7 Source and Effect

7.1 DEFINITION

For practical purposes, the term *waste* includes any material that enters the waste management system. In this chapter, the term *waste management system* includes organized programs and central facilities established not only for final disposal of waste but also for recycling, reuse, composting, and incineration. Materials enter a waste management system when no one who has the opportunity to retain them wishes to do so.

Generally, the term *solid waste* refers to all waste materials except hazardous waste, liquid waste, and atmospheric emissions. *CII waste* refers to wastes generated by commercial, industrial, and institutional sources. Although most solid waste regulations include hazardous waste within their definition of solid waste, *solid waste* has come to mean *nonhazardous solid waste* and generally excludes hazardous waste.

This section describes the types of waste that are detailed in this chapter.

Waste Types Included

This chapter focuses on two major types of solid waste: municipal solid waste (MSW) and bulky waste. MSW comprises small and moderately sized solid waste items from homes, businesses, and institutions. For the most part, this waste is picked up by general collection trucks, typically compactor trucks, on regular routes.

Bulky waste consists of larger items of solid waste, such as mattresses and appliances, as well as smaller items generated in large quantity in a short time, such as roofing shingles. In general, regular trash collection crews do not pick up bulky waste because of its size or weight.

Bulky waste is frequently referred to as C&D (construction and demolition) waste. The majority of bulky waste generated in a given area is likely to be C&D waste. In areas where regular trash collection crews take anything put out, the majority of bulky waste arriving separately at disposal facilities is C&D waste. In areas where the regular collection crews are less accommodating, however, substantial quantities of other types of bulky waste, such as furniture and appliances, arrive at disposal facilities in separate loads.

Waste Types Not Included

In a broad sense, the majority of nonhazardous solid waste consists of industrial processing wastes such as mine and mill tailings, agricultural and food processing waste, coal ash, cement kiln dust, and sludges. The waste management technologies described in this chapter can be used to manage these wastes; however, this chapter focuses on the management of MSW and the more common types of bulky waste in most local solid waste streams.

—*F. Mack Rugg*

7.2 SOURCES, QUANTITIES, AND EFFECTS

This section identifies the sources of solid waste, provides general information on the quantities of solid waste generated and disposed of in the United States, and identifies the potential effects of solid waste on daily life and the environment.

Sources

The primary source of solid waste is the production of commodities and byproducts from solid materials. Everything that is produced is eventually discarded. A secondary source of solid waste is the natural cycle of plant growth and decay, which is responsible for the portion of the waste stream referred to as yard waste or vegetative waste.

The amount a product contributes to the waste stream is proportional to two principal factors: the number of items produced and the size of each item. The number of items produced, in turn, is proportional to the useful life of the product and the number of items in use at any one time. Newspapers are the largest contributor to MSW because they are larger than most other items in MSW, they are used in large numbers, and they have a useful life of only one day. In contrast, pocket knives make up a negligible portion of MSW because relatively few people use them, they are small, and they are typically used for years before being discarded.

MSW is characterized by products that are relatively small, are produced in large numbers, and have short useful lives. Bulky waste is dominated by products that are large but are produced in relatively small numbers and have relatively long useful lives. Therefore, a given mass of MSW represents more discreet acts of discard than the same mass of bulky waste. For this reason, more data are required to characterize bulky waste to within a given level of statistical confidence than are required to characterize MSW.

Most MSW is generated by the routine activities of everyday life rather than by special or unusual activities or events. On the other hand, activities that deviate from routine, such as trying different food or a new recreational activity, generate waste at a higher rate than routine activities. Routinely purchased items tend to be used fully, while unusual items tend to be discarded without use or after only partial use.

In contrast to MSW, most bulky waste is generated by relatively infrequent events, such as the discard of a sofa or refrigerator, the replacement of a roof, the demolition of a building, or the resurfacing of a road. Therefore, the composition of bulky waste is more variable than the composition of MSW.

In terms of generation sites, the principal sources of MSW are homes, businesses, and institutions. Bulky waste is also generated at functioning homes, businesses, and institutions; but the majority of bulky waste is generated at construction and demolition sites. At each type of generation site, MSW and bulky waste are generated under four basic circumstances:

Packaging is removed or emptied and then discarded. This waste typically accounts for approximately 35 to 40% of MSW prior to recycling. Packaging is generally less abundant in bulky waste.

The unused portion of a product is discarded. In MSW, this waste accounts for all food waste, a substantial portion of wood waste, and smaller portions of other waste categories. In bulky waste, this waste accounts for the majority of construction waste (scraps of lumber, gypsum board, roofing materials, masonry, and other construction materials).

