CHAPTER 1

EVOLUTION OF SOLID WASTE MANAGEMENT

Solid wastes comprise all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted. The term *solid waste* as used in this text is all-inclusive, encompassing the heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulation of agricultural, industrial, and mineral wastes. This book is focused on the urban setting, where the accumulation of solid wastes is a direct consequence of life.

The purpose of this chapter is to introduce the reader to the field of solid waste management and to identify the demands that must be met by those practicing in the field. The material is presented in five sections: (1) solid wastes—a consequence of life; (2) waste generation in a technological society; (3) the evolution of solid waste management; (4) integrated solid waste management; and (5) solid waste management systems.

1-1 SOLID WASTE—A CONSEQUENCE OF LIFE

From the days of primitive society, humans and animals have used the resources of the earth to support life and to dispose of wastes. In early times, the disposal of human and other wastes did not pose a significant problem, for the population was

FIGURE 1-1
Solid waste problems are not new. (By permission of Johnny Hart and Creators Syndicate, Inc.)

small and the amount of land available for the assimilation of wastes was large. Although emphasis is currently being placed on recycling the energy and fertilizer values of solid wastes, the farmer in ancient times probably made a bolder attempt at this. Indications of recycling may still be seen in the primitive, yet sensible, agricultural practices in many of the developing nations where farmers recycle solid wastes for fuel or fertilizer values.

Problems with the disposal of wastes can be traced from the time when humans first began to congregate in tribes, villages, and communities and the accumulation of wastes became a consequence of life (see Fig. 1-1). Littering of food and other solid wastes in medieval towns—the practice of throwing wastes into the unpaved streets, roadways, and vacant land—led to the breeding of rats, with their attendant fleas carrying bubonic plague. The lack of any plan for the management of solid wastes thus led to the epidemic of plague, the Black Death, that killed half of the fourteenth-century Europeans and caused many subsequent epidemics with high death tolls. It was not until the nineteenth century that public health control measures became a vital consideration to public officials, who began to realize that food wastes had to be collected and disposed of in a sanitary manner to control rodents and flies, the vectors of disease.

The relationship between public health and the improper storage, collection, and disposal of solid wastes is quite clear. Public health authorities have shown that rats, flies, and other disease vectors breed in open dumps, as well as in poorly constructed or poorly maintained housing, in food storage facilities, and in many other places where food and harborage are available for rats and the insects associated with them. The U.S. Public Health Service (USPHS) has published the results of a study [2] tracing the relationship of 22 human diseases to improper solid waste management.

Ecological phenomena such as water and air pollution have also been attributed to improper management of solid wastes. For instance, liquid from dumps and poorly engineered landfills has contaminated surface waters and groundwaters. In mining areas the liquid leached from waste dumps may contain toxic elements, such as copper, arsenic, and uranium, or it may contaminate water supplies with unwanted salts of calcium and magnesium. Although nature has the capacity to dilute, disperse, degrade, absorb, or otherwise reduce the impact of unwanted residues in the atmosphere, in the waterways, and on the land, ecological imbalances have occurred where the natural assimilative capacity has been exceeded.

1-2 WASTE GENERATION IN A TECHNOLOGICAL SOCIETY

The development of a technological society in the United States can be traced to the beginnings of the Industrial Revolution in Europe; unfortunately, so can a major increase in solid waste disposal problems. In fact, in the latter part of the nineteenth century, conditions were so bad in England that an urban sanitary act was passed in 1888 prohibiting the throwing of solid wastes into ditches, rivers, and waters. This preceded by about 11 years the enactment of the Rivers and Harbors Act of 1899 in the United States, which was intended to regulate the dumping of debris in navigable waters and adjacent lands.

Thus, along with the benefits of technology have also come the problems associated with the disposal of the resultant wastes. To understand the nature of these problems, it will be helpful to examine the flow of materials and the associated generation of wastes in a technological society and to consider the direct impact of technological advances on the design of solid waste facilities.

Materials Flow and Waste Generation

An indication of how and where solid wastes are generated in our technological society is shown in the simplified materials flow diagram presented in Fig. 1-2. Solid wastes (debris) are generated at the start of the process, beginning with the mining of raw materials. The debris left from strip-mining operations, for example, is well known to everyone. Thereafter, solid wastes are generated at every step in the process as raw materials are converted to goods for consumption.

It is apparent from Fig. 1-2 that one of the best ways to reduce the amount of solid wastes that must be disposed of is to limit the consumption of raw materials and to increase the rate of recovery and reuse of waste materials. Although the concept is simple, effecting this change in a modern technological society has proved extremely difficult. Therefore, society has undertaken improved waste management and searched for new permanent locations in which to place solid waste. Unlike water-borne and air-dispersed wastes, solid waste will not go away. Where it is thrown is where it will be found in the future.

