1.5	0.27	Overhead chain conveyors can be used for more materials than automatic carts.
Overhead Chain Conveyor	3	3.0	0.55	Conveyor belt, although able to be used for any materials, might be too risky to be used for trash and clean supplies simultaneously.
Conveyor Belt		1.0	0.18	
		5.5	1.00	

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE I-9. SPECIAL WASTE REMOVAL CAPABILITIES

System	R	K	S	Rationale
Manual with Cart	1.2	0.73	0.13	Advantage is to manual since bulky wastes can be moved with normal pickup. Both require extra pickups for all the other special wastes.
Gravity Chutes	1.2	0.61	0.11	They are essentially equal, except that gravity chutes usually have better bulky waste capacities.
Pneumatic	0.4	0.51	0.09	Automatic carts can carry virtually any waste.
Automatic Carts	0.8	1.28	0.22	Overhead chain conveyor also can handle virtually any waste and is probably a bit safer with hazardous substance since there is less chance of collision.
Overhead Chain Conveyor	1.6	1.60	0.28	Conveyor belts are limited somewhat with respect to bulky wastes.
Conveyor Belts		1.00	0.17	
		5.73	1.00	

TABLE I-10. CAPABILITY OF MOVING WASTES IN MANY DIRECTIONS WITHOUT THE NEED OF MANPOWER

System	R	K	S	Rationale
Manual with Carts	0.5	0.23	0.03	Gravity chutes provide general waste movement in vertical direction without manpower.
Gravity Chutes	0.5	0.45	0.05	Pneumatics can move waste up and down as well as horizontally for a clear advantage over chutes.
Pneumatic	0.3	0.9	0.10	Both can send waste in about any direction, but automatic carts can send waste to any of many destinations. Pneumatics can generally be used only for one or two destinations.
Automatic Carts	1.0	3.0	0.35	They are equally effective.
Overhead Chain Conveyor	3.0	3.0	0.35	Belts like pneumatics are limited as to the number of possible destinations.
Conveyor Belt		1.00	0.12	
		8.58	1.00	

TABLE I-11. SUSCEPTIBILITY TO TOTAL BREAKDOWNS

System	R	K	S	Rationale
Manual with Carts	2	3	0.35	Virtually no possibility for total breakdown of manual and only one for the chutes (clogging).
Gravity Chutes	1.5	1.5	0.18	Both have possibility of clogging, but the narrower pneumatic tubes appear more susceptible to this and electrical failure.
Pneumatic	1.0	1.0	0.12	Both appear equally susceptible to total breakdown.
Automatic Carts	1.0	1.0		Both appear equally susceptible to total breakdown.
Overhead Chain Conveyor	1.0	1.0		Both appear equally susceptible to total breakdown.
Conveyor Belt		1.0	0.11	
		8.5	1.00	

TABLE I-12. SYSTEM EXPANDABILITY

System	R	K	S	Rationale
Manual with Carts	3	3	0.34	Manual systems require the hiring of additional help. Chutes are relatively inflexible for expansion unless the building expands upward.
Gravity Chutes	0.5	1	0.11	Pneumatic chute can be expanded with construction and still feed into the same outside storage receptacle. Gravity chutes may require a second receptacle.
Pneumatic	2	2	0.22	Although both can be expanded with new construction, automatic carts should present greater financial requirements for this purpose.
Automatic Carts	1	1	0.11	Essentially equivalent for expansion.
Overhead Chain Conveyor	1	1	0.11	Essentially equivalent for expansion.
Conveyor Belt		1	0.11	
		9	1.00	

TABLE I-13. MAINTENANCE AND UTILITY COST

System	R	K	S	Yearly Cost	Rationale
Manual with Carts	1	6	0.37	$ 200	Based on cost found in literature (particularly the GAO study) and from unpublished informal estimated data obtained from communication with engineers from various hospitals.
Gravity Chutes	3	6	0.37	$ 200	
Pneumatic	20	2	0.13	$ 600	
Automatic Carts	0.1	0.1	0.01	$11,200*	
Overhead Chain Conveyor	1	1	0.06	$ 1,200	Conveyor belt maintenance cost not found; guesstimated.
Conveyor Belt		1	0.06	$ 1,200	

* Estimated for 1974 for Fairfax Hospital.