A product is discarded, or a structure demolished, after use. This waste typically accounts for 30 to 35% of MSW and the majority of bulky waste.

Unwanted plant material is discarded. This waste is the most variable source of MSW and is also a highly variable source of bulky waste. Yard wastes such as leaves, grass clippings, and shrub and garden trimmings commonly account for as little as 5% or as much as 20% of the MSW generated in a county-sized area on an annual basis. Plant material can be a large component of bulky waste where trees or woody shrubs are abundant, particularly when lots are cleared for new construction.

Packaging tends to be concentrated in MSW because many packages destined for discard as MSW contain products of which the majority is discarded in wastewater or enters the atmosphere as gas instead of being discarded as MSW. Such products include food and beverages, cleaning products, hair- and skin-care products, and paints and other finishes.

Quantities

The most important parameter in solid waste management is the quantity to be managed. The quantity determines the size and number of the facilities and equipment required to manage the waste. Also important, the fee collected for each unit quantity of waste delivered to the facility (the tipping fee) is based on the projected cost of operating a facility divided by the quantity of waste the facility receives.

The quantity of solid waste can be expressed in units of volume (typically cubic yards or cubic meters) or in units of weight (typically short, long, or metric tons). In this chapter, the word ton refers to a short ton (2000 lb). Although information about both volume and weight are important, using weight as the master parameter is generally preferable in record keeping and calculations.

The advantage of measuring quantity in terms of weight rather than volume is that weight is fairly constant for a given set of discarded objects, whereas volume is highly variable. Waste set out on the curb on a given day in a given neighborhood occupies different volumes on the curb, in the collection truck, on the tipping floor of a transfer station or composting facility, in the storage pit of a combustion facility, or in a landfill. In addition, the same waste can occupy different volumes in different trucks or landfills. Similarly, two identical demolished houses occupy different volumes if one is repeatedly run over with a bulldozer and the other is not. As these examples illustrate, the phrases "a cubic yard of MSW" and "a cubic yard of bulky waste" have little meaning by themselves; the phrases "a ton of MSW" and "a ton of bulky waste" are more meaningful.

Franklin Associates, Ltd., regularly estimates the quantity of MSW generated and disposed of in the United States under contract to the U.S. Environmental Protection Agency (EPA). Franklin Associates derives its estimates from industrial production data using the *material flows methodology,* based on the general assumption that what is produced is eventually discarded (see "Estimation of Waste Quantity" in Section 8.2). Franklin Associates estimates that 195.7 million tons of MSW were generated in the United States in 1990. Of this total, an estimated 33.4 million tons (17.1%) were recovered through recycling and composting, leaving 162.3 million tons for disposal (Franklin Associates, Ltd. 1992).

The quantity of solid waste is often expressed in pounds per capita per day (pcd) so that waste streams in different areas can be compared. This quantity is typically calculated with the following equation:

$$\text{pcd} = 2000T/365P \qquad 7.2(1)$$

where:

pcd = pounds per capita per day
T = number of tons of waste generated in a year
P = population of the area in which the waste is generated

Unless otherwise specified, the tonnage T includes both residential and commercial waste. With modification the equation can also calculate pounds per employee per day, residential waste per person per day, and so on.

Franklin Associates's (1992) estimate of MSW generated in the United States in 1990, previously noted, equates to 4.29 lb per person per day. This estimate is probably low for the following reasons:

Waste material is not included if Franklin Associates cannot document the original production of the material.

Franklin's material flows methodology generally does not account for moisture absorbed by materials after they are manufactured (see "Combustion Characteristics" in Section 8.1).

Table 7.2.1 shows waste quantities reported for various counties and cities in the United States. All quantities are given in pcd. Reports from the locations listed in the table indicate an average generation rate for MSW of 5.4 pcd, approximately 25% higher than the Franklin Associates estimate. Roughly 60% of this waste is generated in residences (residential waste) while the remaining 40% is generated in commercial, industrial, and institutional establishments (CII waste). The percentage of CII waste is usually lower in suburban areas without a major urban center and higher in urban regional centers.

Table 7.2.1 also shows generation rates for solid waste other than MSW. The quantity of other waste, most of which is bulky waste, is roughly half the quantity of MSW. The proportion of bulky and other waste varies, however, and is heavily influenced by the degree to which recycled bulky materials are counted as waste. The quantities of bulky waste shown for Atlantic and Cape May counties, New Jersey, include large amounts of recycled concrete, asphalt, and scrap metal. See also "Component Composition of Bulky Waste" in Section 8.1.

