AN ANALYSIS OF INSTITUTIONAL SOLID WASTES

A solid waste management open-file report (SW-2tg)

U.S. ENVIRONMENTAL PROTECTION AGENCY

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U.S. ENVIRONMENTAL PROTECTION AGENCY

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FOREWORD

This Nation is facing the ever-growing problem of how best to manage its solid wastes. Not only are present practices of solid waste storage, collection, processing, and disposal becoming inadequate, but the United States also faces a shortage of trained professional workers in the field who are equipped to deal with the problem.

To help alleviate this shortage, the U.S. Environmental Protection Agency, under authority of the Solid Waste Disposal Act (Public Law 89-272), administers a program of grants-in-aid which supports graduate-level training programs at 13 universities for approximately 65 masters' degree candidates each year. These students receive specific training in the many aspects of modern-day solid waste technology and management. Some of these training programs are located at large urban universities and center their instruction on solid wastes in the urban environment, while other programs are at schools in agricultural regions and may place their emphasis on food-processing and farm waste problems. To date, over 100 engineers have been trained at the graduate level in universities receiving support from the Federal solid waste management training grant program.

One phase of the graduate students' training is to conduct a research project dealing with a specific aspect of solid waste management. This document reports on the results of one such research project and provides information which should be useful to others concerned with better solid waste management practices.

ABSTRACT

The study of institutional solid waste systems has received very little attention compared to municipal refuse systems and individual disposal methods. The author believes that the solid wastes generated by most institutional units are more suited to efficient and economical storage, collection and disposal procedures than the average domestic solid waste. Reclamation or salvage methods are particularly favorable for institutional solid waste systems due to the relative homogeneity of waste materials from individual waste sources. The evaluation of present institutional solid waste systems and the design of proposed systems are discussed. The University of Illinois is studied to provide an example of an institutional solid waste system. Several recommendations are included for improvement of present undersirable conditions.

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I. INTRODUCTION

Solid waste production, one of the pollutional effects of man's daily existence, is just beginning to stir the public conscience to concern, anger and disgust with its deleterious effects upon our natural environment. But the only new aspect of this solid waste problem is the public awareness that a problem exists, and this awareness is, in itself, a major step forward in the control and ultimate solution of the solid waste dilemma. As the common man becomes concerned with a national problem, the needed momentum to rectify the situation is brought to bear in the form of legislative action and economic support to carry out the solutions proposed by the technical experts in the given field. This pressure increases research into the fundamental factors influencing the problem by rewarding those attempting to remedy the situation, and by imposing restrictions or out-lawing current practices which contribute to the undesirable situation.

In this respect the Third Pollution, as solid waste has been called, is in much the same position as water pollution was 15 years ago, and more recently, air pollution. As both of these problems gained public attention, more effort was put forth to control the discharge of these waste into our environment and public cooperation has followed closely. Municipal and industrial management have also been aware of the problems, but their response in curtailing and controlling effluents has been rather slow in many cases.

Now that solid waste has reached this critical stage of public awareness, it is important that the problems presented by this pollutant be adequately described and defined. The present systems for its treatment, or lack of treatment, must be reviewed and modifications or new methods and facilities must be evaluated in light of the standards which must be achieved.

Finally, these controls and treatment processes must be put into operation, carefully monitored to produce the desired end products and the results must be analyzed to predict future needs and possible changes.

A. Heterogeneous Composition

Although there are many individual and peculiar problems in the proper management of solid wastes, two basic factors of difficulty are common to solid waste systems. The first of these is the heterogeneous composition of the waste material itself. Not only is it difficult to categorize a waste with respect to its component materials, but few generalities about a waste can be made which are universally applicable. From any given type of source, many variations in component materials are likely. Even the same source may often vary its components with time due to changing input conditions. For example, restaurants perform essentially the same operation of feeding patrons, but the refuse removed from a drive-in hamburger restaurant would be quite different, and probably much more uniform in components, than the refuse from a dining room service with a sizable menu. Even this latter refuse would vary widely with seasonal tastes of the patrons and the seasonal use of available fresh, frozen or canned food products. The installation of a sink-type garbage grinder would drastically change the type of refuse produced by either of these previously mentioned establishments. This heterogenity of refuse components which handicaps categorization is even more pronounced in residential, industrial and other commercial refuse. Geographic variations are probably of greater significance in this respect than are seasonal variations throughout the country, although these two influences are also related to each other to some degree.

B. Economic Considerations

The second factor of difficulty in solid waste management is not concerned with the refuse material itself, but rather with the economic considerations of various aspects of the solid waste problem. This economic factor is often the controlling element in a solid waste system and may often determine whether an operation is performed properly, poorly, or perhaps, not at all. The underlying problem is that in our society at these affluent times, refuse material is regarded as disposable, unusable material. It is assumed to have no value, and, often, this is economically true. While a tin can or junked automobile certainly contains a finite amount of steel and our society requires more steel production everyday, it is seldom economical to recover the steel present in these discarded materials. Consequently, it is assumed they have "no value." The fallacy in this reasoning is that the assumption of "no value" is dependent on an unlimited and readily accessible supply of cheap iron ore. Although this is untrue, the "no value" idea still represents a tremendous refuse production.

This economic aspect has another viewpoint. This is the traditional belief that when one is through using something and discards the object, the user has no further responsibility for it. Due to the assimilative capacity of our environment, this was no problem in the past. However, today one must do more than simply discard his refuse. It must be collected, transported and disposed of properly. The costs involved in performing these operations are real and must be ultimately paid by the user. This responsibility is not readily accepted by the general population or many industries, as they do not want to spend money to get rid of unusable materials. As a result, the tax monies available for refuse disposal, or the methods themselves, are inadequate for proper protection of the environment.

C. Solid Waste Management - General

The present condition of solid waste management must be described as "state of the art," for it has not progressed enough to be called applied science or engineering. Although some disposal processes are receiving additional study and review and other new methods and innovations are being tried, by far, the field is characterized by out-dated techniques for storage, collection and disposal of refuse because these methods have traditionally been used and little thought has been given to improving them. Improvement could come in the form of correction of the existing system or change to a more efficient or appropriate one. Lack of available money to promote a simple analysis of the present situation is probably the most common obstacle to improvement. Simple records of quantities of refuse disposed, cost of disposal, number of man-hours worked and changes in refuse sources are seldom kept. These figures could easily provide an initial review of total costs involved, population and refuse production trends and expected life of equipment and facilities. Future facilities could be planned more effectively and solid waste management requirements could be predicted over several years from this information.

Currently, solid waste management can be classified into two major divisions, dependent on the responsibility for general management of the refuse which is being produced. Municipal solid waste management is the first division and is concerned, in a broad sense, with the refuse produced by residential and some commercial establishments within a specified governmental boundary. This boundary is often the city limits but may be extended to include one or more counties or a regional territory controlled by several municipal governments. The municipal responsibility may be collection or disposal of the refuse, or both. If the municipality performs only one of these services, the other is provided by a private contractor. In the case of collection by a private hauler, the individual producer is charged directly by the hauler, but private disposal for a municipal agency is paid by contract with that agency.

The degree of refinement of municipal systems is relatively high in larger cities and metropolitan areas due to the availability of some tax monies. The sophistication of the system decreases directly with the size of the municipality, in general. The limited amount of study that has been done on solid waste systems has been concerned primarily with this municipal refuse division. Many of the results of these studies and some worthwhile average data has been collected, summarized and published by the American Public Works Association in two recent volumes. (1,2)

The second division of general management of solid waste can be termed industrial solid waste management. The industrial solid waste production is not defined strictly as refuse produced by industry, but rather by the in-plant collection and disposal of generated wastes by the producer or his privately contracted agent. This designation includes many large industries, manufacturing concerns and some commercial establishments who contribute no wastes to the municipal system. At the same time, there are industries which are provided with municipal refuse service, but these are usually small producers of relatively compatible-type wastes.

The in-house handling of solid waste in this industrial division can be quite well-suited to selective storage of waste products, efficient collection procedures which can be geared to production factors in the plant, and use of the optimum disposal method for the particular waste or wastes produced by the plant. Many of these wastes have a definite recovery value due to their magnitude of production at one source and, more important, the freedom from contamination by other waste products. Reclamation of the refuse may be possible at the plant site itself and the resulting product can be used again as a raw material input. Sometimes, the refuse must be packaged and shipped away for processing to obtain the reclamable portion.

The degree of refinement of these industrial solid waste systems is not well known. Although some concerned industries have well-developed systems, others have not given much thought or action to this problem, or have had difficulty in instituting proper procedures. A number of researchers are attempting to collect significant data about refuse management by industry-type classification. The most rapid initial results and the disclosure of peculiar refuse problems of particular industries have been received in extensive questionnaire surveys of selected typical companies. (3)

II. INSTITUTIONAL SYSTEMS

One particular type of refuse production, which is not clearly defined by either of the two previously mentioned refuse management divisions, can be classified as institutional solid waste production. There has been very little investigation of this type of waste production and its subsequent disposal. The data available in this area are limited and are not readily transferable and applicable to other institutions and their wastes. The purpose of this paper is to carefully define the institutional refuse classification, to present a complete review of present systems, and to analyze and evaluate procedures which are the basis for design of future systems. The University of Illinois at Urbana-Champaign will be studied as an example of a large institution. The suitability of this institution for solid waste analysis as a complete system will be evaluated and proposals for possible changes and improvements in this system will be included.

A. Definition

The institution itself can be generally defined as any large, physical organization of persons and, perhaps, materials, which are arranged in a specific manner in a given location, and through the interaction of various groups within this organization, a specific function or mission is performed. The significance of the definition is the ordered arrangement and unified central purpose of the institution. These are two important factors which favor the development of a system approach to the management of institutional solid waste. These factors influence the characteristics of the waste, the volume and location of its production, the collection system parameters and the disposal method. Also, the planning of systems, financing the operations and ultimate responsibility for proper control of the solid waste is much simplified due to this definite, institutional entity.

B. Examples

The definition of institution used in the context of this paper will be reinforced by the citation of some specific examples of institutions which may lend themselves to solid waste systems management. A university is a good example of an institution, although this group could include other large educational complexes.

Air terminals on major air routes are institutions processing both people and freight preparatory to their air transport.

Hospitals and combined medical center facilities in large metropolitan areas form a distinct type of institution with its own peculiar wastes. This institution may often be located adjacent to a medical school, which would be included in the system.