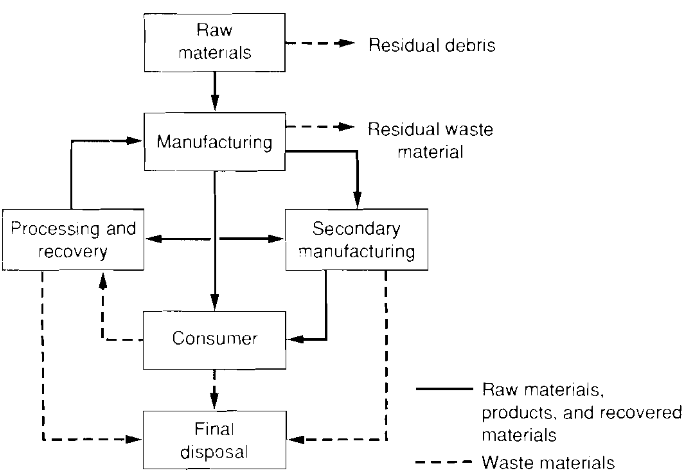

FIGURE 1-2
Materials flow and the generation of solid wastes in a technological society.

The Effects of Technological Advances

Modern technological advances in the packaging of goods create a constantly changing set of parameters for the designer of solid waste facilities [7]. Of particular significance are the increasing use of plastics and the use of frozen foods, which reduce the quantities of food wastes in the home but increase the quantities at agricultural processing plants. The use of packaged meals, for example, results in almost no wastes in the home except for the packaging materials. These continuing changes present problems to the facilities designer because engineering structures for the processing of solid wastes involves such large capital expenditures that they must be designed to be functional for approximately 25 years. Thus, the engineers responsible for the design of solid waste facilities must be aware of trends, even though they cannot, of course, predict all the changes in technology that will affect the characteristics of solid wastes.

On the other hand, every possible prediction technique must be used in this ever-changing technological society so that flexibility and utility can be designed into the facilities. Ideally, a facility should be functional and efficient over its useful life, which should coincide with the maturity of the bonds that were floated to pay for it. But important questions arise: Which elements of society generate the greatest quantities of solid waste and what is the nature of these wastes? How can the quantities be minimized? What is the role of resource recovery? Can disposal and recovery technology keep up with consumer product technology?

1-3 THE DEVELOPMENT OF SOLID WASTE MANAGEMENT

Solid waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that is also responsive to public attitudes. In its scope, solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in solutions to all problems of solid wastes. The solutions may involve complex interdisciplinary relationships among such fields as political science, city and regional planning, geography, economics, public health, sociology, demography, communications, and conservation, as well as engineering and materials science.

Historical Development

> To describe the characteristics of the different classes of refuse, and to draw attention to the fact that, if a uniform method of nomenclature and record of quantities handled could be kept by the various cities, then the data obtained and the information so gained would be a material advance toward the sanitary disposal of refuse. Such uniformity would not put any expense upon cities, and direct comparisons and correct conclusions could be made for the benefit of others. [6]

This statement of objectives was written in 1906 by H. de B. Parsons in *The Disposal of Municipal Refuse* [6], which may have been the first book to deal solely with the subject of solid wastes from a rigorous engineering standpoint. It is interesting to note that many of the basic principles and methods underlying what is known today as the field of solid waste management were well-known even then. For example, although the motor truck has replaced the horse-drawn cart (see Fig. 1-3), the basic methods of solid waste collection remain the same; they continue to be labor intensive. (The development of uniform data for purposes of comparison is still an important need.)

The most commonly recognized methods for the final disposal of solid wastes at the turn of the century were (1) dumping on land, (2) dumping in water, (3) plowing into the soil, (4) feeding to hogs, (5) reduction, and (6) incineration [3, 6]. Not all these methods were applicable to all types of wastes. Plowing into the soil was used for food wastes and street sweepings, whereas feeding to hogs and reduction were used specifically for food wastes [3].

Enlightened solid waste management, with emphasis on controlled tipping (now known as "sanitary landfilling"), began in the early 1940s in the United States and a decade earlier in the United Kingdom [4]. New York City, under the leadership of Mayor La Guardia, and Fresno, California, with its health-minded Director of Public Works, Jean Vincenz, were the pioneers in the sanitary landfill method for large cities. During World War II, the U.S. Army Corps of Engineers, under the direction of Jean Vincenz, who then headed its Repairs and Utilities Division in Washington, DC, modernized its solid waste disposal programs to serve as model landfills for communities of all sizes. The medical Department of the Army, through Col. W. A. Hardenbergh of the Sanitary Corps' engineering group, took an active part in vector control and the prevention of disease by helping to sponsor the sanitary landfill program.