TABLE I-14. DERIVATION OF ALTERNATIVE SCORES FOR 200 BEDS AND UNDER HOSPITAL

	Manual		Chutes		Pneumatic		Automatic Carts		Overhead Chain Conveyor		Conveyor	
	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)
Sanitary Removal	0.11	0.030	0.14	0.040	0.28	0.075	0.14	0.040	0.28	0.075	0.05	0.010
People Problems	0.37	0.018	0.18	0.009	0.18	0.009	0.09	0.005	0.09	0.005	0.09	0.004
Annoyance Factor	0.03	0.000	0.13	0.003	0.26	0.005	0.25	0.005	0.25	0.005	0.08	0.002
Reliability	0.43	0.043	0.21	0.012	0.11	0.011	0.07	0.007	0.11	0.011	0.07	0.007
Responsive to Needs	0.07	0.004	0.23	0.001	0.20	0.010	0.06	0.003	0.22	0.011	0.22	0.011
Overall Costs	0.22	0.060	0.31	0.084	0.19	0.051	0.04	0.011	0.05	0.013	0.19	0.051
Materials Supply	0	0.000	0	0.000	0	0.000	0.27	0.019	0.55	0.038	0.18	0.013
Removal Capabilities	0.13	0.004	0.11	0.003	0.09	0.003	0.22	0.007	0.28	0.008	0.17	0.005
Multidirectional Waste Movement	0.03	0.001	0.05	0.001	0.10	0.002	0.35	0.007	0.35	0.007	0.12	0.002
System Expandability	0.34	0.007	0.11	0.002	0.22	0.005	0.11	0.002	0.11	0.002	0.11	0.002
Maintenance and Utility Costs	0.37	0.030	0.37	0.029	0.13	0.010	0.01	0.001	0.06	0.005	0.06	0.005
		0.204		0.207		0.184		0.109		0.182		0.114

Conclusion: Chute and manual systems.

2. Waste Transportation, Decision Making, 400 Bed Existing Facility. The calculations follow the same procedure outlined in Appendix H. Criteria listed in Table I-1 are defined in paragraph 1.a.. Transportation systems evaluated in Tables I-2 through I-13 are defined in paragraph 5d(3) of the report.

a. Factor Weight Calculation. Table I-1 presents the calculation of the weights for each factor (criteria) listed in paragraph 1a. Paragraph 1b(1) presents the rationale for each rating of relative importance (R).

b. Calculation of Factor Subscores for an Existing Hospital, 200 to 400 Beds. The only factor which varies according to the size of the hospital is total cost. Total cost factor subscores are recalculated in Table I-15. The remainder of the factor subscores are simply taken from Tables I-2 to I-6 and I-8 to I-13.

c. Calculation of Best Alternative. Table I-16 presents the calculation of the best alternative for an existing hospital with a capacity of 400 beds.

TABLE I-15. TOTAL COST FOR 400 BED HOSPITAL

System	R	K	S		Rationale
Manual	0.6	0.84	0.18	$ 283,000	Based on costs pre-
Gravity Chute	1.6	1.40	0.30	$ 170,000	sented immediately
Pneumatic	4.2	0.88	0.19	$ 280,000	to the left of this.
Automatic Cart	0.7	0.21	0.05	$1,180,000	(The cost presented here
Overhead Chain Conveyor	0.3	0.30	0.06	$ 880,000	represents the sum of the total capital cost
Conveyor Belt		1.00	0.22		and labor cost for a
		4.63	1.00		10-year period.)

ATION OF ALTERNATIVE SCORES FOR 400 BED HOSPITAL (Existing Facility)

Manual (S)	Manual (WS)	Chutes (S)	Chutes (WS)	Pneumatic (S)	Pneumatic (WS)	Automatic Carts (S)	Automatic Carts (WS)	Overhead Chain Conveyor (S)	Overhead Chain Conveyor (WS)	Conveyor (S)	Conveyor (WS)
	0.144		0.123		0.133		0.098		0.169		0.063
0.18	0.049	0.30	0.081	0.19	0.051	0.05	0.014	0.06	0.016	0.22	0.059
	0.193		0.204		0.184		0.112		0.185		0.122

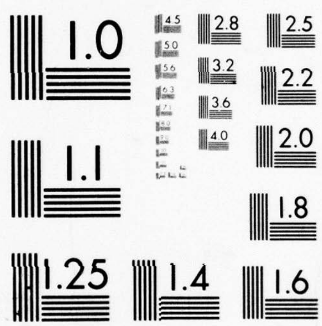
1, pneumatic and overhead chain conveyor systems.

AD-A053 219 ARMY ENVIRONMENTAL HYGIENE AGENCY ABERDEEN PROVING GR--ETC F/G 6/12
MEDICAL FACILITY SOLID WASTE MANAGEMENT, APRIL 1975 - JUNE 1976--ETC(U)
JUN 76 K P STACHIW

UNCLASSIFIED USAEHA-26-0406-78 NL

2 OF 2
AD
A053219

END
DATE
FILMED
6-78
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

3. Waste Transportation, Decision Making, 600 Bed Existing Facility. The calculations follow the same procedure outlined in Appendix H. Criteria listed in Table I-1 are defined in paragraph 1a. Transporation systems evaluated in Tables I-1 through I-13 are defined in paragraph 5d(3) of the report.

a. Factor Weight Calculation. Table I-1 presents the calculation of the weights for each factor (criteria) listed in paragraph 1a. Paragraph 1b(1) presents the rationale for each rating of relative importance (R).

b. Calculation of Factor Subscores for an Existing Hospital, 600 Beds. The only factor which varies according to the size of the hospital is total cost. Total cost factor subscores are presented in Table I-17. The remainder of the factor subscores are simply taken from Tables I-2 through I-6 and I-8 through I-13.

c. Calculation of Best Alternative. Table I-18 presents the calculation of the best alternative for an existing hospital with a capacity of 600 beds.