Certain industrial complexes are grouped together in such a way as to use common utilities and have other interdependent functions, or perhaps, use one another's finished product in their own process. The industrial park complexes are becoming more and more prevalent on the outskirts of metropolitan areas and near smaller outlying cities. Their individual site development is usually controlled by a corporation board, and uniform code restrictions are placed on each industry within the complex. This institutionalization of industries can be very advantageous for a unified, comprehensive plan for solid waste management.

A similar situation exists for some few giant shopping centers in the metropolitan areas. These conglomerations of many diverse commercial operations on one site are the equivalent of an entire business district in a medium-sized city. Their individual refuse production, being very compatible, if not totally alike, is most economically handled by one, well-designed system.

Another institution suitable for refuse management is the research park, where several companies involved in the investigation and pilot-project operation of new processes or equipment are situated in close proximity. The wastes from these research labs and development shops may be quite different, but their special and changing nature can be coordinated into a refuse system.

Harbor and port facilities are a rather nebulous example of an institution. However, this complex of different operations might, in some cases, be most adequately managed by one solid waste system. Not only is there refuse from the docking ships, but there is also packaging and shipping materials and containers which accumulate at shipside and around neighboring warehouses.

Military bases are certainly not a new institution, but they do illustrate, to a very high degree, the unification of many different operations under one organizational structure. Although some refuse management has been practiced at most bases and several extensive studies have been conducted, there is still a major need for solid waste systems to adequately unify the different refuse production sources. (4)

C. Design of Proposed Systems

The designing of a proposed solid waste management system, or at least one being given serious consideration for possible future implementation, is very close to an ideal situation. The problem of refuse management has been realized and the opportunity now exists for some concrete action to be taken to correct and solve the problem. This design of a new system is ideal in that no operating system is present, or one that is present is of such low economic value that it can be scrapped without hesitation.

Before the design procedures themselves are discussed, there are several factors of importance which will influence the design and, hence, the future operation of any system that may be installed. These factors, which are not directly related to the refuse production itself, are concerned with the organization accepting the responsibility for the solid waste management. This organization may be some governmental unit which is the institution itself, or it may sponsor the institution, as is the case of state universities. It may be the county board, municipal government or a branch of the federal government. In the case of many of the previous examples of institutions, the management responsibility lies with the company itself, a private corporation of representative members or a board of directors.

This responsible agency exercises control over solid waste management practices in two forms. The first is in the form of regulations. The agency enforces compliance of individuals or employees with the established refuse storage, collection and disposal procedures. It must see to it that all the regulations are being met, that health hazards and nuisance situations are avoided, and that operations are being conducted safely.

The second form of control by this agency is very important to proper refuse management. This agency is responsible for the financing of the solid waste management from the initial design to daily collection and final disposal of the waste materials. As will become very evident in this discussion, the economic factors determine whether a given operation is a success or a failure; whether it is conducted properly or improperly. Thus, the allocation of monies for various stages of the refuse management system is critical to the performance of the system, and must be given careful consideration in the design of the system.

The financing of solid waste systems for industry is often simplified in that the implementation decision and financial appropriations may be made by one management group. Difficulties arise for governmental agencies as they may make the implementation decision, but they require financial approval from other agencies or by public referendum. Future financing, especially when it has been predicted within certain limits, usually is also rather easily accomplished. However, with many governmental agencies this is not true. A minimum-cost design is sometimes required at the expense of a more favorable design, or one more easily adapted to possible changes. Present capital expenditures to meet future needs are not readily approved. This aspect will influence the design of the system and, perhaps, the amount of money allocated for design itself.

In the design of the proposed system, initial surveys must be made to establish the solid waste production. These surveys record the location of all sources of refuse production. This establishes the number of collection points that may be necessary and shows the relation of each source to the others in terms of travel distance. The surveys also record the volume of refuse produced at each source. This usually is an average figure, and if weights of refuse can be collected, this is desirable. The principal components and general composition of the waste is noted. If the generation of the waste is cyclical, varying with time or other controlling parameters, this is recorded.

From the survey results, a study is made of the total refuse production. The total volume of refuse, its particular components and general characteristics, and its frequency of production will influence the type of disposal method selected. A preliminary survey will disclose the types of disposal methods which may be considered. This will depend on the land use within a reasonable haul distance, land values, air pollution restrictions and possible public relations difficulties, which may be foreseeable. Assuming the disposal method has been selected, a detailed study can be made of various collection systems. The variables to be considered in this system are numerous, but review of pertinent literature on the collection variables being studied, and possible use of computer programs to explore different combinations, should reduce the many possible situations to several, equally efficient ones. Some of the variables in the collection system are directly determined by the disposal method, such as haul distance, transfer station, size of truck, compaction necessity, separation of refuse components and rejection of certain components.

Estimates are prepared from the final determination of the study. They include the number and size as well as capital, operating and maintenance costs of the equipment required in the refuse system. They will also include the amount of labor involved and its cost. Depreciation costs for the capital investments may be included, if a time basis for depreciating them is established.

The surveys, studies and determination of estimates constitute the planning of a proposed system for solid waste management. Predictions of future requirements and specific recommendations are necessary to complete the design of the system. (5)

D. Evaluation of Present Systems

The evaluation of existing refuse management systems is accomplished in much the same manner as the design of a proposed system. The necessity of evaluation may be for changes or improvement in the present system. These changes may be replacement of existing equipment, addition of new equipment or processes, automation of certain labor consuming steps now in use, or simply changes in operating techniques to improve the efficiency or economy of the system. The most limiting factor in this evaluation is the capital investment in equipment, which cannot be instantaneously depreciated or assumed to be a loss. This existing equipment must continue to be used to some extent, and must consequently be incorporated into the flow of any changes in the system. The use of this equipment sets some limits on the type of treatment, collection or disposal of the refuse which may be considered.

The evaluation is prepared by a series of surveys to establish the sources of waste production and their location. The volume of waste from each source is measured and weights are taken if practical. A good characterization of the waste is possible by examining the relative proportions of different components present in the refuse. The surveys record the storage conditions of the refuse, the number of collection stops, the size and number of containers, the method of transfer to the collection vehicle, the labor required to effect this transfer and the frequency of collection. If the refuse production is not uniform this is important. A survey of the disposal methods includes the haul distance, transfer required, method of disposal, daily volume processed, excess capacity available with the present method, expected life, labor involved and any operating problems which are significant and need to be corrected.

A study of the survey information is made to determine the effectiveness of the present operation. Cost information is analyzed, when it is available, to obtain unit cost figures in terms of capital costs, depreciation charges, operating costs and total costs for pieces of equipment, unit operations, and total refuse management. There is no standardization of units for quoting this type of data, but values in terms of dollars per unit volume or unit weight of refuse disposed is probably the most meaningful and most easily interpreted by others studying the report.

Economy and efficiency are two parameters which require definition with respect to solid waste systems. The most economical system is the one meeting environmental quality requirements for solid waste management at the lowest cost. The most efficient one is the system providing the most convenience in terms of reducing time and number of individual operations involved, and requiring least effort, such as manual labor, while meeting equality requirements. To evaluate these two criteria, alternative methods for storage, collection and disposal of the refuse are considered to supplement or replace existing methods. In this consideration, efficiency and economic factors determine which methods represent the most desirable combinations for the remodeled system. This may result in fewer collection stops, longer frequency between certain collections, mechanical loading of refuse vehicles, shorter haul distances, transfer for longer hauls, greater volume reduction by compaction in storage units, less volume for final disposal, reclamation of some components of the refuse for recycle or sale of salvagable materials. New costs can be estimated for each of these alternatives based on current refuse volumes. A comparison of these individual costs with those costs of present service will show which individual operations are most economic. However, the most economic system can only be evaluated by the comparison of total costs for each total solid waste system including all component parts. It is very likely that the system having the most efficient, alternative operations is not the most economical, so a compromise between optimum efficiency and optimum economy must be chosen. This should be done in light of probable future changes, to maintain a high degree of economy in an efficient system.

The agency responsible for the solid waste management may establish other limits on the evaluation of the present system by authorizing expenditures only for certain operations in the system, such as refuse disposal methods. Therefore, any changes in the existing collection system will be ones that do not result in any increased collection costs. This is not a true system approach to improving the solid waste management, as some major variables must be held constant.

At the time of this evaluation it may be possible for the agency responsible for solid waste management to assume greater power in terms of jurisdictional boundaries, legality of regulation enforcement and assessment of finance charges on the parties served by this system. This may be of no difficulty as few agencies want to be responsible for solid wastes, and there are few precedents to overrule this assumption of authority for solid waste control.

III. SOLID WASTE PRODUCTION

Solid waste production must be thoroughly sampled, studied and analyzed in any attempt to provide proper solid waste management. Three major areas are of concern to fully evaluate this production and to determine how it will influence collection and disposal procedures. Economic aspects of the total system will also be affected to a great degree by these factors.

A. Sources

The first factor is the source of the solid waste production. This is the point where the waste is actually discharged from a process, or where it is initially stored following removal from the actual living space. This source gives a spatial location of the refuse production or its storage with respect to other production locations. When these locations are plotted on a map, a specific distribution will be given in terms of number of points at which refuse must be collected. This may be in the form of individual pick-ups by some collection vehicle or the entry point of refuse into a conveyor system. This could possibly be a gravity chute, mechanical conveyor or vacuum-pressure pipeline to transfer the waste to a centralized storage area. It may also discharge directly to the disposal equipment or some intermediate device for accomplishing volume reduction.

This listing of distribution of waste sources also gives information about the type of waste to be expected at each point. When the types of operations conducted at the institution are analyzed with respect to their waste production, the type of waste found at any particular source will be dependent on the operations contributing refuse to that source. In most cases, this will limit the refuse to only one particular class or type of refuse. If the institution has an assembly line operation, the waste production will be distributed along this line. All refuse of each particular composition will be produced at the same point on this line and may be easily removed. It may also be possible to integrate the conveyance of this waste along the production line, as if it were another component. On the other hand, if there are many similar operations conducted throughout the institution, it will be necessary to collect these wastes with a certain set of collection vehicles if separation of this waste component is going to be maintained.