But municipalities did not follow these programs with consistency. The California Department of Health Services, along with several other progressive state health departments, established standards for municipal sanitary landfills and carried out aggressive campaigns for the elimination of conventional dumps. Still, in 1965, after a thorough review of solid waste management practices in the United States, Congress concluded that

> ... inefficient and improper methods of disposal of solid waste result in scenic blights, create serious hazards to public health, including pollution of air and water resources, accident hazards, and increase in rodent and insect vectors of disease, have an adverse effect on land values, create public nuisances, otherwise interfere with community life and development; ... the failure or inability to salvage and reuse such materials economically results in the unnecessary waste and depletion of natural resources. [1]

Congress also found that the trend of population concentration in metropolitan and urban areas had presented these communities with serious financial and administrative problems in the collection, transportation, and disposal of solid wastes.

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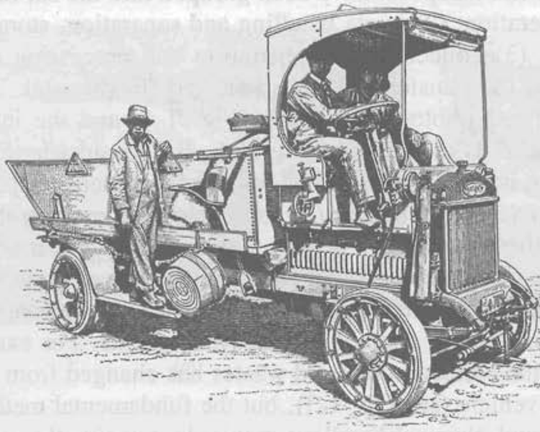

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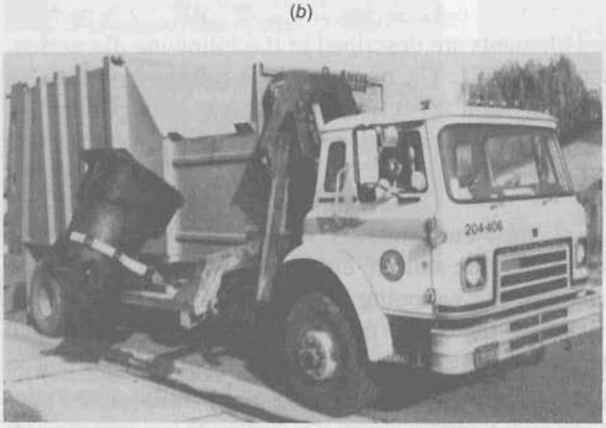

(*c*)

FIGURE 1-3
Evolution of vehicles used for the collection of solid waste: (*a*) horse-drawn cart, circa 1900; (*b*) solid tire motor truck, circa 1925; and (*c*) modern collection vehicle equipped with container-unloading mechanism.

Functional Elements of a Waste Management System

The problems associated with the management of solid wastes in today's society are complex because of the quantity and diverse nature of the wastes, the development of sprawling urban areas, the funding limitations for public services in many large cities, the impacts of technology, and the emerging limitations in both energy and raw materials. As a consequence, if solid waste management is to be accomplished in an efficient and orderly manner, the fundamental aspects and relationships involved must be identified, adjusted for uniformity of data, and understood clearly.

In this text, the activities associated with the management of solid wastes from the point of generation to final disposal have been grouped into the six functional elements: (1) waste generation; (2) waste handling and separation, storage, and processing at the source; (3) collection; (4) separation and processing and transformation of solid wastes; (5) transfer and transport; and (6) disposal. The functional elements are illustrated photographically in Fig. 1-4, and the interrelationship between the elements is identified in Fig. 1-5. By considering each functional element separately, it is possible (1) to identify the fundamental aspects and relationships involved in each element and (2) to develop, where possible, quantifiable relationships for the purposes of making engineering comparisons, analyses, and evaluations. This separation of functional elements is important because it allows the development of a framework within which to evaluate the impact of proposed changes and future technological advancements. For example, the means of transport in the collection of solid wastes has changed from the horse-drawn cart to the motor vehicle (see Fig. 1-3), but the fundamental method of collection—that is, the manual physical handling required—remains the same (see Chapter 8).

The individual functional elements are described in the following discussion. Each one is considered in detail in Part III. The purpose of the following discussion is to introduce the reader to the physical aspects of solid waste management and to establish a useful framework within which to view the activities associated with management of solid wastes.