TABLE I-17. TOTAL COST FOR 600 BED HOSPITAL (Existing Facility)

System	R	K	S		Rationale
Manual	0.7	1.05	0.19	$ 424,000	Based on the costs
Gravity Chute	1.1	1.5	0.27	$ 320,000	presented immediately
Pneumatic	4.8	1.34	0.24	$ 360,000	to the left. Data
Automatic Cart	0.7	0.28	0.05	$1,720,000	obtained from para-
Overhead Chain Conveyor	0.4	0.4	0.07	$1,170,000	graphs 1c(7) and 2c(7).
Conveyor Belt		1.00	0.18		
		5.57	1.00		

TABLE I-18. DERIVATION OF ALTERNATIVE SCORES FOR 600 BED HOSPITAL (Existing Facility)

	Manual (S)	Manual (WS)	Chutes (S)	Chutes (WS)	Pneumatic (S)	Pneumatic (WS)	Automatic Carts (S)	Automatic Carts (WS)	Overhead Chain Conveyor (S)	Overhead Chain Conveyor (WS)	Conveyor (S)	Conveyor (WS)
Sum of all but the overall costs		0.144		0.123		0.133		0.098		0.169		0.063
Overall costs (0.27)	0.19	0.051	0.27	0.073	0.24	0.065	0.05	0.013	0.07	0.019	0.18	0.049
		0.195		0.196		0.198		0.111		0.188		0.112

Conclusion: Manual, chutes, pneumatic and overhead chain conveyor systems.

4. Waste Transportation, Decision for 200 Beds or Less Planned Facility. The calculations follow the same procedure outlined in Appendix H. Criteria listed in Table I-1 are defined in paragraph 1a. Transportation systems evaluated in Tables I-2 through I-13 are defined in paragraph 5d(3) of the report.

a. Factor Weight Calculation. Table I-1 presents the calculation of the weights for each factor (criteria) listed in paragraph 1a. Paragraph 1b(1) presents the rationale for each rating of relative importance.

b. Calculation of Factor Subscores for a Planned Hospital, 200 Beds and Under. Total cost is the only factor which varies for planned and existing facilities. Total cost factor subscores are recalculated and presented in Table I-19. The remainder of the factor subscores are simply taken from Tables I-2 through I-6 and I-8 through I-13.

c. Calculation of Best Alternative. Table I-20 presents the calculation of the best alternative for a planned hospital with a capacity of less than 200 beds.

TABLE I-19. TOTAL COST FOR 200 BED AND UNDER PLANNED FACILITY

System	R	K	S		Rationale
Manual	0.75	1.13	0.21	$160,000	Same costs as para-
Gravity Chutes	1.40	1.51	0.28	$120,000	graph 1c, Table I-7,
Pneumatic	4.17	1.08	0.20	$168,000	with cost reduction of
Automatic Carts	0.74	0.26	0.05	$700,000	20 percent for some of
Overhead Chain Conveyor	0.35	0.35	0.07	$520,000	automated system because
Conveyor Belt		1.00	0.19		of reduced construction.
		5.33	1.00		

TABLE I-20. DERIVATION OF ALTERNATIVE SCORES FOR 200 BED AND UNDER PLANNED FACILITY

	Manual		Chutes		Pneumatic		Automatic Carts		Overhead Chain Conveyor		Conveyor	
	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)
Sum of all but the overall cost		0.144		0.123		0.133		0.098		0.169		0.063
Overall cost (0.27)	0.21	0.057	0.28	0.076	0.20	0.054	0.05	0.013	0.07	0.019	0.19	0.051
		0.201		0.199		0.187		0.111		0.188		0.114

Conclusion: Manual and chute systems.

5. Waste Transportation, Decision Making, 400 Bed Planned Facility. The calculations follow the same procedure outlined in Appendix H. Criteria listed in Table I-1 are defined in paragraph 1a. Transportation systems evaluated in Tables I-2 through I-13 are defined in paragraph 5d(3) of the report.

a. Factor Weight Calculation. Table I-1 presents the calculation of the weights for each factor (criteria) listed in paragraph 1a. Paragraph 1b(1) presents the rationale for each rating of relative importance.

b. Calculation of Factor Subscores for a Planned Hospital, 400 Beds. Total cost is the only factor which varies for planned facilities from existing ones. Total cost factor subscores are recalculated and presented in Table I-21. The remainder of the factor subscores are simply taken from Tables I-2 through I-6 and I-8 through I-13.

c. Calculation of Best Alternative. Table I-22 presents the calculation of the best alternative for a planned hospital with a capacity of 400 beds.

TABLE I-21. TOTAL COST FOR A 400 BED PLANNED FACILITY

System	R	K	S		Rationale
Manual	0.60	0.85	0.17	$283,000	Based on costs presented immediately to the left. They include capital and 10-year labor costs.
Gravity Chutes	1.40	1.43	0.29	$170,000	
Pneumatic	4.10	1.02	0.21	$240,000	
Automatic Carts	0.75	0.25	0.05	$980,000	
Overhead Chain Conveyor	0.33	0.33	0.07	$720,000	
Conveyor Belt		1.00	0.21	$240,000	
		4.88	1.00		

TABLE I-22. DERIVATION OF ALTERNATIVE SCORES FOR A 400 BED PLANNED FACILITY

	Manual		Chutes		Pneumatic		Automatic Carts		Overhead Chain Conveyor		Conveyor	
	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)
Sum of all but the overall cost		0.144		0.123		0.133		0.098		0.169		0.063
Overall costs (0.27)	0.18	0.049	0.30	0.081	0.19	0.051	0.05	0.014	0.06	0.016	0.22	0.059
		0.193		0.204		0.184		0.122		0.185		0.122

Conclusion: Manual, chute, pneumatic and overhead chain conveyor systems.