B. Quantities

The volume of waste produced at a given source is one measure of its magnitude. The second measure would be the weight of refuse produced. These two measures are directly related by the density of the refuse. This is a critical factor in the required capacity of storage facilities, collection vehicles and disposal method. In most cases, measurements of refuse production, as it is collected, are given in terms of volume measurements. This would describe and determine the required size of storage containers in terms of cubic yards (C.Y.). Collection vehicles and attendant compaction devices are designed in these same units of volume. Due to the density variations, which range from 200 lbs. per C.Y. for loose, combustible material to 1200 lbs. per C.Y. for ashes and other inert materials, the required volume for refuse removal will be large for low density paper wastes and relatively small for dense wet garbage and inert wastes. (6)

The total volume of solid wastes to be handled from all sources will determine the scale factor of the plant required to process the refuse materials. This magnitude will eliminate some disposal methods from consideration, while others will be the optimum choice for this volume of refuse. A good estimate of equipment and personnel can be made on the basis of the total refuse to be disposed of daily.

The total weight of refuse handled is used to assign costs to the collection and disposal of solid wastes. Weight in pounds is a more uniform measure for assigning the real capital and operating costs involved in processing a given amount of waste material. Therefore, weight measurements should be, and often are, made prior to disposal of the refuse. These costs are quoted in dollars per ton on either an "as received" basis or dry-weight basis.

C. Composition

The second factor in solid waste production has already been referred to in the previous discussion of refuse volume. This is the composition of the solid waste or the type of material present. The following nine components have been suggested for use in the classification of general refuse. This is based on a municipal-type waste having all of these components present in varying amounts. However, many institutional wastes will be composed of several of these components in different percentages, so the classes of refuse are still useful. This classification is based mostly on ease of recognition of the particular components, and to some degree on their chemical composition. (2)

SOLID WASTE COMPOSITION

Paper
Garbage (food trimmings, preparation, residue)
Lawn and tree trimings
Plastics, leather, rubber
Textiles
Wood
Metals
Glass, ceramics
Ashes, stone, dirt

The percentages of each of these components will vary greatly at different institutions and even at one institution during different seasons. However, as it was mentioned earlier, the institutions tend to produce refuse at given sources consisting of only one component of the above composition.

This initial separation can be easily maintained throughout the solid waste system, if it is desired. In certain cases it is desirable to keep some components separated to allow different collection frequencies, use of different collection and disposal methods, and to facilitate salvage of valuable materials. Institutional solid wastes exhibit a predominance of certain components, which make them particularly suitable for efficient differential treatment of some of the components. This can be economically justified, if part of the waste can be disposed of by a less expensive method, or if its salvage value will offset disposal costs. Occasionally, the sale of reclamable materials will realize an income for the institution, but this is a rare case.

D. Characteristics

The third factor in solid waste production of significance to the designer of a solid waste system is the refuse characteristics. These characteristics describe the physical and chemical properties of the refuse. This description is different from the composition, which describes the refuse material by its previous use or service that it performed. A study of the characteristics of the waste is important because it will limit the possible collection and disposal methods which will provide the proper treatment for the waste material. It will determine whether recovery of some value can be obtained from the waste, will set limits on the operating procedures and time intervals involved, and will require that special precautions be taken with hazardous refuse material.

One widely variable characteristic is moisture content. This is usually due to the garbage component and it may require the use of water-tight collection vehicles. A high moisture content may promote rapid decomposition on the refuse and consequent odor and nuisance problems. It may also make incineration impractical due to the amount of heat necessary for vaporization of the water.

A large proportion of inert material in the refuse makes it a desirable fill material, but it would not be desirable for composting operations. This characteristic of the refuse would also give a low heat value, as well as high residue content, making incineration impractical.

The compressibility of the refuse is an important characteristic to the storage, collection and transport of the material. If the refuse is compacted on-site, in the collection vehicle itself, or at a transfer station before being hauled to the disposal site, the degree of compressibility will determine the volume and number of containers and vehicles necessary to do the job. Compactability also determines the final volume placed in the landfill site, affecting its expected life as a disposal method.

The size of individual items will certainly affect the collection and disposal operations. Bulky items may not fit in regular collection vehicles, necessitating special collections. Some may be damaging to compaction or grinding mechanisms. Physical dimensions may be too large to permit entry into the incinerator charging hopper.

Refuse that is highly putrescible, inflammable, explosive, toxic or contaminated with pathogenic organisms requires careful handling and disposal with proper supervision. The storage interval may be very short and special containers may be used. Collection with other refuse may increase the hazards involved in its transport and disposal. Incineration may be required for some of these types of refuse, while others must not be incinerated. Landfilling may be desirable for some, but not for others. In any case, considerable pre-planning and close supervision are necessary to prevent contamination of the environment and hazardous exposure of man to these special characteristics of this refuse.

Refuse with reclamable characteristics, such as high heat value for incineration to produce steam, should not be overlooked. An analysis should be made of refuse production and all costs involved to determine the desirability of the reclamation process.

E. Compatibility

If several sources of refuse production are to be combined for collection and disposal, an analysis of their characteristics should be made to determine their compatibility for both collection and disposal. Some combinations of characteristics may be hazardous in themselves, while others may cause inefficiences in the disposal method or reduce the economy of the total system.

IV. INTERRELATIONSHIP OF SOLID WASTE OPERATIONS: COLLECTION, DISPOSAL AND RECLAMATION

The different unit operations involved in a solid waste system, such as collection, disposal and salvage of refuse materials, are usually developed and studied as individual, independent processes. However, in any solid waste system, these processes do not act independently of one another. Variable factors of refuse production relate the action of one operation to the others, causing a dependency within the system. In the design and implementation of an efficient solid waste system, a thorough analysis of these relationships will be necessary.

In general, the disposal method is probably the most independent variable with respect to collection and reclamation procedures. The type of disposal method is also subject to more limitations and restrictions than the other two operations in a given area. A sanitary landfill would not be considered where land was below the groundwater table, or in an area where land-use codes would prevent its operation. Incineration may not be acceptable due to extreme air pollution restrictions. Composting may be unacceptable, if the volume of waste to be treated is very large. In the case of an existing system, the disposal method may be fixed by existing plant investments. Generally, this means that the collection procedures and equipment will be dependent on the type of disposal method used (1). Special preparation of the refuse for disposal, such as the wrapping of wet garbage, will eliminate the need for water tight collection vehicles. If the disposal method requires separation of different refuse components, extra collection vehicles or special compartmented ones must be used. This will also affect the collection frequency and time per pick-up.

Salvage or reclamation procedures will depend on the disposal method to a large extent. If the salvage of certain components effects significant reduction in the total volume to be disposed, this will reduce the burden on the disposal method. The efficiency of an incineration system would be reduced if the paper and plastic components of the waste were salvaged, as the heat value of the refuse would be lowered. Conversely, incineration disposal would favor the salvage of inert materials and ashes for fill material to improve incinerator performance. Reclamation of steam generation from waste heat production would require the use of central incineration disposal. If composting were selected as the disposal method, salvage of glass, metals, and organic soil conditioner could be realized.

The design of the collection system will depend on the reclamation procedures to be used. Efficient salvage will require the maintenance of separation of certain components to promote their salvage or prevent contamination from other undesirable waste components. Collection frequencies may be reduced as a result of this separation procedure.

A. Disposal Methods

The sanitary landfill is a very acceptable disposal method which traces its development from the undesirable open dump. In landfill operations, refuse is deposited by collection vehicles on a working face or adjacent to an open trench. A tractor device places and compacts the refuse to the desired density in a series of two-foot lifts. At the end of the working day, a cover of earth or fill material is placed and compacted over the refuse. This cover protects the environment from the refuse in several respects. Health and nuisance hazards from insect and rodent breeding are eliminated. Burning of refuse material is practically eliminated and fire hazards are negligible. If proper slopes are maintained during operation and compaction of the cover is adequate, surface water run-off and groundwater pollution problems will be avoided. The operation of a sanitary landfill requires only a minimum of earth-moving equipment and labor. Supervisory personnel are required for proper planning and operation of the site. One disadvantage is the sizable amount of land required, which is often unavailable in or near large metropolitan areas (7)

Incineration of refuse is considered a disposal method, because of the great volume reduction accomplished in this process. The final inert residue from the incinerator is usually 5 to 25 percent of the initial weight of refuse. This results in even greater volume reduction, as the density of the ash residue is much greater than the density of the mixed refuse fed into the incinerator. Proper incineration implies the high temperature combustion of the organic material present in refuse and the near complete burning of volatile gases driven off in the process. The incinerator may be centrally located or it may be of a smaller on-site design. In either case, the incinerator is a complex mechanical device requiring skilled labor, competent supervision and frequent maintenance for its proper operation. The major advantages of incineration are the possible close location of the incinerator site to the source of refuse production due to small land requirements and all-weather operation. The disadvantages are attendant air pollution problems, ultimate disposal of residue material and high capital, operating and maintenance costs compared to landfilling.

Composting has been given much attention in the literature as a third major refuse disposal method (2,8). In reality, it is a conversion process of refuse material into a supposedly economically valuable organic soil conditioner. Composting is accomplished by a manual or mechanical separation of the refuse into readily reclamable materials, inert, undesirable materials, and bulk organic refuse which is shredded for composting. This organic material is aerobically stabilized by bacteria present in the refuse. During a variable length period of up to one month, the compost is occasionally mixed to maintain aerobic conditions and uniform elevated temperatures, which result from the stabilization activity. The compost material has been treated in some instances with sewage sludge to increase the nitrogen content, and then advertised for sale as a soil conditioner and fertilizer. Attempts to sell the compost in plastic bags and bulk carload lots have met with limited success. There does not at this time appear to be any appreciable constant market for the finished product. Thus, composting cannot be considered a disposal method of significance (9,10).

Grinding of refuse must be given consideration as a disposal method, as it is currently used by many institutions for disposal of garbage wastes in their food service operations. However, it must be realized that grinding is not an ultimate disposal method in itself. It is a different transport mechanism for the waste, which must then be treated with other sewage solids at the wastewater treatment plant. It is only a disposal method from the viewpoint of the institution removing its garbage in this way.

The principal of operation is the same as the home garbage grinder installed in the kitchen sink and it serves the same purpose. The wet garbage component of refuse from food packaging, preparation and residue is ground into small particles by a series of rotating knife blades and flushed to the sanitary sewer by water flowing through the unit. The refuse solids are transported to the wastewater treatment plant and are readily treatable like the other sewage solids. The organic nature of the garbage is compatible to the treatment processes, but the organic load is likely to be excessively high for the plant, even if dilution effects are substantial. Problems are encountered when grinders are installed on old, poorly designed sewer lines or ones with inadequate flow or slope. In these cases clogging is common and new sewerage must be installed to accommodate the grinder system. Some larger grinder units are hammermill units, which pound and tear the refuse into small diameter pieces. These have been used extensively by the commercial fruit and vegetable wholesale houses for rapid, economic disposal of large shipments of spoiled or damaged produce. The advantage of this disposal method is the on-site, immediate disposal of putrescible refuse, eliminating collection and storage requirements, and preventing health and nuisance conditions. The operation of a grinder unit is very economical as water and power costs are low (2). However, the hidden costs of treating this waste at the treatment plant are excessively high.