Franklin Associates (1992) projects that the total quantity of MSW generated in the United States will increase by 13.5% between 1990 and 2000 while the population will increase by only 7.3%. On a per capita basis, therefore, MSW generation is projected to grow 0.56% per year. No comparable projections have been developed for bulky waste. Table 7.2.2 shows the potential effect of this growth rate on MSW generation rates and quantities.

Effects

MSW has the following potential negative effects:

- Promotion of microorganisms that cause diseases
- Attraction and support of disease vectors (rodents and insects that carry and transmit disease-causing microorganisms)
- Generation of noxious odors
- Degradation of the esthetic quality of the environment
- Occupation of space that could be used for other purposes
- General pollution of the environment

Location	Year	Residential Fraction of MSW (%)	Commercial/ Industrial Fraction of MSW (%)	Total MSW (pcd)	Bulky Waste (pcd)	Other Solid Waste (pcd)[a]	Total Solid Waste (pcd)
Atlantic County, NJ	1991	—	—	6.0	5.9	0.3	12.2
Bexar County, TX	1990	—	—	—	—	—	6.5
Cape May County, NJ	1990	—	—	6.6	6.0	0.6	13.2
Delaware (state)	1990	—	—	—	—	—	7.1
Fairfax County, VA	1991	55	45	4.8	1.3	0.0	6.1
Marion County, FL	1989	—	—	5.4	—	—	—
Middlesex County, NJ	1988	—	—	4.4	2.1	1.6	8.2
Minnesota Metro Area	1991	—	—	6.5	2.6	0.0	9.1
Monmouth County, NJ	1987	75	25	4.8	2.7	0.0	7.5
Monroe County, NY	1990	—	—	5.7	—	—	—
Rhode Island (state)	1985	52	48	4.9	—	—	—
San Diego, CA	1985	—	—	—	—	—	8.0
Sarasota County, FL	1989	—	—	—	—	—	9.2
Seattle, WA	1987	37	63	7.6	—	—	—
Somerset County, NJ	1989	—	—	4.2	1.5	0.6	6.3
Warren County, NJ	1989	—	—	3.2	0.4	0.9	4.5
Wichita, KA	1990	61	39	6.6	1.1	0.0	7.7
	Average[b]	56	44	5.4	2.6	0.5	8.1
	Minimum	37	25	3.2	0.4	0.0	4.5
	Maximum	75	63	7.6	6.0	1.6	13.2
USA (Franklin Associates)	1990	62	38	4.3	—	—	—

Sources: Data from references listed at the end of this section.

Note: pcd = pounds per capita per day

[a]Most waste in this category falls within the definition of either MSW or bulky waste. Specific characteristics vary from place to place.

[b]Because different information is available from different locations, the overall average is not the sum of the averages for the individual waste types.

Bulky waste also has the potential to degrade esthetic values, occupy valuable space, and pollute the environment. In addition, bulky waste may pose a fire hazard.

MSW is a potential source of the following useful materials:

- Raw materials to produce manufactured goods
- Feed stock for composting and mulching processes
- Fuel

Bulky waste has the same potential uses except for composting feed stock.

The fundamental challenge of solid waste management is to minimize the potential negative effects while maximizing the recovery of useful materials from the waste at a reasonable cost.

Conformance with simple, standard procedures for the storage and handling of MSW largely prevents the promotion of disease-causing microorganisms and the attrac-

TABLE 7.2.2 PROJECTED GENERATION OF MSW IN THE UNITED STATES IN THE YEAR 2000

Year	Population (in millions)	MSW Quantity Projected by Franklin Associates (millions of tons)	Per Capita Generation Based on Franklin Associates (lb/day)	Average Annual Growth of Per Capita Generation Represented (%)	Per Capita Generation Based on Average in Table 7.2.1 (lb/day)	MSW Quantity Based on Average in Table 7.2.1 (millions of tons)
1990	249.9	195.7	4.3	—	5.4	247.6
2000	268.3	222.1	4.5	0.56	5.7	281.0

Source: Data from Franklin Associates, Ltd., 1992, *Characterization of municipal solid waste in the United States: 1992 Update* (EPA/530-R-92-019, NTIS PB92-207-166, U.S. EPA).

Note: Derived from Table 7.2.1.

tion and support of disease vectors. Preventing the remaining potential negative effects of solid waste remains a substantial challenge.

Solid waste can degrade the esthetic quality of the environment in two fundamental ways. First, waste materials that are not properly isolated from the environment (e.g., street litter and debris on a vacant lot) are generally unsightly. Second, solid waste management facilities are often considered unattractive, especially when they stand out from surrounding physical features. This characteristic is particularly true of landfills on flat terrain and combustion facilities in nonindustrial areas.