6. Waste Transportation, Decision Making, 600 Bed Planned Facility. The calculations follow the same procedure outlined in Appendix H. Criteria listed in Table I-1 are defined in paragraph 1a. Transportation systems evaluated in Tables I-2 through I-13 are defined in paragraph 5d(3) of the report.

a. Factor Weight Calculation. Table I-1 presents the calculation of the weights for each factor (criteria) listed in paragraph 1a. Paragraph 1b(1) presents the rationale for each rating of relative importance.

b. Calculation of Factor Subscores for a Planned Hospital, 600 Beds. Total cost is the only factor which varies for planned facilities from existing ones. Total cost factor subscores are recalculated and presented in Table I-23. The remainder of the factor subscores are simply taken from Tables I-2 through I-6 and I-8 through I-13.

c. Calculation of Best Alternative. Table I-24 presents the calculation of the best alternative for a planned hospital with a capacity of 600 beds.

TABLE I-23. TOTAL COST FOR A PLANNED 600 BED HOSPITAL

System	R	K	S		Rationale
Manual	0.75	0.90	0.18	$ 424,000	Based on cost data
Gravity Chute	0.97	1.20	0.24	$ 320,000	presented immedi-
Pneumatic	4.61	1.24	0.25	$ 312,000	ately to the left.
Automatic Cart	0.67	0.27	0.05	$1,440,000	
Overhead Chain Conveyor	0.41	0.41	0.08	$ 960,000	
Conveyor Belt		1.00	0.20	$ 400,000	
		5.02	1.00		

TABLE I-24. DERIVATION OF ALTERNATIVE SCORES FOR 600 BED PLANNED HOSPITAL

	Manual		Chutes		Pneumatic		Automatic Carts		Overhead Chain Convevor		Conveyor	
	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)	(S)	(WS)
Sum of all but the overall costs		0.144		0.123		0.133		0.098		0.169		0.063
Overall costs (0.27)	0.18	0.049	0.24	0.065	0.25	0.067	0.05	0.013	0.08	0.022	0.20	0.054
		0.193		0.188		0.200		0.111		0.191		0.117

Conclusion: Pneumatic, overhead chain conveyor, manual and chutes systems.

APPENDIX J

CALCULATIONS FOR SELECTION OF WASTE PROCESSING AND DISPOSAL SYSTEM

1. The calculations follow the same procedure outlined in Appendix H. Criteria used for evaluation are defined below in paragraph 1a. Processing and disposal systems are evaluated in Tables J-2 through J-13 for a 200 bed hospital in paragraph 5e(2) of the report. Many of the calculations presented are based on the author's subjective judgments. Thus, the reader is encouraged to attempt calculations choosing factors more applicable to his situation.

a. Waste Processing and Disposal Technique Evaluation Criteria.

(1) Sanitation. This factor is used to indicate the ability of the system to process, haul and dispose of waste while minimizing possible disease transmission from aerosols, rodents insects or direct contact with the waste.

(2) Total Cost. This is the total equipment and operational (labor and fuel) costs for each entire processing and disposal system.

(3) Maintenance Cost. Self explanatory.

(4) Ability to Process and Dispose all Types of Waste. This is the ability of the method to dispose of infectious, pathological, and bulky waste.

(5) Simplicity. This is an evaluation of the competence required to successfully operate the system.

(6) Amenable to Automatic Feed. This is the ability of the system to be fed automatically by chute, pneumatic tube or overhead chain conveyor.

(7) Availability. This is the ability of the system to operate any time day or night, without the constant presence of an operator.

(8) Air and Water Pollution Problems. Self-explanatory.

(9) Resource Recovery. This is an evaluation of the systems potential for providing recovery or reclamation of the waste generated.

(10) Nuisance Problems. This is an evaluation of the noise, insect and odor problems created by use of this system.

(11) Reliability. Self-explanatory.

b. Table J-1 presented the calculation of the weights for each factor (criteria) listed in paragraph 1a. Paragraph 1b(1) presents the rationale for each rating of relative importance (R).

TABLE J-1. FACTOR WEIGHT CALCULATION

Decision	Factor	R	K	W
A	Sanitation	1.2	2.10	0.18
B	Total cost	2.0	1.75	0.15
C	Maintenance cost	0.8	0.87	0.08
D	Handles all varieties of waste	1.7	1.09	0.09
E	Simplicity	0.7	0.64	0.05
F	Amenable to automatic feed	2.0	0.92	0.08
G	Availability	0.25	0.46	0.04
H	Air and water pollution problems	8.00	1.84	0.16
I	Resource recovery possibilities	0.33	0.23	0.02
J	Nuisance problems	0.7	0.70	0.06
K	Reliability		1.00	0.09
			11.6	1.00

Where:

R is the rating of the relative importance of the given factor as compared to the factor immediately below it.