B. Disposal Costs (See Table 1).

Costs of refuse disposal have been studied extensively and general tendencies are reasonably evident. However, in a given locality and for particular refuse characteristics, the costs of disposal may vary appreciably from established average costs. Landfill has been found to have the lowest capital investment by far, and in some cases, this cost may even have a negative value as land appreciation will often return a sizable profit on the initial investment. A private corporation operated a landfill near Barrington, Illinois, purchasing approximately 100 acres of marginal farm land for $1500 per acre and planning the site for development of a future golf course. They expect to receive $5-6000 per acre for the completed fill site for a 200-300% return on their capital investment. (17) Average operating costs for landfills are also the lowest with respect to the other disposal methods, since a minimum of labor and complicated equipment is required.

Incineration costs are higher due to skilled labor requirements,

TABLE 1

DISPOSAL METHOD COSTS

Disposal Method	Costs in dollars per ton		
	Capital	Operating & Maintenance	Total
Sanitary Landfill (2, 11)	0.10 - 0.50	1.00 - 2.00	1.10 - 2.50
Incineration (12, 13)	0.75	3.50 - 5.50	4.25 - 6.25
Composting (14, 15)	1.50 - 2.50	3.00 - 4.00	4.50 - 6.50
Garbage Grinding to Sanitary Sewer (2)	0.40	0.50 - 3.00	1.00 - 3.50

Incineration capital costs based on $6000./ton-capacity plant over a 30-year expected life.

Composting costs do not include nutrient addition.

Garbage grinding costs for 300 ton/day central grinding operation do not include solids treatment and disposal costs. These would be $40. - 60./ton dry solids at treatment plant, exclusive of primary treatment costs. (16)

maintenance of complicated mechanical equipment and high capital costs. Capital costs are based on a cost per ton rated-daily capacity of the incinerator. To convert this cost to a cost per ton refuse disposed, a 30-year economic life is often assumed, and daily refuse disposal is assumed to be at or near rated-capacity.

Average costs for composting are unrealistic and unreliable, as they are based on only a small number of operations, often over short intervals of time, and many of these have been abandoned or forced to close down. Operating costs are very dependent on the amount of hand labor required for separation of the refuse components. Some of the composting operations studied to obtain these costs were likely to be operating at a loss, since they may be recipients of Federal Demonstration Grants, or subsidized by a corporation from other funds until they prove their operation to be successful.

The costs for grinding disposal of only garbage are calculated for a 300-ton per day central grinder unit. These costs do not include the very expensive disposal of solids at $40-60/ton, exclusive of primary treatment, at the wastewater treatment plant. This is included for comparison purposes only and cannot represent the variations in costs due to the change in scale of the operation. It must be remembered that storage and collection costs are eliminated with this method, making it more competitive with the other disposal methods, if the only refuse produced is garbage and, if only the actual grinding costs must be paid by the institution. The disposal costs are then included in the wastewater treatment plant operating costs.

C. Reclamation Methods

Three of the disposal methods for solid wastes have inherent reclamation or recovery aspects, which may make one method more desirable than the others for an institutional system. Incineration can be used to generate steam from waste heat. This can be used for heating purposes or power generation, as the cities of Zurich, Switzerland, and Boston are currently using this reclaimed resource to heat and light city hospitals and other municipal buildings. (17,18) The ash residue from a properly operated incinerator makes very good fill material and may even be sold to a contractor, if demand is great enough.

Sanitary landfilling can be used to reclaim hilly or low bottom land for extra land use by an institution. It may provide parking lots, storage areas, playing fields or park areas. With suitable precautions, such as gas relief from the fill and pile foundations, some limited, temporary facilities may be constructed. However, adequate study must be made before construction begins, or severe settling problems under structures may be encountered. One Los Angeles County landfill, constructed to a depth of 185 feet, settled over 22 feet in some places and caused severe foundation problems on a single-story structure nearby. (19)

Composting can produce a stabilized soil conditioner which may aid gardeners and agriculture in some areas where soils have poor water-holding capacity or become too cohesive. Addition of sewage sludge to increase nitrogen content will make this reclaimable refuse into a fertilizer. It may be competitive with inorganic fertilizers in some limited areas.

More direct reclamation of refuse may be accomplished by the salvage of separate components of the solid waste production which have value themselves, or may be reprocessed as a raw material. It may be technically possible to separate a salvagable component from the general refuse material, but this will be limited by the economic costs of removal compared to the salvage value. If the desirable component can be maintained in a separated state from the other refuse at the source of production, separation will not be required. In this respect, institutions are often well-suited to reclamation due to the separate production of valuable refuse.

Paper and paper products such as corrugated boxes, cardboard clippings, office mixed paper and newsprint are components of refuse which have a recovery value, depending on the quality of the refuse, degree of separation, freedom from contamination and current market value. In the Chicago paperstock market, for example, in 1967, the following representative prices were paid for various quality waste paper: (20)

Category	Value in dollars per ton
No. 1 mixed paper	6
Old corrugated boxes	14
Corrugated clippings	25
Newsprint	(negligible)

In a survey of the packaging industry for the ten-year period 1966-1976, the outlook for paper recovery was toward decreasing recovery of waste paper due to greater use of virgin fibers and increasing contamination of waste paper sources. (20)

The recovery of metals from waste materials is profitable, if the metal is all of one kind and free from contamination with other wastes or coating materials. Production of metal scrap from certain manufacturing and packaging processes, and from metal-working shops can be stored and periodically collected for sale to a scrap dealer. Market values will determine the economic value to be realized, or the disposal cost reduction available through reclamation. Copper and aluminum are the principal non-ferrous scrap metals, but demand for all scrap metal is falling. (21)

Glass and plastics are two components of refuse production which seem likely candidates for salvage. Glass can be separated from less dense refuse by agitation and settling. New air pressure and vacuum devices to separate lightweight plastics are being tested. The market for used glass is negligible due to the high cost of at least $15 per ton to clean and process it for reuse. However, glass from an uncontaminated refuse source may be salvageable, as these costs would not apply. Plastics are so variable in their composition that, unless they are sizable quantities of one particular type, they are worthless.

Reclamation of waste products will become more necessary and, perhaps, more economical in the future for two reasons. There is only a limited amount of raw material available for production and secondly, there is a limited amount of disposal space available, if we intend to preserve the quality of our environment.

D. Collection Methods

Collection methods will be dependent, to some extent, on the disposal method and any reclamation procedures in the solid waste system. However, they usually account for 80% of the total management costs of solid waste production. The collection methods and practice, therefore, deserve thorough analysis to obtain an economical system which is efficient and compatible with respect to disposal methods in use.

Although there are many collection systems in use with countless variations to fit particular requirements, most of them will fit into one of several categories based on storage-load characteristics and transport of refuse to disposal site.

The use of an open- or closed-bodied truck or a closed compactor truck with a collection crew is probably the most common method for collection of many small refuse sources spaced at short distances, but not easily amenable to common storage of refuse. This is the type of collection system found in residential areas, but it is also widely used by private collectors of commercial and light industrial wastes. It requires the most labor and usually frequent collections. The truck is restricted to hauling to the disposal site between collected loads, which is a rather inefficient use of the vehicle.

A method requiring only the driver as labor is the compactor truck which self-loads special containers at the collection site. Often several of these relatively small containers (1 - 3 C.Y.) are stored on one site, reducing the number of required collection stops. This method is not suitable where separation of refuse is required, unless two or more clearly marked containers are used, specifying particular separation of components.

The use of large storage containers, which can be loaded onto the collection vehicle and hauled to the disposal site, are a definite advantage over other methods, if the refuse characteristics and production meet several requirements. If the refuse production at a single point is large enough to fill the container in a reasonable time, or if the refuse contains no putrescible matter, this method is desirable. The number of collections and frequency of collection can be reduced. The haul truck is used only to transport refuse to the disposal site and is not tied up during collection of refuse in the container. This is efficient use of the capital invested in the vehicle itself. If the composition of the refuse produced at each large container is homogeneous, the separation of components is automatically achieved, and reclamation procedures may be possible. The particular containers with reclamable refuse are hauled to a separate site for processing or shipment. This system is particularly well-suited to institutional solid wastes, where production at each source is limited to one or several components, which can be placed in separate containers.

Vacuum pipeline systems and mechanical conveyors are in limited use and have been proposed for large in-house collection of institutional wastes with direct transport to either disposal on site, or to large containers for subsequent transport to the disposal site. The capital costs for such systems would be high, even when installed in the initial construction of a facility. However, the advantage of branch and trunk collection points over a large spatial area or volume, would allow the collection of refuse produced in small quantities by many processes. The adaptation of this system to separate refuse component collection would present problems and added capital costs.

Transfer stations are a necessary intermediate step where refuse must be hauled long distances from collection area to the disposal site. The collection vehicle or large containers are taken to a centrally located transfer station and dumped into large semi-trailers for haul to distant disposal sites, which are usually landfill operations. Compaction may be provided by the transfer station or within the semi-trailer itself. The collection vehicle is then available for additional collections. It is difficult to determine a specific haul distance above which transfer operations are more economical than direct haul. Orange County, California, operates four transfer sites handling 910 tons each per day with a round trip haul of 26 miles. Total transfer and haul costs are $1.64 per ton. This cost agrees with a graph of costs of transfer haul vs. direct haul for the Los Angeles County Southgate transfer station. However, the graph shows that it is more economical to use direct-haul with an average-sized collection vehicle than to transfer the refuse for this particular haul distance. (4 p. IX-7, 1 p. 213) This illustrates the necessity for cost estimates based on the particular system being studied and the analysis of more than one possible method of collection and haul.