Solid waste landfills occupy substantial quantities of space. Waste reduction, recycling, composting, and combustion all reduce the volume of landfill space required (see Sections 9.1 to 10.6).

Land on which solid waste has been deposited is difficult to use for other purposes. Landfills that receive unprocessed MSW typically remain spongy and continue to settle for decades. Such landfills generate methane, a combustible gas, and other gases for twenty years or more after they cease receiving waste. Whether the waste in a landfill is processed or unprocessed, the landfill generally cannot be reforested. Tree roots damage the impermeable cap applied to a closed landfill to reduce the production of leachate.

Solid waste generates odors as microorganisms metabolize organic matter in the waste, causing the organic matter to decompose. The most acute odor problems generally occur when waste decomposes rapidly, consuming available oxygen and inducing anaerobic (oxygen deficient) conditions. Bulky waste generally does not cause odor problems because it typically contains little material that decomposes rapidly. MSW, on the other hand, typically causes objectionable odors even when covered with dirt in a landfill (see Section 10.5).

Combustion facilities prevent odor problems by incinerating the odorous compounds and the microorganisms and organic matter from which the odorous compounds are derived (see Section 10.1). Composting preserves organic matter while reducing its potential to generate odors. However, the composting process requires careful engineering to minimize odor generation during composting (see Section 10.6).

In addition to odors, solid waste can cause other forms of pollution. Landfill leachate contains toxic substances that must be prevented from contaminating groundwater and surface water (see Section 10.5). Toxic and corrosive products of solid waste combustion must be prevented from entering the atmosphere (see Section 10.1). The use of solid waste compost must be regulated so that the soil is not contaminated (see Section 10.6).

While avoiding the potential negative effects of solid waste, a solid waste management program should also seek to derive benefits from the waste. Methods for deriving benefits from solid waste include recycling (Section 9.2), composting (Section 10.6), direct combustion with energy recovery (Section 10.1), processing waste to produce fuel (Sections 9.3 and 10.4), and recovery of landfill gas for use as a fuel (Section 10.5).

— *F. Mack Rugg*

References

Cal Recovery Systems, Inc. 1990. *Waste characterization for San Antonio, Texas.* Richmond, Calif. (June).

Camp Dresser & McKee Inc. 1990a. *Marion County (FL) solid waste composition and recycling program evaluation.* Tampa, Fla. (April).

———. 1990b. *Sarasota County waste stream composition study.* Draft report (March).

———. 1991a. *Cape May County multi-seasonal solid waste composition study.* Edison, N.J. (August).

———. 1991b. *City of Wichita waste stream analysis.* Wichita, Kans. (August).

———. 1992. *Atlantic County (NJ) solid waste characterization program.* Edison, N.J. (May).

Cosulich, William F., Associates, P.C. 1988. *Solid waste management plan, County of Monroe, New York: Solid waste quantification and characterization.* Woodbury, N.Y. (July).

Delaware Solid Waste Authority. 1992. *Solid waste management plan.* (17 December).

Franklin Associates, Ltd. 1992. *Characterization of municipal solid waste in the United States: 1992 update.* U.S. EPA, EPA/530-R-92-019, NTIS no. PB92-207 166 (July).

HDR Engineering, Inc. 1989. *Report on solid waste quantities, composition and characteristics for Monmouth County (NJ) waste recovery system.* White Plains, N.Y. (March).

Killam Associates. 1989; 1991 update. *Middlesex County (NJ) solid waste weighing, source, and composition study.* Millburn, N.J. (February).

———. 1990. *Somerset County (NJ) solid waste generation and composition study.* Millburn, N.J. (May). Includes data for Warren County, N.J.

Minnesota Pollution Control Agency and Metropolitan Council. 1993. *Minnesota solid waste composition study, 1991–1992 part II.* Saint Paul, Minn. (April).

Rhode Island Solid Waste Management Corporation. 1987. *Statewide resource recovery system development plan.* Providence, R.I. (June).

San Diego, City of, Waste Management Department. 1988. *Request for proposal: Comprehensive solid waste management system.* (4 November).

SCS Engineers. 1991. *Waste characterization study—solid waste management plan, Fairfax County, Virginia.* Reston, Va. (October).

Seattle Engineering Department, Solid Waste Utility. 1988. *Waste reduction, recycling and disposal alternatives: Volume II—Recycling potential assessment and waste stream forecast.* Seattle (May).