K is the factor weights calculated simply by assigning the value one to the K column of the last factor and forming each succeeding value by determining the product of the R value of the factor and the K value of the preceding factor.

W is the factor weights from K converted to the sum to one to facilitate subsequent calculation.

Decisions: This column is used annotating comparisons to facilitate reference to particular comparison in the text. Therefore, decision A refers to the comparison of sanitary processing and disposal of general and infectious waste to the total cost of processing and disposal.

---

(1) Comments on comparisons found in Table J-1.

(a) Decision A. Disposing waste in a sanitary manner takes a greater priority in this study than the ultimate cost to accomplish this task. However, one must pay some attention to the cost.

(b) Decision B. Maintenance cost is important, but since capital outlay and labor are usually more significant, total cost was given higher priority.

(c) Decision C. Both are important, but the benefits of being able to put in most any type of waste into the system and thus eliminating waste segregation is considered slightly more important.

(d) Decision D. Again the benefit of not having to segregate is considered worth having to sacrifice some simplicity.

(e) Decision E. Amenability to automatic feed is crucial to all the waste handling systems mentioned previously. It is, therefore, considered more important than the overall simplicity of the system.

(f) Decision F. Rating based on the same as for decision E. Also, it is not so crucial to be able to dispose waste all night long.

(g) Decision G. Elimination of air and water pollution problems are considered essential attributes to the system selected.

(h) Decision H. The ability to recover resources is considered only an "added extra" and peripheral to real needs.

(i) Decision I. Resource recovery is considered just an added extra; being rid of nuisances such as odors, rodents and noise is considered a much more valuable attribute.

(j) Decision J. It is felt that a system which is usually in good working order is perhaps worth putting up with some minor nuisances.

c. Tables J-2 through J-12 present the calculation of factor subscores for each criteria listed in Table J-1.

d. Table J-13 presents the calculation from all the factor subscores of the best alternatives for 200 bed hospital.

e. In the calculation for 400 bed hospital, only the factor "total cost" changes. Table J-14 recalculates the cost factor subscore for a 400 bed hospital. Table J-15 presents a revision of Table J-13 with the changed total cost factor subscore.

f. In the calculation for a 600 bed hospital, only the factor total cost changes. Table J-16 recalculates the cost factor subscore for a 600 bed hospital. Table J-17 presents a revision of Table J-13 with the changed total cost factor subscore.

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE J-2. SANITATION

System	R	K	S	Rationale
Unprocessed waste hauled to the landfill	0.5	0.91	0.05	Waste contains infectious materials exposing residents and landfill operators to potential health hazards. Stationary compactor offers a closed container of waste limiting the number of people who might come in contact with it.
Stationary Compaction/Landfill	0.5	1.82	0.11	Sterilized waste is obviously safer to handle than potentially infectious waste and is thus more desirable from a sanitation standpoint.
Sterilization/Stationary Compaction/Landfill	0.9	3.65	0.22	Incineration because of temperatures achieved should produce a cleaner product.
Incineration	1.5	4.05	0.24	Sewage treatment plant process does not disinfect the effluent of viruses injected by hospital solid waste.
Pulping/Sanitary Sewer	0.9	2.7	0.16	Dewatering/landfilling process offers more control of dangerous viruses than the sanitary sewer method.
Pulping/Dewatering/Landfilling	3.0	3.0	0.16	Pulped waste is disinfected; no attempt is made to disinfect shredded waste.
Shredding/Landfilling		1.0	0.06	
		17.13	1.00	

TABLE J-3. TOTAL COST

System	R	K	S	Cost	Rationale
Unprocessed/Landfilled	0.5	1.3	0.16	$119,000	Based on estimated total 10-year cost listed on left.
Stationary Compaction/Landfill	3.66	2.6	0.33	$ 59,999	
Retort Sterilization/Stationary Compaction/Landfill	1.40	0.71	0.09	$216,000	
Incineration	0.50	0.51	0.06	$308,000	
Pulping/Sanitary Sewer	1.20	1.02	0.13	$161,000	
Pulping/Dewatering/Landfilling	0.85	0.85	0.11	$198,000	
Shredding/Landfilling		1.0	0.12		
		7.99	1.00		

TABLE J-4. MAINTENANCE COST

System	R	K	S	Cost	Rationale
Unprocessed/Landfilled	0.40	0.30	0.07	$2,100	Based on estimated yearly maintenance costs listed on left; obtained from the following sources.*
Stationary Compaction/Landfill	0.55	0.75	0.16	$ 900	
Retort Sterilization/ Compaction/Landfill	2.20	1.36	0.30	$ 500	
Incineration	2.30	0.62	0.14	$1,100	
Pulping/Sanitary Sewer	1.10	0.27	0.06	$2,500	
Pulping/Dewatering/Landfilling	0.25	0.25	0.05	$2,700	
Shredding/Landfilling		1.00	0.22	$ 700	
		4.55	1.00		

* "Hospital Wastes Management Study of Los Angeles County, University of Southern California Medical Center," prepared by the School of Public Health, UCLA Environmental Health Management Program (Spring 1974)[12]
Comptroller General of the United States, "Study of the Health Facilities Construction Costs," Report to the Congress of the United States (December 1972)[18]
Telephone calls to hospitals.