The combined use of long-distance rail haul with the transfer station has been proposed for solution of the solid waste disposal problems in large metropolitan areas, such as San Francisco, Philadelphia, Denver and Upstate

New York. Central compaction and transfer of the refuse from collection vehicles to enclosed, large-volume rail cars promises to increase possible round trip haul distance considerably, and make available disposal sites considered much too distant for semi-trailer haul. However, none of these sizable rail-haul plans have been implemented. (22)

Baling of refuse has been demonstrated to be an effective method for maintaining the high compaction ratio of compressed refuse when it is subject to handling, transfer and landfill disposal techniques. It is also effective for processing and bulk shipment of reclaimed refuse components, such as waste paper and metal scrap.

The Tezuka Process, a Japanese-developed process for compressing and baling refuse into 1 C.Y. blocks, has received much attention lately. The company claims the blocks have a final density of 64-120 lbs. per ft. and can be coated with asphalt, concrete, sheet metal or vinyl material, and can possibly be used for construction purposes. The claims also state that biological degradation within the block is insignificant due to a lack of oxygen. The cost of refuse disposal is quoted as $2.60 per ton, excluding building costs and enclosure material costs, which could be substantial for sheet metal. (23)

The claims for the Tezuka Process are difficult to believe, and possible translation errors in the manufacturer's literature could be at fault. Biological activity certainly can continue under anaerobic conditions, causing gas production and voids within the enclosed block. The additional building, auxillary equipment, and maintenance costs, plus coating material could make the process economically undesirable. The final refuse block densities quoted do not agree with the initial refuse density of 500 lbs./C.Y. and a claimed compaction ratio of 5:1 or 7:1. A preliminary report of the Tezuka

Process by the American Public Works Association Research Foundation is a critical analysis of the claims of the equipment manufacturer. (23)

V. UNIVERSITY OF ILLINOIS SOLID WASTE SYSTEM

The University of Illinois at Urbana-Champaign is an example of a large institution with a moderately refined organizational structure that produces a substantial annual volume of solid waste. The student enrollment at the University is approximately 32,000, but this number is reduced by one-half during the three summer months of June, July and August. During vacation periods, semester break and two summer periods when school is not in session, this population is reduced to a mere few hundred students left on campus. These fluctuations have a significant effect on the refuse production at certain sources (see Fig. 1) and will dictate collection volumes and frequencies. (See Table 2) Figure 1 shows that refuse produced by the student population, which is collected from housing, is high from September to May. The construction and lawn debris production is low most of this time, but becomes high from May to October. This equilization effect eliminates a high peak demand for vehicles, keeping capital investment costs low. The University employs 10,000 permanent faculty and staff for its operation. This population is relatively constant, and continuously present on campus, except for slight variation during the summer months.

The areal layout of the campus covers three-fourths of a square mile in a roughly L-shaped pattern, one mile long on each side. (See Fig. 2) There are approximately 100 major buildings and 25 minor ones located within this campus area, which does not include the south university farm area and its associated buildings. The majority of the classroom and administrative office space is located in the dozen large buildings surrounding the central quadrangle. Directly north of the quad is the engineering campus with associated offices, labs and shops, occupying five large blocks. South of the main quad

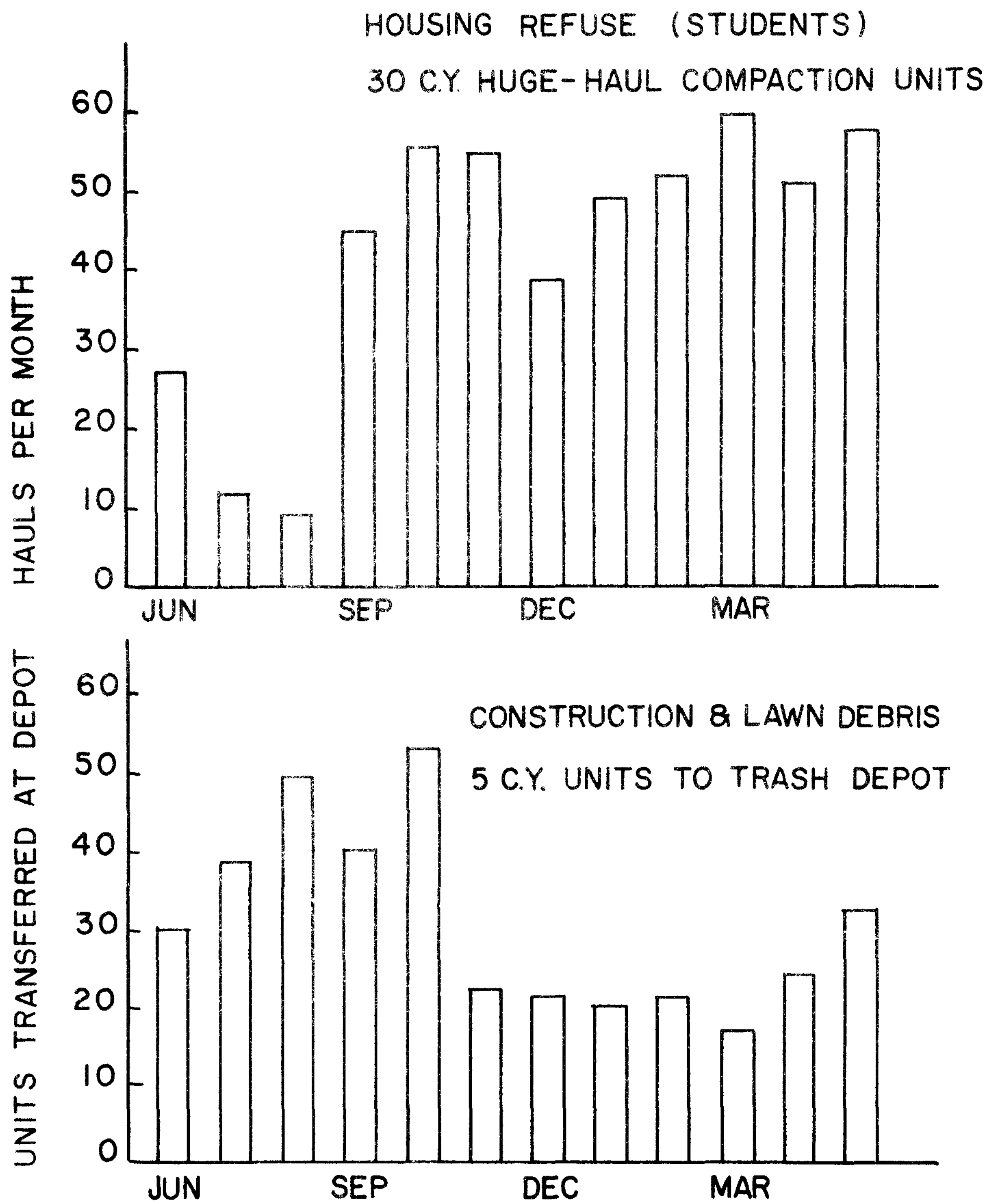

FIGURE I. VARIATIONS IN REFUSE VOLUME
UNIVERSITY OF ILLINOIS

(REF. 24)

TABLE 2

TRASH VOLUMES - 1968-1969

NUMBER OF TRASH CONTAINERS HAULED

Item	Month	Transportation							Housing			
		Central Trash Depot	Constr. Debris	Load-Luggers				H.H.	L.L.	Huge-Haul		
		33 Compacted C.Y.	5(4-6) C.Y.	5 C.Y.	6 C.Y.	8 C.Y.	10 C.Y.	30 C.Y.	8 C.Y.	20 C.Y.	30 C.Y.	30 Compacted * C.Y.
	1969											
1	May	35	32	8	10	303	7	68	73	9	30	57
2	April	36	23	8	13	347	9	56	60	7	27	51
3	March	40	17	11	8	351	9	63	90	9	33	59
4	February	39	21	13	10	344	7	61	68	8	29	52
5	January	28	20	11	11	349	7	65	62	9	37	49
	1968											
6	December	29	21	7	8	295	6	52	48	9	37	38
7	November	33	22	8	10	296	8	56	58	10	31	55
8	October	39	53	9	16	351	7	67	66	13	34	56
9	September	39	40	11	12	330	6	56	32	6	36	44
10	August	30	49	5	12	304	3	43	18	0	27	9
11	July	34	38	7	13	315	6	40	27	0	30	12
12	June	29	30	7	9	275	3	37	44	3	30	27
Total Containers		411	336	105	132	3,860	78	668	696	83	381	509
Total Volume (C.Y.)		13,563	1,680	525	792	30,880	780	19,920	5,568	1,660	11,430	15,270 * 45,810
Transportation Loose Total Volume		54,577 C.Y.										
Housing Loose Total Volume									64,468 C.Y.			

* Compaction rate is assumed to be 3:1. Volume is expanded to loose state for total volume calculations.

(Ref. 24)