Waste Generation. *Waste generation* encompasses activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal. For example, the wrapping of a candy bar is usually considered to be of little further value to the owner once the candy is consumed, and more often that not it is just thrown away, especially outdoors. It is important in waste generation to note that there is an identification step and that this step varies with each individual waste.

Waste generation is, at present, an activity that is not very controllable. In the future, however, more control will be exercised over the generation of wastes. In states where waste diversion goals are set by law, and must be met under threat of economic penalty, it is necessary to put in place a manifest system to

FIGURE 1-4
Views of the functional elements that constitute a solid waste management system: (*a*) waste generation; (*b*) waste handling and separation, storage, and processing at the source; (*c*) collection; (*d*) separation and processing and transformation of solid wastes; (*e*) transfer and transport; and (*f*) disposal.

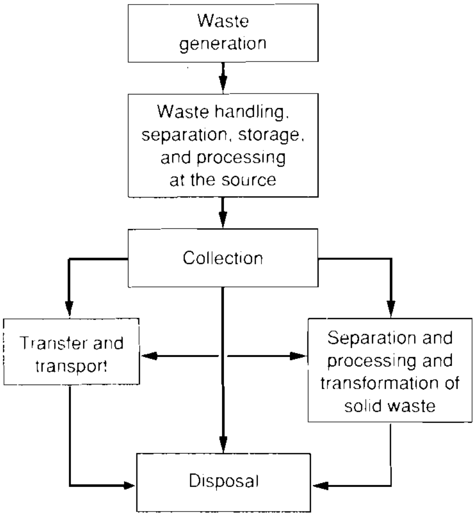

FIGURE 1-5
Simplified diagram showing the interrelationships between the functional elements in a solid waste management system.

monitor waste diversion. Source reduction, although not controlled by solid waste managers, is now included in system evaluations as a method of limiting the quantity of waste generated.

Waste Handling and Separation, Storage, and Processing at the Source. The second of the six functional elements in the solid waste management system is *waste handling and separation, storage, and processing at the source*. Waste handling and separation involves the activities associated with management of wastes until they are placed in storage containers for collection. Handling also encompasses the movement of loaded containers to the point of collection. Separation of waste components is an important step in the handling and storage of solid waste at the source. For example, from the standpoint of materials specifications and revenues from the sale of recovered materials, the best place to separate waste materials for reuse and recycling is at the source of generation. Homeowners are becoming more aware of the importance of separating newspaper and cardboard, bottles, yard wastes, aluminum cans, and ferrous materials. Currently, source separation of hazardous wastes by homeowners is being discussed widely and implemented to varying degrees.

On-site storage is of primary importance because of public health concerns and aesthetic considerations. Unsightly makeshift containers and even open ground storage, both of which are undesirable, are often seen at many residential and commercial sites. The cost of providing storage for solid wastes at the source is normally borne by the homeowner or apartment owner in the case of individuals, or by the management of commercial and industrial properties. Processing at the source involves activities such as compaction and yard waste composting.

Collection. The functional element of *collection*, as used in this book, includes not only the gathering of solid wastes and recyclable materials, but also the transport of these materials, after collection, to the location where the collection vehicle is emptied. This location may be a materials processing facility, a transfer station, or a landfill disposal site. In small cities, where final disposal sites are nearby, the hauling of wastes is not a serious problem. In large cities, however, where the haul distance to the point of disposal is often greater than 15 miles, the haul may have significant economic implications. Where long distances are involved, transfer and transport facilities are normally used.

As shown in Table 1-1, collection accounts for almost 50 percent of the total annual cost of urban solid waste management. This service may cost the individual homeowner \$200/yr or more (1990), depending on the number of containers and frequency of collection. Typically, collection is provided under various management arrangements, ranging from municipal services to franchised private services conducted under various forms of contracts. In several parts of the country, large solid waste disposal companies, with contracts in many cities, own and

TABLE 1-1
Estimated cost of solid waste collection and disposal in the U.S. in 1990 and the year 2000[a]

	1990			2000 (estimated)[b]		
	Low	Medium	High	Low	Medium	High
Solid waste,[c] tons × 10^6/yr						
Collected	149	190	238	149	196	257
Recycled[d]	15	24	42	50	65	86
Total	164	214	280	199	261	343
Unit costs, \$/ton						
Collection	20	50	200	Future costs will depend on legislation and technological developments		
Recycling[e]	60	100	400			
Disposal	15	40	200			
Total national costs,[f] 10^6 dollars						
Collection		9,500		Future costs will depend on legislation and technological developments		
Recycling		2,400				
Disposal		7,600				
Total		19,500				

[a] Adapted in part from Ref. 8.