TABLE J-5. ABILITY TO HANDLE ALL TYPES OF WASTE

System	R	K	S	Rationale
Unprocessed/Landfilled	0.5	0.32	0.05	Stationary compaction has an advantage since its container is leak-proof; thus, it has the ability to adequately contain high moisture content and liquid waste.
Stationary Compaction/Landfill	0.5	0.64	0.10	Sterilization provides a greater degree of flexibility; after the waste has been sterilized, it is eligible for landfills which would normally reject infectious waste.
Retort Sterilization/Stationary Compaction/Landfill	0.8	1.28	0.20	Incineration can be used for all waste; sterilization cannot be used for pathological waste.
Incineration	2.0	1.6	0.25	Incineration can handle virtually everything; in the pulping process, nonpulpables must be removed.
Pulping/Sanitary Sewer	1.0	0.8	0.12	Both have equal ability.
Pulping/Dewatering/Landfilling	0.8	0.8	0.12	Shredders can process a greater variety of waste than pulpers.
Shredding/Landfilling		1.00	0.16	
		6.44	1.00	

TABLE J-6. SIMPLICITY

System	R	K	S	Rationale
Unprocessed/Landfilled	1.0	3.2	0.27	Both rated essentially equal as far as user operation is concerned.
Stationary Compaction/Landfill	2.0	3.2	0.27	Sterilization process required as an additional step; thus, there is a greater chance for error.
Retort Sterilization/Stationary Compaction/Landfill	2.0	1.6	0.14	Sterilizers are much less complex to operate and require no monitoring.
Incineration	0.8	0.8	0.07	Incinerators are considered slightly more complex to operate.
Pulping/Sanitary Sewer	1.0	1.0	0.08	Both are considered relatively equal in simplicity.
Pulping/Dewatering/Landfilling	1.0	1.0	0.08	
Shredding/Landfilling		1.0	0.09	
		11.8	1.00	

TABLE J-7. AMENABLE TO AUTOMATIC FEED

System	R	K	S	Rationale
Unprocessed/Landfilled	0.33	0.4	0.07	Normal refuse containers do not provide sufficient volume or a means to distribute the waste throughout the container; stationary compactors provide both.
Stationary Compaction/Landfill	2.0	1.2	0.21	Automatic feed for retort would be extremely difficult.
Retort Sterilization/Stationary Compaction/Landfill	1.5	0.6	0.11	Both pose the same mechanical difficulties for automatic feeding. Automatic feeding of an incinerator may pose a fire hazard if chute fed.
Incineration	0.4	0.4	0.07	Automatic feed of waste is practical; problems with incineration have been discussed.
Pulping/Sanitary Sewer	1.0	1.0	0.18	Both are essentially the same.
Pulping/Dewatering/Landfilling	1.0	1.0	0.18	
Shredding/Landfilling		1.0	0.18	
		5.6	1.00	

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE J-8. AVAILABILITY

System	R	K	S	Rationale
Unprocessed/Landfilled	1	3	0.27	Equivalent; compactor or dumpsters should be available for use 24 hours per day.
Stationary Compaction/Landfill	3	3	0.27	Retort sterilizer is limited to the hours of work of the sterilizer operator.
Retort Sterilization/Stationary Compaction/Landfill	1	1	0.10	Equivalent; all are limited to the hours the operator is present.
Incineration	1	1	0.09	
Pulping/Sanitary Sewer	1	1	0.09	
Pulping/Dewatering/Landfilling	1	1	0.09	
Shredding/Landfilling		1	0.09	
		11	1.00	

TABLE J-9. AIR AND WATER POLLUTION PROBLEMS

System	R	K	S	Rationale
Unprocessed/Landfilled	0.8	1.04	0.13	Chances for unprocessed waste resulting in water pollution are greater since it probably will not be given special treatment at the landfill.
Stationary Compaction/Landfill	0.8	1.3	0.16	Sterilized waste has considerably less pollution potential than contaminated waste.
Retort Sterilization/Stationary Compaction/Landfill	2.0	1.62	0.21	Regardless of how well designed or operated, incineration always poses a potential particulate and gaseous emissions problem.
Incineration	1.0	0.81	0.10	Emissions problems with incineration and potential discharge of harmful viruses into surface streams are considered essentially equivalent.
Pulping/Sanitary Sewer	0.6	0.81	0.10	Problems of sanitary sewer disposal of pulped waste are mentioned above; pulping and dewatering allows the disinfection of the pulp.
Pulping/Dewatering/Landfilling	1.35	1.35	0.17	Disinfection applied during pulping process makes the final product safer for landfilling than the untreated shredded product.
Shredding/Landfilling		1.00	0.13	
		7.93	1.00	