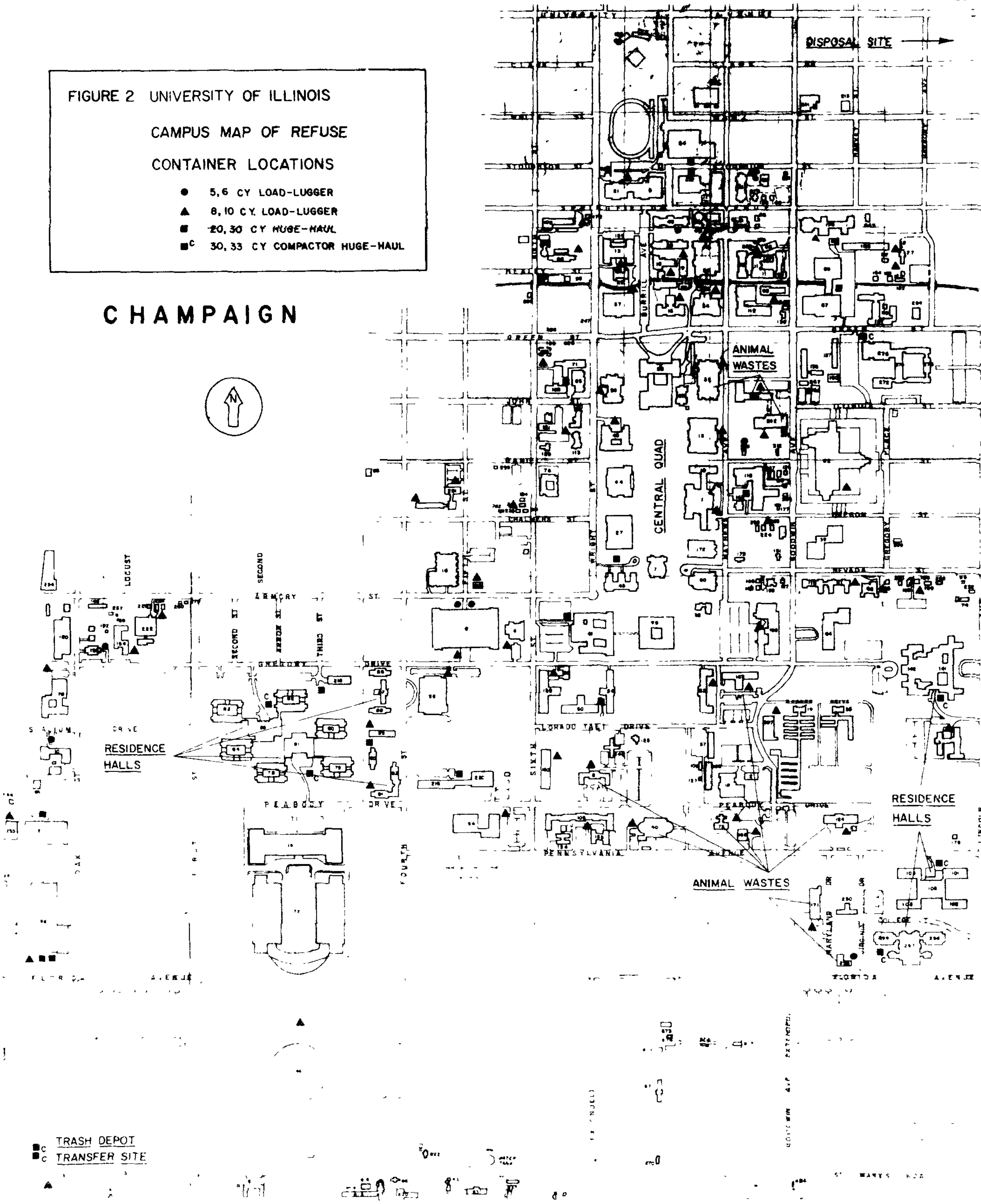

FIGURE 2 UNIVERSITY OF ILLINOIS CAMPUS MAP OF REFUSE CONTAINER LOCATIONS

is an area of less structural density and diverse building use, such as fine and applied arts, law, veterinary medicine and animal labs, plant science, commerce and state natural history and geological surveys. University residence halls are located principally on the southeast and southwest corners of the campus area. The design of major buildings ranges from two-story engineering labs to fourteen-story residence halls with the average building about four-stories tall. The street pattern is mainly an east-west and north-south rectangular grid, but with many discontinuous east-west streets making travel in this direction difficult and roundabout. North-south streets are usually "through" streets, but in the central campus area, they are often one-way. The topography can be described as absolutely flat.

Climatic conditions are significant at Urbana, as the summer is hot, with average temperatures in the 75-90°F range, and humidity above 75%. It is usually sunny and clear. In the winter, the climate changes to cold and damp, with freezing temperatures down to zero degrees and rain, ice and wet snow common until late March.

A. Classification of Solid Waste Sources and Characteristics

There are several major, distinct refuse source designations which can be made, based on the composition of the refuse produced. These are readily identified with particular building-use characteristics. The residence halls and associated food service facilities produce one mixed-type refuse. The office and classroom refuse are another designation. The life science, veterinary medicine and agriculture buildings have a characteristic waste. The physical plant operation concentrates construction and demolition refuse to a certain extent. The engineering buildings are in the office-classroom designation, although the labs produce a smaller, variable amount of completely heterogenous wastes.

The residence hall food operations are serviced by a total of six compactor-type huge-haul units; one located at each operation. Twelve of the large buildings away from the quad, such as the Civil Engineering Building, are also serviced by individual huge hauls. The classroom-office buildings in the quad area are serviced by individual 8 C.Y., on-site load-lugger units, due to the restricted space available in this conjested area. Three buildings have no load-lugger space available and office refuse is daily carted out to a Dempster paper-packer unit mounted on a truck body. Physical plant construction waste and tree- and lawn-trimmings are concentrated at the trash depot near the physical plant, if quantities are not large enough to warrant direct trips to the disposal site.

The composition of the solid waste produced by the university falls into four specific categories and one miscellaneous category. Dry refuse consists of all paper wastes from offices, classrooms, labs, libraries and residence halls and other wastebasket refuse produced in these buildings. Wet garbage is the packaging materials, food preparation trimmings and food residue from the residence hall kitchens and Bevier Hall home economics classes and cafeteria. The Illini Union food service produces a substantial garbage waste. The third category is animal wastes, which include carcasses, bedding material and manure, and residue from meat processing. The animal carcasses are from the large and small animal clinics, veterinary medicine and zoology research and labs in the life sciences buildings. Assorted bedding of sawdust, newspaper, cedar shavings and straw, and animal feces are produced at these buildings and the animal science building. Fat, bones, hides, offal and greases are residue from meat processing at the central foods cold storage unit. The wastes from construction projects, demolition of old structures, maintenance and landscaping are the fourth major category of refuse. The miscelleneous category includes special wastes that are usually randomly produced. Their characteristics are different from the other refuse categories and some require additional attention or special disposal precautions. They may include chemicals, waste oil, concrete test cylinders and beams, waste ink and solvents, wood powder, metal shavings, grease from traps, and cinder and clinker material. (25)

The ash production by Abbott Power Plant averages 35 tons per day, but this waste is removed by private contract with the coal company. This solid waste will be eliminated by 1972, when the university expects to complete conversion of the power plant to gas-fired boilers.

The total volume of refuse transported by the University of Illinois at the Urbana campus to the disposal site in the 1968-1969 school year was almost 120,000 C.Y. This volume was measured from the total cubic yard capacity of container volumes removed for disposal and assumes full or near-full utilization of container capacity. (See Table 2) At an average density of 200 lbs./C.Y., the weight of this refuse for cost assessment purposes was 12,000 tons. A breakdown of percentages of component categories listed above on a weight basis can be obtained from the Estimated Generation Survey of Solid Wastes (25): (See Table 3)

Refuse Composition Category	Percent Weight of Total Refuse
Dry Refuse	51%
Wet Garbage	2%
Animal Wastes	10%
Construction and Maintenance Wastes	25%
Special Wastes	12%

The characteristics of the refuse produced in each of the categories is uniform, except in the construction-landscape refuse because components vary with the season, and the special refuse which depends on the particular

TABLE 3

ESTIMATED GENERATION OF SOLID WASTES

CHAMPAIGN-URBANA CAMPUS - UNIVERSITY OF ILLINOIS

Refuse Category	Pounds Per Year	Tons Per Year
Dry Refuse		
Load packer	535,000	
Load lugger	3,969,000	
Huge haul	5,297,000	
Private contractor	1,400,000	
Total Dry Refuse	11,201,000	5,600
Wet Garbage		
Residence hall kitchens	513,000	
Bevier hall (Home Economics)	56,000	
Total Wet Garbage	569,000	280
Animal Wastes		
Carcasses	575,000	
Fat, Bones, Hides, Offal & Grease	359,000	
Bedding Material & Manure	1,304,000	
Total Animal Wastes	2,238,000	1,100
Construction & Maintenance Wastes		
House demolitions	1,912,000	
Open-top containers	2,400,000	
Landscape debris	765,000	
Total Construction & Maintenance Wastes	5,077,000	2,500
Special Wastes		
Chemicals	300	
Waste oils	102,000	
Concrete test cylinders & beams	170,000	
Waste ink & solvent	4,100	
Wood powder	2,400	
Cinders & clinkers	2,527,000 *	
Metal shavings	41,000	
Grease from traps	11,200	
Total Special Wastes	2,858,000	1,400
Total All Wastes	21,943,000	11,000

* Source of this figure is unknown. Does not agree with Abbott Power Plant cinder production, which is 35 tons/day.

(Ref. 25)

waste being disposed. The characteristics of the refuse, as noted earlier in the discussion, describe the chemical and physical qualities of the refuse and relate to the effectiveness of possible collection and disposal methods. A relative comparison of the university refuse composition categories, with respect to applicable characteristics for collection and disposal, is given in Table 4. Examination of this table will show which methods of collection and disposal are best suited to the types of refuse being produced, but relative percentage of total production and economic considerations will dictate the final method to be chosen.

B. Present Solid Waste Management

1. Collection

The collection system for the university refuse production is primarily the periodic removal of truck-mountable refuse storage containers from their respective building sites for transport to the disposal site or to the trash depot. The total of 113 containers vary in size from small 5 C.Y. load-lugger units to the 30 C.Y. huge-haul units, 6 of which are equipped with compactor rams which will reduce the refuse volume to 1/2 - 1/3 of its original volume. (See Figure 2) The large containers are transported directly to the disposal site, while some of the smaller 5 - 10 C.Y. containers located on the south and west sides of the campus area are taken to the trash depot for compaction and transfer. This trash depot is a transfer and compaction station where not only small container units, but construction and maintenance wastes, are dumped through a floor charging-hopper into a compactor equipped huge-haul for less frequent trips to the disposal site. It is located at the southwest corner of the campus near the physical plant. This transfer point is located on the opposite corner of the campus with respect to the disposal site location.

TABLE 4

REFUSE CHARACTERISTICS BY COMPOSITION CATEGORIES

UNIVERSITY OF ILLINOIS

Component Category / Characteristic	Dry Refuse	Wet Garbage	Animal Wastes	Construction, Maintenance & Landscape Wst.	Special Wastes excl. ashes	Cinders & Ash	Affect & Influence
Moisture content	v. low	v. high	high	low-med.	low	low	Incineration
Inert material	low	low	low	med.	med.	high	Incineration
Heat value	high	med.	med.	med.	med.-hi.	none	Incineration
Reclaimable materials	yes	no	no	no	some	yes	Reclamation
Compressibility & compactibility	high	high	high	low	low	low	Landfill
Size (bulky items)	no	no	yes	yes	no	no	Collection
Putrescible matter	no	yes	yes	no	no	no	Collection
Flammable mat'l	yes	no	no	yes	yes	no	Collection
Hazardous, toxic, pathogenic, contaminated	no	no	yes	no	yes	no	Collection
Peculiar handling problems	no	no	yes	no	yes	no	Collection

The frequency of collection varies, based on the rate of production of waste at a source and the storage capacity of the containers. The small load-luggers are usually emptied 3 times per week, while some of the huge hauls are only emptied once weekly. Garbage contaminated wastes in the huge haul units at the residence halls are emptied every third day.