[b] Derived by assuming a population growth of 1 percent per year, a 1 percent per year increase in the quantity of waste generated per person, and that the entire country will achieve a 25 percent diversion goal.

[c] Municipal solid waste exclusive of wastes from municipal services, treatment plant sludges, and industrial and agricultural wastes.

[d] Based on recycle rates of 9, 11, and 15 percent in 1990.

[e] Gross cost excluding credits for revenue from the sale of recovered materials.

[f] Medium value only.

Note: tons × 907.2 = kg

\$/ton × 0.001221 = \$/kg

operate collection vehicles and landfill disposal sites. Collection services for industries vary widely. Some industrial wastes are handled like residential wastes; some companies have disposal sites on their own properties that use conveyor belts or water slurry transport. The latter is used for mineral wastes and agricultural wastes in many cases. Each industry requires an individual solution to its waste problems.

Separation, Processing, and Transformation of Solid Waste. The *separation, processing, and transformation of solid waste materials* is the fourth of the functional elements. The recovery of separated materials, the separation and processing of solid waste components, and transformation of solid waste that occurs primarily in locations away from the source of waste generation are encompassed by this functional element. The types of means and facilities that are now used for the recovery of waste materials that have been separated at the source include curbside collection, drop off, and buy back centers. The separation and processing of wastes that have been separated at the source and the separation of commingled wastes usually occur at a materials recovery facility, transfer stations, combustion facilities, and disposal sites. Processing often includes the separation of bulky items, separation of waste components by size using screens, manual separation of waste components, size reduction by shredding, separation of ferrous metals using magnets, volume reduction by compaction, and combustion.

Transformation processes are used to reduce the volume and weight of waste requiring disposal and to recover conversion products and energy. The organic fraction of municipal solid waste (MSW) can be transformed by a variety of chemical and biological processes. The most commonly used chemical transformation process is combustion, which is used in conjunction with the recovery of energy in the form of heat. The most commonly used biological transformation process is aerobic composting. The selection of a given set of processes will depend on the waste management objectives to be achieved.

Transfer and Transport. The functional element of *transfer and transport* involves two steps: (1) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and (2) the subsequent transport of the wastes, usually over long distances, to a processing or disposal site. The transfer usually takes place at a transfer station. Although motor vehicle transport is most common, rail cars and barges are also used to transport wastes.

For example, in the city of San Francisco the collection vehicles, which are relatively small because of the need to maneuver in city streets, haul their loads to a transfer station at the southern boundary of the city. At the transfer station, the wastes unloaded from the collection vehicles are reloaded into large tractor-trailer trucks. The loaded trucks are then driven to a disposal site located about 60 miles away.

Disposal. The final functional element in the solid waste management system is *disposal*. Today the disposal of wastes by landfilling or landspreading is the ultimate fate of all solid wastes, whether they are residential wastes collected and transported directly to a landfill site, residual materials from materials recovery facilities (MRFs), residue from the combustion of solid waste, compost, or other substances from various solid waste–processing facilities. A modern sanitary landfill is not a dump; it is an engineered facility used for disposing of solid wastes on land or within the earth's mantle without creating nuisances or hazards to public health or safety, such as the breeding of rats and insects and the contamination of groundwater.

In most cities, planning for waste disposal involves dealing with city, county, or other regional planning commissions and agencies. Thus, land-use planning becomes a primary determinant in the selection, design, and operation of processing facilities and landfills. Environmental impact statements (see Chapter 2) are required for all new landfill sites to ensure compliance with public health, aesthetics, and future use of land.

1-4 INTEGRATED SOLID WASTE MANAGEMENT

When all of the functional elements have been evaluated for use, and all of the interfaces and connections between elements have been matched for effectiveness and economy, the community has developed an integrated waste management system. In this context *integrated solid waste management* (ISWM) can be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals. Because numerous state and federal laws have been adopted, ISWM is also evolving in response to the regulations developed to implement the various laws [9]. The waste diversion goals adopted in California (25 percent by 1995 and 50 percent by the year 2000) are an example. A hierarchy of waste management activities has also been established by recent regulations.

Hierarchy of Integrated Solid Waste Management

A hierarchy (arrangement in order of rank) in waste management can be used to rank actions to implement programs within the community. The ISWM hierarchy adopted by the U.S. Environmental Protection Agency (EPA) is composed of the following elements: source reduction, recycling, waste combustion, and landfilling [9]. The ISWM hierarchy used in this book is source reduction, recycling, waste transformation, and landfilling. The term *waste transformation* is substituted for the U.S. EPA's term *combustion*, which is too limiting. In the broadest interpretation of the ISWM hierarchy, ISWM programs and systems should be developed in which the elements of the hierarchy are interrelated and are selected to complement each other. For example, the separate collection of yard wastes can be used to affect positively the operation of a waste-to-energy combustion facility.