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE J-10. RESOURCE RECOVERY

System	R	K	S	Rationale
Unprocessed/Landfilled	1.0	0.6	0.01	Reclamation of unsterilized waste is not recommended; thus, both offer little recyclability.
Stationary Compaction/Landfill	0.15	0.6	0.01	Sterilized waste offers some possibility of waste recovery, whereas there is no possibility by the stationary compaction method.
Retort Sterilization/Stationary Compaction/Landfill	0.10	4.0	0.08	Heat recovery from incineration is one of the best alternatives for hospital waste resource recovery.
Incineration	40.0	40.0	0.83	Same as above. Although metals separation may result from pulping process, the metals may be contaminated.
Pulping/Sanitary Sewer	1.0	1.0	0.02	Essentially the same potential for both pulping processes.
Pulping/Dewatering/Landfilling	1.0	1.0	0.02	Essentially the same potential for each.
Shredding/Landfilling	-	1.0	0.02	
		48.2	1.00	

TABLE J-11. NUISANCE PROBLEMS

System	R	K	S	Rationale
Unprocessed/Landfilled	0.8	0.33	0.07	Enclosure and control provided by stationary compactors should provide better control over nuisance factors than routine storage methods.
Stationary Compaction/Landfill	1.0	0.41	0.08	In both cases, wastes are both equally susceptible to nuisance problems.
Retort Sterilization/Stationary Compaction/Landfill	0.25	0.41	0.08	Waste is rendered more innocuous by incineration.
Incineration	1.5	1.65	0.33	Both essentially reduce waste before nuisance problems can take place.
Pulping/Sanitary Sewer	1.1	1.10	0.22	Dewatered pulp may result in fly and odor problems.
Pulping/Dewatering/Landfilling	1.0	0.1	0.02	Both considered equal with respect to nuisance problem elimination.
Shredding/Landfilling		1.00	0.20	
		5.00	1.00	

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE J-12. RELIABILITY

System	R	K	S		Rationale
Unprocessed/Landfilled	1.0	4.16	0.27	0	Based on direct telephone communication with hospitals using the system; numbers on the far right indicate average number of days per year the system was not available for use due to repairs.
Stationary Compaction/Landfill	1.0	4.16	0.29	0	
Retort Sterilization/Stationary Compaction/Landfill	8.0	4.16	0.29	0	
Incineration	2.6	0.52	0.04	8	
Pulping/Sanitary Sewer	1.0	0.2	0.01	21	
Pulping/Dewatering/Landfilling	0.2	0.2	0.01	21	
Shredding/Landfilling		1.00	0.07	4*	
		14.40	1.00		

* No data available, guesstimate.

TABLE J-13. DERIVATION OF ALTERNATIVE SCORES

Factors	S	Unprocessed Waste Hauled to Landfill	S	Stationary Compaction/ Landfill	S	Sterilization/ Stationary Compaction/ Landfill	S	Incineration/ Landfill	S	Pulping/ Sanitary Sewer	S	Pulping/ Dewatering/ Landfilling	S	Shredding/ Landfilling
Sanitation (0.18)	0.05	0.009	0.11	0.020	0.22	0.040	0.24	0.043	0.16	0.029	0.16	0.029	0.06	0.011
Total cost (0.15)	0.16	0.024	0.33	0.049	0.09	0.014	0.06	0.009	0.13	0.019	0.11	0.017	0.12	0.018
Maintenance cost (0.08)	0.07	0.005	0.16	0.013	0.30	0.024	0.14	0.011	0.06	0.005	0.5	0.004	0.22	0.018
Ability to handle all types of waste (0.09)	0.05	0.004	0.10	0.009	0.20	0.018	0.25	0.023	0.12	0.011	0.12	0.011	0.16	0.014
Simplicity (0.05)	0.27	0.013	0.27	0.013	0.14	0.007	0.07	0.004	0.08	0.004	0.08	0.004	0.09	0.005
Amenable to automatic feed (0.08)	0.07	0.006	0.21	0.017	0.11	0.009	0.07	0.005	0.18	0.014	0.18	0.003	0.09	0.004
Air and water pollution problems (0.16)	0.13	0.021	0.16	0.026	0.21	0.034	0.10	0.016	0.10	0.016	0.17	0.026	0.13	0.021
Resource recovery (0.02)	0.01	0	0.01	0	0.09	0.002	0.83	0.017	0.02	0	0.02	0.001	0.02	0
Nuisance problems (9.06)	0.07	0.004	0.08	0.005	0.08	0.005	0.33	0.020	0.22	0.013	0.02	0.001	0.20	0.012
Reliability (0.09)	0.29	0.026	0.29	0.026	0.29	0.026	0.04	0.004	0.01	0.001	0.01	0.001	0.07	0.006
		0.123		0.189		0.183		0.155		0.116		0.111		0.123

Conclusion: Stationary compaction/landfill; stationary compaction/sterilization/landfill; incineration.