A paper packer unit mounted on a truck body is used to remove office refuse daily from several of the central quad buildings, which have no refuse container space. It is operated on a one-half day basis.

Five additional vehicles are required for transport of the container units to the disposal or transfer sites. These vehicles, however, are not used exclusively for collection purposes. The personnel required to operate the collection vehicles varies from 3 to 6 with an average of 5 working an eight-hour day. One to three supervisory personnel are required, depending on the particular problems being encountered.

The majority of the wet garbage wastes produced at the residence hall food services and Bevier Hall are ground on-site by institutional garbage grinders and flushed with water to the sanitary sewer. This waste does not enter the solid waste collection and disposal system. The charges for this service are included in the costs of sanitary connections and wastewater production by the University paid to the Champaign-Urbana Sanitary District. A small amount of this garbage waste including wet slop, cans, glass and other containers is put into the huge haul units, contaminating the contents with wet garbage.

The garbage from the Illini Union food service is not collected by the University, but is removed by private contract. At the present time, a farmer collects this wet slop and garbage for hog-feeding purposes.

Animal carcasses and wastes require some special preparation and handling to be disposed of in an aesthetically acceptable and sanitary way.

These wastes from Veterinary Medicine Lab, Small and Large Animal Clinic and the Zoology Department in Morrill Hall and Natural History Building are placed in plastic bags and then in the load-luggers. The bag keeps the contents free from insect pests, prevent odors and disagreeable handling, and retains the high moisture content within the refuse container. The small animals and litter from Burrill Hall are incinerated daily in a small, 500 lb. per hour on-site incinerator. The Animal Science Building wraps the animal carcasses in plastic and stores them in a freezer. Periodically they are collected by a private scavenger for rendering. A thorough study of the handling of these wastes and specific recommendations for immediate improvement of collection and disposal methods are contained in a report on the Solid Waste Disposal of Animal Remains and Wastes - University of Illinois. (26)

2. Disposal

The principal disposal method for the university solid waste production is landfill at the Urbana City Landfill. This was formerly an open dump, and its present site characteristics and operation make the sanitary aspects of this disposal operation doubtful. The present site occupies 37 acres with possible expansion of 22 additional acres. The expected life of the present site is about five years. This assumes that the Illinois State Public Health Department or Water Pollution Control Board take no major action to suspend or halt the use of the disposal site due to unsatisfactory conditions.

The university is not involved in the operation of the landfill, but merely transports its refuse to the site for disposal. It assumes one-third share in the total cost of the landfill operation with the City of Urbana.

It was previously mentioned that most of the garbage waste from the food services was ground and flushed to the sanitary sewer. No additional disposal is necessary.

Garbage slop from the Illini Union is collected by private contract for a nominal fee with a local hog farmer for swine-feeding. This is a very small part of the total refuse production.

Meat processing wastes such as fat, bones, and offal from Davenport Hall and Central Food Stores, and large uncontaminated animals from Animal Science are removed by contract by a Decatur rendering plant.

Ashes and cinders from the Abbott Power Generating Plant using coal-fired boilers is removed by private contract included in the price of the purchased coal.

3. Reclamation Procedures

Scrap metal and machine shop shavings are collected in a storage bin at the Physical Plant Building. Depending on market value of the scrap metal and volume on hand, the material is removed by a local scrap and salvage dealer. The reclaimed sale value usually just offsets the removal cost.

No other reclamation procedures are in use at the present time.

4. Costs

The costs of refuse collection and disposal at the University are difficult to evaluate due to the many hidden costs involved in the system. Collection work performed by janitors and other help in removing refuse to collection containers are not included. Kitchen help disposing of garbage to grinders are not included. Collection vehicle maintenance and depreciation are not included in the collection costs because accounting procedures include these costs in the Transportation Division costs. The rendering contract for removal and disposal of animal carcasses from Animal Science has recently increased substantially in cost to $26.00 per ton. The removal of garbage and wet refuse from the Illini Union by private contract for hog-feeding costs $20.60 per ton. (25) It was not possible to assign operating-maintenance cost and capital cost for the collection or disposal methods.

UNIVERSITY OF ILLINOIS REFUSE MANAGEMENT COSTS (24)

	Total Annual Cost	Dollars Per Ton
Collection(1)	$44,486.	3.65
Disposal(2)	$10,000.	0.83
Total	$54,486.	4.48

(1)Collection costs include hauling, container maintenance and wages.

(2)Disposal cost is 1/3 of Urbana City Landfill costs, including operating, maintenance and equipment capital investments.

C. Alternative Methods of Solid Waste Management

In the use of the total system approach to solid waste management, there is the tendency to organize the system for the optimum efficiency. This is a very creditable objective, but, especially for systems in existence, it is difficult to achieve this goal without sacrificing economy to a large degree.

The University of Illinois could improve the total efficiency of solid waste disposal by reducing the number of different disposal methods and overlapping disposal of similar waste materials. Hog-feeding and rendering contracts are an added problem in this respect. The different disposal of animal remains makes development of handling and storage procedures and regulations difficult. The operation of one small animal incinerator requires more time per pound of waste incinerated than a larger-scale incinerator. Keeping the relatively small volumes of garbage contaminated wastes separate from the general dry refuse in the huge hauls, would reduce the frequency of collection from perhaps 3 times per week to once weekly. Compaction devices may reduce collection frequencies by one-half.

Optimum economy of the solid waste system is difficult to assess, since all present costs are lumped together as one total collection cost or total disposal costs. Many costs are also hidden costs, budgeted under the individual department and not included in the total cost figures. The disposal costs at present are extremely low and it is highly doubtful any changes in disposal method would reduce this disposal cost. Collection and storage costs may be reduced in some particular situations. The freezing and storage of animals to be collected by the rendering company costs more than sterilization and haul to the landfill with other refuse. The disposal of other animals by this company is not more economical than landfill, but a removal service is provided which otherwise must be performed by laboratory or janitorial help. Flushing of waste trays under larger animal cages and grinding of the waste materials to the sanitary sewer would reduce the amount of expensive hand labor required presently.

The disposal of some of the larger animals by landfill would probably not be the best disposal procedure. Their large size and subsequent decomposition may affect the stability and settlement of the fill. Serious odor and nuisance conditions would be likely, as well as health hazards from pest harborage. Incineration of these large animal carcasses at a centrally located incinerator could eliminate these concerns and is a preferable disposal method for this waste, but it certainly is not as economical as landfill operations.

Disposal of the paper component of the total refuse production could be eliminated if this mixed paper and cardboard were to be salvaged. This salvage would reduce the total disposal costs, as it is a substantial part of the waste production. As long as the sum of the market value of the salvaged paper and the present disposal costs was greater than the salvage processing and shipping costs, the method would be more economical than the present method. As an approximation, the dry refuse component of university solid waste production is almost entirely paper. If this 5600 tons of mixed paper per year could be kept separated from contaminating wastes, like wet garbage, which would not be difficult, the recovery value would be $33,000. per year at a nominal price of $6. per ton of mixed paper. This does not include the additional savings in reduced disposal costs. Certainly a paper packer unit could be purchased and operated for less than this figure.

Incineration of university refuse has been suggested as a practical, efficient and aesthetically pleasing method of disposal. However, this incineration would probably be very uneconomical due to the relatively small amount of refuse produced by the University of Illinois. The average total solid waste production of 12,000 tons per year amounts to only an average 33 tons per day. This is far below the average size municipal incinerator of 250 tons per day capacity per single furnace. The capital cost alone for a 33-ton per day incinerator would be at least $6600. per year based on a capital cost of $6000. per ton capacity and a 30-year expected life. Not only would capital costs be high for a small plant of this size, but operating costs could not be justified to insure proper incineration of the refuse. Development of small-scale incinerators requiring less labor and maintenance than conventional units may deserve further consideration.

D. Proposed Solid Waste Disposal System

Sanitary landfill offers the best characteristics for general disposal of university solid waste. It is efficient, sanitary, aesthetically acceptable, and above all, very economical, both absolutely and when compared to other disposal methods.

Although the continued operation of the present landfill site is questionable beyond several years, other disposal sites are available within an easily justifiable haul distance of the university. For example, at a haul distance of 10 miles, there is approximately 100 acres of used gravel pit land south of Mahomet which would be suitable for landfilling with some site grading. At a distance of 30 miles, there is unlimited strip mine land available near Oakwood. Figure 3 shows that landfill disposal costs, including collection and haul costs, are cheaper than incineration costs for direct haul or transfer haul up to distances of 25 miles (6, p. 44).

Land requirements for the disposal of all present production of university refuse are easily calculated. Associated costs for the land required are based on the most conservative figures and, yet, this method is still very inexpensive.

From previously reported production figures of 120,000. C.Y. of refuse per year, and assuming a compaction ratio of 3:1, 10 foot depth of fill and 20% cover material, the annual land requirement is:

$$\underset{\text{(Volume)}}{\left(\frac{120{,}000\ \text{C.Y.}}{\text{yr.}}\right)} \underset{\text{(Compaction)}}{\left(\frac{1}{3}\right)} \left(\frac{27\ \text{C.F.}}{\text{C.Y.}}\right) \left(\frac{\text{Acre}}{43{,}560\ \text{Acre-ft.}}\right) \underset{\text{(depth of fill)}}{\left(\frac{1}{10\ \text{ft. depth}}\right)} \underset{\text{(allowance for cover)}}{(1.2)}$$

$$= 3.1\ \frac{\text{Acres}}{\text{yr.}}$$

Assuming land costs of $1000. per acre, which is an excessive cost in this area for poor quality, degraded land, the total annual land cost would not exceed $3100. Although equipment capital costs and operating costs must be added, the total cost of landfill disposal would be considerably less than total incineration costs, due to high operating and maintenance costs with incineration. Finally, appreciation of the land value will be a negative cost of landfill operation, and may even be great enough to return some of the disposal operating costs, when the finished landfill site can be sold for other future uses.