It is important to note that the U.S. EPA does not make a distinction between waste transformation (combustion) and landfilling; both are viewed as viable components of an integrated waste management program. Nevertheless, some states and organizations have adopted a more restrictive interpretation of the ISWM hierarchy. In the more restrictive interpretation, recycling can only be considered after all that can be done to reduce the quantity of waste at the source has been done. Similarly, waste transformation is considered only after the maximum amount of recycling has been achieved. A distinction is made between transformation and disposal in California and other states. Interpretation of the ISWM hierarchy will, most likely, continue to vary by state.

Source Reduction. The highest rank of the ISWM hierarchy, source reduction, involves reducing the amount and/or toxicity of the wastes that are now generated. Source reduction is first in the hierarchy because it is the most effective way to reduce the quantity of waste, the cost associated with its handling, and its environmental impacts. Waste reduction may occur through the design, manufacture, and packaging of products with minimum toxic content, minimum volume of material, or a longer useful life. Waste reduction may also occur at the household, commercial, or industrial facility through selective buying patterns and the reuse of products and materials [9].

Recycling. The second highest rank in the hierarchy is *recycling*, which involves (1) the separation and collection of waste materials; (2) the preparation of these materials for reuse, reprocessing, and remanufacture; and (3) the reuse, reprocessing, and remanufacture of these materials. Recycling is an important factor in helping to reduce the demand on resources and the amount of waste requiring disposal by landfilling.

Waste Transformation. The third rank in the ISWM hierarchy, *waste transformation*, involves the physical, chemical, or biological alteration of wastes. Typically, the physical, chemical, and biological transformations that can be applied to MSW are used (1) to improve the efficiency of solid waste management operations and systems, (2) to recover reusable and recyclable materials, and (3) to recover conversion products (e.g., compost) and energy in the form of heat and combustible biogas. The transformation of waste materials usually results in the reduced use of landfill capacity. The reduction in waste volume through combustion is a well-known example.

Landfilling. Ultimately, something must be done with (1) the solid wastes that cannot be recycled and are of no further use; (2) the residual matter remaining after solid wastes have been separated at a materials recovery facility; and (3) the residual matter remaining after the recovery of conversion products or energy. There are only two alternatives available for the long-term handling of solid wastes and residual matter: disposal on or in the earth's mantle, and disposal at the bottom of the ocean. Landfilling, the fourth rank of the ISWM hierarchy, involves the controlled disposal of wastes on or in the earth's mantle, and it is by far the most common method of ultimate disposal for waste residuals. Landfilling is the lowest rank in the ISWM hierarchy because it represents the least desirable means of dealing with society's wastes.

Planning for Integrated Waste Management

Developing and implementing an ISWM plan is essentially a local activity that involves the selection of the proper mix of alternatives and technologies to meet changing local waste management needs while meeting legislative mandates [5, 8, 9]. The proper mix of technologies, flexibility in meeting future changes, and the need for monitoring and evaluation are considered briefly in the following discussion and are considered in more detail throughout this text.

Proper Mix of Alternatives and Technologies. A wide variety of alternative programs and technologies are now available for the management of solid wastes. Several questions arise from this variety: What is the proper mix between (1) the amount of waste separated for reuse and recycling, (2) the amount of waste that is composted, (3) the amount of waste that is combusted, and (4) the amount of waste to be disposed of in landfills? What technology should be used for collecting wastes separated at the source, for separating waste components at MRFs, for composting the organic fraction of MSW, and for compacting wastes at a landfill? What is the proper timing for the application of various technologies in an ISWM system and how should decisions be made?

Because of the wide range of participants in the decision-making process for the implementation of solid waste management systems, the selection of the proper mix of alternatives and technologies for the effective management of wastes has become a difficult, if not impossible, task. The development of effective ISWM systems will depend on the availability of reliable data on the characteristics of the waste stream, performance specifications for alternative technologies, and adequate cost information.

Flexibility in Meeting Future Changes. The ability to adapt waste management practices to changing conditions is of critical importance in the development of an ISWM system. Some important factors to consider include (1) changes in the quantities and composition of the waste stream, (2) changes in the specifications and markets for recyclable materials, and (3) rapid developments in technology. If the ISWM system is planned and designed on the basis of a detailed analysis of the range of possible outcomes related to these factors, the local community will be protected from unexpended changes in local, regional, and larger-scale conditions [9].