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE J-14. TOTAL COST (400 BED HOSPITAL)

System	R	K	S	Cost	Rationale
Unprocessed/Landfilled	0.45	0.84	0.12	$238,000	Based on costs listed to the immediate left.
Stationary Compaction/Landfill	2.50	1.87	0.27	$112,000	
Retort Sterilization/Stationary Compaction/Landfill	1.50	0.75	0.11	$279,000	
Incineration	0.45	0.50	0.07	$425,000	
Pulping/Sanitary Sewer	1.40	1.12	0.16	$182,000	
Pulping/Dewatering/Landfilling	0.80	0.80	0.12	$256,000	
Shredding/Landfilling		1.00	0.15		
		6.88	1.00		

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE J-15. DERIVATION OF ALTERNATIVE SCORES (400 BED HOSPITAL)

	Unprocessed/ Landfilled		Stationary Compaction/ Landfill		Retort Sterilization/ Stationary Compaction/ Landfill		Incineration		Pulping/ Sanitary Sewer		Pulping/ Dewatering/ Landfilling		Shredding/ Landfilling	
Sum of other factors		0.099		0.140		0.169		0.146		0.097		0.094		0.105
Total cost (0.15)	0.12	0.018	0.27	0.040	0.11	0.017	0.07	0.011	0.16	0.024	0.12	0.018	0.15	0.022
		0.117		0.180		0.186		0.157		0.121		0.112		0.127

Conclusion: Retort sterilization/stationary compaction/landfill; stationary compaction; incineration.

Solid Waste Sp Study No. 26-0406-78, Apr 75 - Jun 76

TABLE J-16. TOTAL COST (600 BED HOSPITAL)

System	R	K	S	Cost	Rationale
Unprocessed/Landfilled	0.45	0.69	0.11	$357,000	Based on costs listed to the immediate left.
Stationary Compaction/Landfill	2.30	1.54	0.25	$163,000	
Retort Sterilization/Stationary Compaction/Landfill	1.76	0.67	0.11	$380,000	
Incineration	0.35	0.38	0.06	$670,000	
Pulping/Sanitary Sewer	1.45	1.08	1.18	$243,000	
Pulping/Dewatering/Landfilling	0.75	0.75	0.12	$355,000	
Shredding/Landfill		1.00	0.17		
		6.11	1.00		

TABLE J-17. DERIVATION OF ALTERNATIVE SCORES (600 BED HOSPITAL)

	Unprocessed Landfilled	Stationary Compaction/ Landfill	Retort Sterilization/ Stationary Compaction/ Landfill	Incineration	Pulping/ Sanitary Sewer	Pulping/ Dewatering/ Landfilling	Shredding/ Landfilling
Sum of other factors	0.099	0.140	0.169	0.146	0.097	0.094	0.105
Total cost (0.15)	*0.11* 0.017	*0.75* 0.037	*0.11* 0.017	*0.06* 0.009	*0.18* 0.027	*0.12* 0.018	*0.17* 0.025
	0.116	0.177	0.186	0.155	0.124	0.112	0.130

Conclusion: Retort sterilization/stationary compaction/landfill; stationary compaction/landfill; incineration.

APPENDIX K

BIBLIOGRAPHY

1. Ross Hoffman Associates, "A Study of Pneumatic Solid Waste Collection Systems," National Technical Information Service. US Department of Commerce, Springfield, VA (1974)

2. Esco Greenleaf, "Solid Waste Handling and Disposal in Multistory Buildings and Hospitals," Vol 1, US Government Printing Office, Washington, DC (1972) NOTE: This report was sponsored and approved by the EPA.

3. Mid-Ohio Health Planning Federation, "Legal Implications of Franklin County Hospital Solid Waste Management," Columbus, OH (1972)

4. Oviatt, V. R., "Waste Handling, An Old Problem," Technical Information Report, Hicksville, L.T., Institute of Sanitation Management (1967)

5. Plate, Cup and Container, Inc., "Elmhurst Hospital Study," New York Plate, Cup and Container Institutes, Inc. (February 1969)

6. "Hospital Solid Waste Management in Community Facilities," School of Public Health, University of Minnesota, Minneapolis, MN.

7. Arnold, Frank, "Defining Categories of Solid Waste," presented at the American Hospital Association (AHA) Institute on Hospital Waste Management, Chicago, IL (May 1972)

8. Brewer, John B., "A Case History," presented at AHA Institute on Hospital Waste Management, Chicago, IL (May 1972)

9. EPA, "Hospital Waste," US Government Printing Office, Washington, DC (1974)

10. Esco Greenleaf, "Solid Waste Handling and Disposal in Multistory Buildings and Hospitals," Vol 4, US Government Printing Office, Washington, DC (1972)

11. DeRoos, Roger, "Environmental Concerns in Hospital Waste Disposal Hospitals," JAHA (February 1974)

12. "Hospital Wastes Management Study of Los Angeles County, University of Southern California Medical Center," prepared by School of Public Health, UCLA Environmental Health Management Program (Spring 1974)

13. Korneff, Allen, "Hospital Reports It Resorts to Retorts to Reduce the Bulk of Its Refuse to Residue," Modern Hospital (1973)

14. Syska & Hennessy, "Solid Waste Handling System for Navy Hospitals," Syska and Hennessy, New York, NY (1972)

15. Anon., "Canadian Study Shows its Cheap and Safe to Burn and Dispose Infectious Wastes at the Hospital," Modern Hospital, Vol 119:53 (September 1972)

16. Lewis, F. M., Rinker, F.G., "Thermal Processing of Hospital Waste by Controlled Air Incineration."

17. Peterson, M. L., and F. J. Stutzenburger, "Microbiological Evaluation of Incineration of Incinerator Operations," Applied Microbiology, 18:8-13 (July 1969)

18. Comptroller General of the United States, "Study of the Health Facilities Construction Costs," Report to the Congress of the United States (December 1972)