Landfill, as a disposal method, offers flexibility over other disposal methods. Capital investment in disposal equipment is low, so the university will not be bound by large plant investment to this disposal method, if

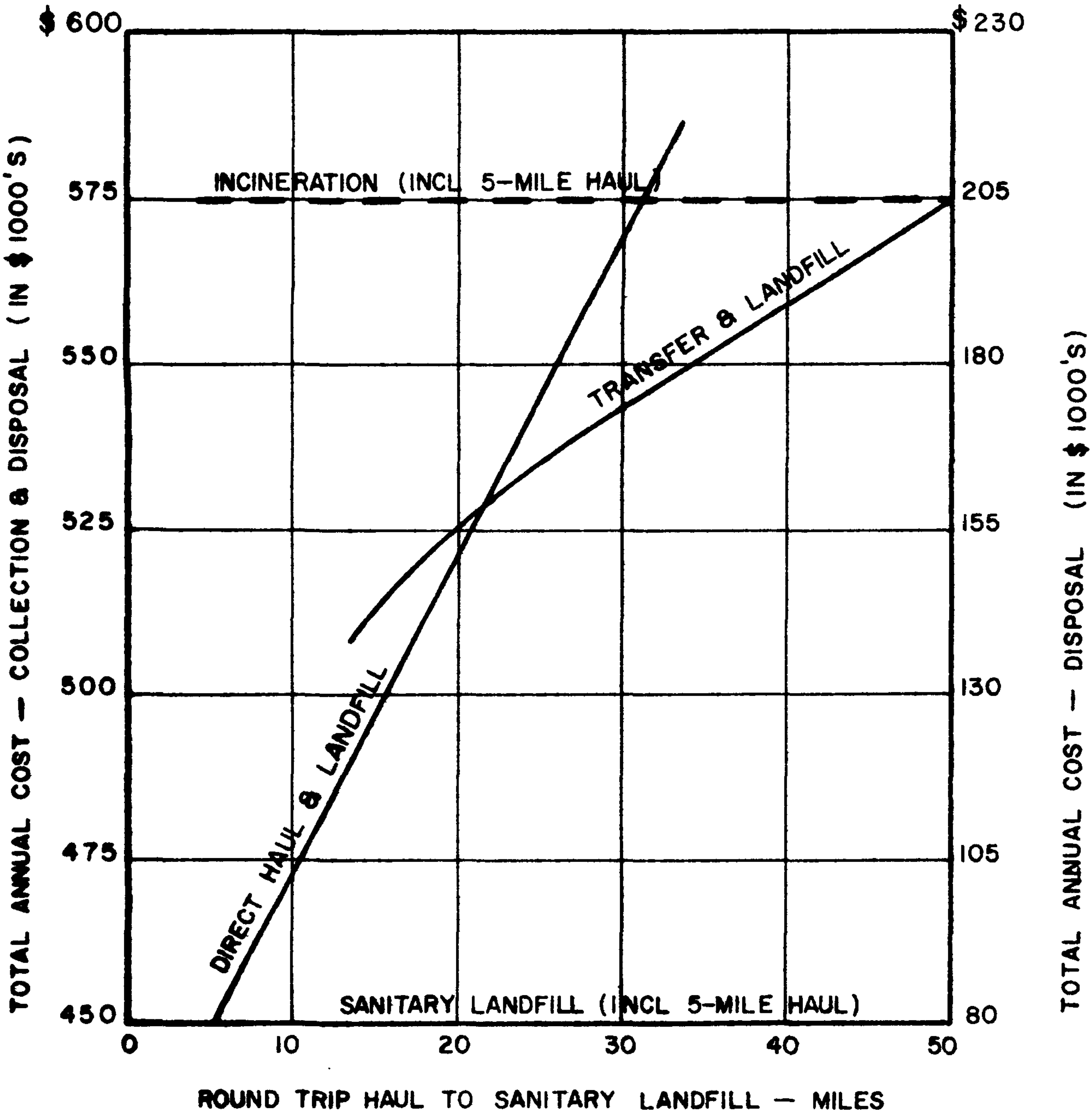

FIGURE 3. EFFECT OF HAUL DISTANCE ON TOTAL DISPOSAL COST.

Population 50,000

(REF. 6)

technological changes produce a more desirable method. Changes in refuse composition or seasonal fluctuations in production of refuse will not affect the operation of a sanitary landfill. This is particularly important, if the university at a later time found salvage of a refuse component to be economical. The reduction of total refuse for disposal would simply mean less land would be required annually.

Salvage of mixed paper and corrugated box is the only reclamation procedure that appears to be economically attractive and of significant magnitude to allow efficient recovery. The value of the reclaimed paper varies considerably over short time intervals. A thorough investigation of an outlet market and a fixed price contract would be necessary to initiate this recovery operation.

The disposal of the various animal carcasses, wastes and bedding materials would be improved by incineration of all of these components at a convenient location on campus. The buildings producing these wastes are located in the south-east corner of the campus, so site selection would be limited to this area. A daily pick-up by one special vehicle and a properly trained crew could eliminate all storage, health, odor and handling problems, and provide enough waste to justify part-time operation of a well-designed on-site incinerator. Auxillary fuel may be required to get adequate incineration of all wastes and limit air pollution problems. The supervisory control on such a collection and disposal system would be much easier than the present situation of diverse disposal schemes.

VI. RECOMMENDATIONS

A. University of Illinois Solid Waste System

The University of Illinois has an ideal solid waste disposal operation at the present time, with regard to economics of the disposal method. It would not be possible to create a more economic disposal method than the operation with the City of Urbana. However, this situation will inevitably change due to public and governmental pressure to provide more sanitary disposal conditions. The university will then be forced to develop its own disposal system, or combine with one or more municipalities or a county agency for disposal of refuse.

The most sensible approach would be a combined disposal system for the cities of Champaign and Urbana and their outlying communities and the University of Illinois. This combined system would provide sanitary disposal of solid wastes for the small communities, insure the university of a permanent disposal method and eliminate the undesirable Urbana city landfill. It would also be more economical than operating duplicate facilities, as is presently done. The increase in scale of the operation would allow better supervision of the disposal and use of more sophisticated equipment to improve the aesthetic and sanitary conditions of the disposal site. For example, sanitary landfill land requirements for Champaign-Urbana and the University of Illinois would be about 10 acres per year, assuming a city population of 90,000, 0.75 tons refuse produced per capita per year (2), loose refuse density of 200 lbs. per C.Y., a compaction ratio of 3 to 1 and a ten foot depth of fill. This land requirement of ten acres per year would be easily satisfied by purchase of available marginal land in sufficient quantities within economical haul distance. The best management would be obtained if the disposal system was developed on a regional basis, such as a sanitary district, and was responsible to the county board or its own representative board of supervisors.

Sanitary landfill disposal is the cheapest disposal method when all costs are considered. It will continue to be so, as long as labor and construction material costs continue to increase. Landfill operation also is the most flexible disposal operation to changes in refuse composition, refuse production volumes and changes in the disposal method itself.

Animal wastes and carcasses are the solid waste component of most concern at the university. They pose both a storage and contamination problem, and at the present time, are handled and disposed of in many varied methods.

The only component of university refuse that has any potential salvage value is the mixed paper from office and classroom buildings. This can be easily kept separated from other contaminating wastes, and be compacted and baled for rail shipment. The value of this paperstock is determined by market prices, which are depressed at the present time. However, in the future this may change with increased recycling of used paper in paper products. The university production of 5600 tons annually would not only realize a market value, but also reduce the amount of total refuse to be disposed by the university.

The collection and transportation system for solid waste removal from the university is an efficient and reasonably economical system in its present state. The use of truck-mountable containers has reduced the labor required for collection to a minimum, and has allowed the efficient use of vehicle time primarily for transportation to the disposal site. The use of independent containers for separation of putrescible garbage wastes and dry refuse could allow less frequent collection of the volumes of dry refuse. This may reduce the total number of required pick-ups or allow the pick-up schedule to be more flexible to changes in dry refuse quantities.

The central quad buildings, producing mainly office and classroom paper wastes, and their attendant lack of refuse storage space requiring daily paper-packer service, would be a likely area for study and implementation of a pressure or vacuum collection and transport system. Gravity-type chutes within buildings and vacuum-tube transport between buildings through existing steam tunnels to a central collection and storage site near the quad should be given consideration in the not-to-distant future. Periodic construction and modification of existing utility corridors and tunnels for other purposes would allow gradual implementation of this system at a minimum capital cost.

The trash depot facility on the far southwest corner of the campus provides a limited service for collection, compaction and transfer of small quantities of construction and lawn debris arriving at the Physical Plant. However, it is not particularly efficient to use this transfer facility for emptying small load-lugger containers into a larger unit for haul to the present disposal site. The distance and amount of time required to directly haul these small units to the Urbana disposal site is not significantly more than to the transfer site. The transfer time, labor and subsequent transfer haul trips can be eliminated or reduced. In the future, if a more distant disposal site is used, this transfer station will be very practical for eliminating inefficient direct haul of small container units to the disposal site.

An administrative structure for solid waste management at the University of Illinois should be established to concentrate in one unit the responsibility for economy and proper sanitary quality control in present operations, and to provide adequate future planning for changes or additions in facilities. The present responsibility for solid waste management is divided, on the basis of the operation involved, among the physical plant transportation department, the sanitary engineer for the university, the animal caretakers of various science and agriculture departments and the custodial labor force. This segregated responsibility allows conflicting policies and procedures to develop, which reduce the efficiency of the total solid waste system. Coordinated under the responsibility of one director, uniform regulations, inspections and corrective procedures could be instituted more effectively.

B. Institutional Solid Waste Systems

Institutional solid waste systems need to be developed to properly and economically process specialized refuse produced by the operation of these organizations. The solid waste must be considered a reclamable resource that in many cases is very amenable to recovery as a raw material, conversion to a new product or use as a source of energy. With anticipated increases in future growth, refuse production and management will receive greater consideration from the viewpoint of limited natural resources and limited disposal space and assimilative capacity of our environment.

Institutional sources of solid waste production need to be studied to modify and optimize collection and disposal methods for existing institutions, and to develop design criteria for planning solid waste systems for future, proposed institutions. The benefit of installation of solid waste systems during initial construction, like other utilities, promises simultaneous efficient and economic removal and disposal of refuse. To accomplish this optimization, surveys of present typical institutions need to be made to analyze refuse production, characteristics, collection, disposal and relative costs involved. Meaningful results of this survey can only be obtained if standard units and methods of measurement and evaluation are used. This problem currently hampers any comparison of two existing systems, as data are reported in terms of different weight, volume and time units.

The solution being sought in analysis of institutional solid waste systems cannot be a fixed standard of performance, such as an effluent concentration of x milligrams per liter or a percent removal. Instead, the goal is to improve the environment of man by reducing the burden of solid waste, which must be ultimately returned to the environment, at reasonable economic costs. Technological progress in developing new treatment methods and critical review of existing facilities will help achieve this goal.

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