Monitoring and Evaluation. Integrated solid waste management is an ongoing activity that requires continual monitoring and evaluation to determine if program objectives and goals (e.g., waste diversion goals) are being met (see also Section 2-5). Only by developing and implementing ongoing monitoring and evaluation programs can timely changes be made to the ISWM system that reflect changes in waste characteristics, changing specifications and markets for recovered materials, and new and improved waste management technologies.

1-5 OPERATION OF SOLID WASTE MANAGEMENT SYSTEMS

The facilities that compose a solid waste management system are often identified as *solid waste management system units*. The planning and engineering of solid waste management units include social, political, and technical factors. The combination of all of these factors forms a series of issues that must be addressed by community decision makers. Some contemporary solid waste management issues and future challenges and opportunities are introduced in the following discussion; these subjects will also be addressed in greater detail later in the text.

Management Issues

In addition to meeting the requirements associated with ISWM, a number of other management issues must be addressed in the operation of ISWM systems. The solid waste practitioner must acknowledge these management issues or face a high risk of failure in the implementation of solid waste management programs.

Setting Workable but Protective Regulatory Standards. Solid waste management units are subject to an increasing number of regulations. The attention is justified and timely, but strict adherence to very protective regulatory standards often causes failure of the processes by which waste management units are put in place.

Municipal solid waste management is caught in the backlash of understandable public concern over hazardous waste management. Regulatory agencies, in setting standards for construction, operation, and monitoring of units, are beset by lawyers and environmental groups recently armed with scientific data derived from experiments with massive doses of toxic compounds. Municipal waste does not contain massive quantities of toxics, but it does contain the small amounts found in the wastes from normal household activities. An unworkable regulation is one that ignores reality and deals only with certain technical data.

Nobody wants wastes. Solid waste cannot be wished away or hidden by the paper of regulations. In 1987 the attention of the U.S. public, news media, regulatory agencies, and Congress was focused on a garbage barge from New York. The episode started when a regulation forced wastes from a landfill when there was no other place to put 3000 tons of waste. The waste was loaded on a barge for shipment by sea to a place where it would be accepted. The barge was rejected by numerous states and foreign countries. After three months afloat the barge was unloaded where it started from—in New York.

Improving Scientific Methods for Interpretation of Data. The need to know about hazards in the environment has generated large amounts of data on toxics.

Billions of dollars have been invested in analytical equipment, laboratories, and data accumulation since the passage of the *Comprehensive Environmental Response Compensation and Liability Act* (CERCLA) (see Chapter 2). Even with all the data, however, there is a lack of a uniform basis for data interpretation. Analytical equipment and laboratory techniques produce data of accuracy in parts per billion or parts per trillion. What does such a detection accuracy mean to a solid waste management unit? If the component detected at a solid waste management system unit is on a regulatory list of cancer-causing agents, the unit may be shut down.

The goal is to understand the effects of very small quantities of toxic components on the environment. In the meantime, how much data should be presented to the public? When should data be delivered to the public? How does the public participate in data gathering and interpretation?

Identification of Hazardous and Toxic Consumer Products Requiring Special Waste Management Units. Municipal solid waste is a heterogeneous mass made up of every discard from homes, businesses, and institutions. Although small in quantity, some discards are hazardous, as identified on the product container. Examples are bleach, cleaning fluids, insecticides, and gasoline.

The issue is whether household hazardous waste contaminates the municipal waste management unit and whether, because of the large land areas in landfills, certain household wastes should be removed from the garbage can for disposal in smaller, highly controlled waste management units. Which products are most hazardous? How will the consumer store hazardous discards until they are picked up or delivered to the special management unit? Who will set up and operate special waste management units as such units will be defined by regulators as hazardous waste units?

Paying for Improved Waste Management Units. Solid waste management has a tradition of low cost. The improvements demanded by a concerned public are more costly than past practices (see Fig. 1-6). The increased costs must be paid by waste generators. This issue involves changing the manner in which a consumer thinks about paying for waste disposal. How is the cost of waste disposal presented to the consumer? When is the consumer asked to pay—at the time of product purchase or when the product is discarded? Since solid waste decays very slowly, who pays for long-term maintenance of land disposal waste management units—the generator at the time of discard or future users as maintenance costs are incurred?

Designating Land Disposal Units at or near Large Urban Centers. Waste management units are difficult to place in an urban environment. A suspicious public views these units as open dumps and littered transfer stations served by odorous, dripping garbage collection trucks. Yet it is within urban centers that the greatest quantity of solid waste is generated. Urban land use planning is facing a severe challenge to provide designated waste management units, especially land disposal units.

FIGURE 1-6
Landfill liner system under construction. A geomembrane liner has been placed over a compacted clay layer in the upper portion of the landfill, while the rest of the site is being prepared (background). Note: modern landfills are equipped with geomembrane liner systems for the protection of groundwater and to control the migration of landfill gases.

The issues are identifying environmentally acceptable land areas for land disposal units and then preserving lands for the intended use. Who will set a standard for "environmentally acceptable"? Will different standards apply for urban and rural areas? Can a scientific basis be identified that will satisfy a suspicious public regarding the safety of land disposal units?

Establishing and Maintaining More Qualified Managers to Develop and Operate Waste Management Units. Solid waste management units are increasing in quantity and complexity. In response, a set of managers must be trained and put in the appropriate positions to develop and operate expanded and improved management units.

The goal is to develop the human resources needed to develop and operate waste management units. Who will train the managers? How will the cost of training be paid? What standards will apply during the interim period while managers receive training?

Future Challenges and Opportunities

The multibillion-dollar industry of solid waste management can be supported only by the public, which is responsible for the generation of the vast tonnage of wastes (see Table 1-1). Public attitudes must be modified to reduce the environmental and economic burden placed on society for the disposal of solid waste. National concern must transcend the question of cost in an attempt to implement whatever individual or societal action is necessary.

Unfortunately, the standard of living in the United States is inevitably tied to the generation of solid wastes—the squandering of natural resources from this country and abroad, the one-time use of materials of so many types, and the philosophy of wastefulness and rapid obsolescence of products. It is reasonable to assume that a departure from this philosophy of wastefulness will reduce the tonnage of wastes to be managed. This concept inevitably leads to the need for source reduction and the reuse and recycling of recovered materials.

Changing Consumption Habits in Society. Product consumption is a natural activity. Society changes a standard of living by changing the quantity and quality of products it consumes. Solid wastes, the discards of product consumption, vary in quantity and quality as changes occur in the standard of living. Consumption habits must be changed if the quantity of solid wastes from consuming activities is to be reduced. The challenge is to change consumption habits that have been established over many years, as a result of advertising pressure that glamorizes increased consumption.

Reducing the Volume of Waste at the Source. Efforts must be made to reduce the quantity of materials used in both packaging and obsolescent goods and to begin the process of recycling at the source—the home, office, or factory—so that fewer materials will become part of the disposable solid wastes of a community. Source reduction is an alternative that will conserve resources and also has economic viability.

Making Landfills Safer. Landfills will always be the final disposal place for wastes that cannot be recovered. For this reason, every effort must be made to reduce the toxicity of the wastes that will ultimately be placed in landfills. The design of landfills must also improve to provide the safest possible location for the long-term storage of waste materials. The data base for existing landfills is expanding as improved construction and operations are implemented at new facilities. With an expanded data base comes the opportunity to understand how landfills function and how to manage the wastes placed in landfills more effectively.

Development of New Technologies. There are numerous opportunities to introduce new technologies into the solid waste management system. The challenge is to encourage the development of technologies that are most conservative of natural resources and that are cost-effective. Because many unproven technologies have been sold to unsuspecting cities, it may be necessary to write laws to regulate the use of technology. The testing and implementing of new technologies will be an important part of ISWM in the future.

1-6 DISCUSSION TOPICS AND PROBLEMS

1-1. Waste composition is the basis of all subsequent waste management programs. Do you feel that the changes in the composition of solid wastes will be significant in the next 10, 25, or 50 years? Explain.

1-2. Describe your present concept of resource recovery. In what ways can it affect the costs of solid waste disposal?

1-3. What is being done in your community for the recycling of bottles, cans, and paper? In your opinion, is the program successful? How can the program be improved?

1-4. From historical records, develop a brief chronology of the disposal methods used in your community during the past 50 years. Identify, where possible, the major events that led to the abandonment of one given method in favor of another.

1-5. In your opinion, what effect do the ownership and operation of landfill disposal sites by private contractors (as compared to public agencies) have on the economics, efficiency, and environmental aspects of operation?

1-6. Has your state set a hierarchy of integrated waste management? If so, identify the components of the hierarchy and explain why the hierarchy is important to a solid waste system manager.

1-7. Call the solid waste system manager in your community and determine the amount of education and formal training of the person. Do you think it is adequate for the management of an integrated waste management system?

1-8. List the functional elements of waste management. In your own terms, how does integrated waste management incorporate the functional elements?

1-9. Why have solid waste management practices been so slow in developing? Will changes come more quickly in the future? Explain.

1-10. Identify and discuss briefly the issues that you feel will be important in the field of solid waste management in the late 1990s.

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