Chapter 3

Generation and Composition of MSW

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Generation and Composition of MSW

INTRODUCTION

The rate at which the Nation creates municipal solid waste (MSW; see box 3-A) is increasing because our total population is growing, as is the average amount that each person throws away. It is important to have adequate information about MSW generation if we are to make wise decisions about future waste management. In addition, knowing what products and materials comprise MSW and evaluating trends in their use can guide efforts to reduce MSW generation and toxicity.

To help understand MSW generation and composition, the Environmental Protection Agency (EPA) commissioned Franklin Associates to develop and periodically update a model providing a general picture of the quantities and composition of MSW generated each year, and how different products (including but not limited to packaging) contribute to the waste stream. Although the EPA/Franklin model is not without limitations, it is the only available major source of national-scale MSW information.

The national scale of the model presents some problems, however. Community officials who must make decisions about how to manage MSW need data on local conditions and generation. Indeed, recognizing that the generation and composition of MSW varies greatly among communities, EPA and Franklin Associates repeatedly caution against using the model's national estimates for State and local planning.

This chapter discusses the EPA/Franklin model's estimates of national MSW generation rates. It then examines estimates of the average amount of MSW generated in different communities as a way to illustrate variability among communities. The local per-capita rates are compared with some State and National estimates to indicate the problems that can arise in estimating these rates at any level. Information on the relative weights and volumes of different materials and products in MSW also is reviewed. Finally, information on the types of chemical substances in MSW is reviewed briefly.

MSW GENERATION ESTIMATES

National Estimates From the EPA/Franklin Model

The best national estimates of MSW generation are derived from the EPA/Franklin model. This model was first developed in the early 1970s and it is periodically updated (1 O). Box 3-B includes a brief description of the model and some of its limitations.

According to the model, 158 million tons of MSW were generated in 1986; by the year 2000, MSW generation will reach 193 million tons, an increase of 22 percent in 14 years (10). For comparison, at least 250 million tons of hazardous waste are generated annually, and the amount of nonhazardous industrial solid wastes is even greater. The model may underestimate total MSW generation somewhat, however, because some local data suggests that per-capita generation rates may be greater than those estimated by the model (see ' 'Per-Capita Generation Rates" below).

The model% conclusion that MSW generation **has grown and will continue to grow is significant. There are two primary reasons for this growth—increases in total population and increases in the average amount of MSW generated**

[1]These numbers refer to the weight of "Woss' discards, that is, the total amount generated. The model's estimates of past and future generation have been revised periodically. For example, in 1979 the model estimated that MSW discards for 1977 were 136 million tons, while in 1986 the model estimated that discards for 1977 were 122 mill ion tons (8). Adjustments are to be expected with any model as its resumptions and data inputs arc refined over time. In this model, for example. adjustments have been made for food and yard wastes, based on additional field sampling data, and to correct for moisture loss in sampling these wastes (12). More recent estimates, however, are generally presented with fewer qualifiers (such as a range of estimates).

per person (the per-capita rate). Population growth appears to be the more important factor. From 1970 to 1986, the U.S. population increased by 18 percent while MSW as estimated by the model increased by about 25 percent. This suggests that about 70 percent of the growth in total generation is attributable to population growth and about 30 percent is the result of increased per-capita generation.

Per-Capita Generation Rates

Any community planning to develop MSW management capacity (whether for recycling, landtilling, or incineration) must know what types and quantities of MSW it is producing, both currently and in the future. Projections to determine management capacity needs often are calculated on the basis of the average amount of MSW generated by each person (i.e.. per-capita rates). However, as the following discussion shows, standardized sampling methods need to be developed so that communities can make reasonable estimates.

Estimates of Per-Capita Rates

OTA obtained sample information on MSW generation rates from 28 cities and 9 counties (table 3-1).[2] This table should *not* be used to rank cities and counties in terms of MSW generation because of problems with the comparability and consistency of the data. For example, communities gather data on different portions of MSW. Some communities probably included items such as construction and demolition debris, even though asked not to do so; others were not sure what portions of MSW were included in their data.

Furthermore, the estimates presented in any given study can differ from other investigators' estimates for the same area. Some variability in per-capita MSW estimates is to be expected. Some of the variability stems from actual local and/or seasonal differences in waste streams, or from demographic and socioeconomic factors. However, variation also can be attributed to different definitions and sampling methods (23, 29). One study in Brevard County, Florida, attempted to evaluate definition differences (21). According to county records, the total per-capita generation rate for all waste materi-

Box 3-A—Defining MSW

MSW is defined here as post-consumer solid wastes generated at residences (e.g., single-family units and apartment buildings), commercial establishments (e.g., offices, retail shops, restaurants), and institutions (e.g., hospitals, schools, government offices). These wastes may be categorized as either materials or products:

- *Materials*
  —paper, yard waste, food waste, glass, ferrous and non-ferrous metals, plastics, textiles, rubber, wood, management residues (e. g., incinerator ash, some recycling residues).
- *Products*
  -durable goods (e.g., appliances, furniture, tires);
  —nondurable goods (e.g., magazines, tissue paper, clothing, motor oil, small plastic products, batteries, household cleansers);
  -containers (e.g., cans, bottles, boxes) and packaging/wrapping (e.g., made of paper, paperboard, plastic, glass, metals, ceramics, wood).

Defining MSW is not always straightforward, as different people will often include different materials and products. These "gray areas" can add confusion to MSW debates. As defined here, for example, MSW does not include automobile bodies, demolition and construction debris, municipal wastewater or drinking water sludges, and ash from industrial boilers, Some municipalities are responsible for managing these items, and some of the materials are discarded into MSW landfills. As a result, some observers may consider the first two items in particular (i.e., auto bodies and construction debris) to be components of MSW. These differences must be recognized when data from different reports are compared, especially with respect to waste generation and recycling rates.

In addition, industries generate nonhazardous process waste and ''small quantity generators' produce hazardous wastes that often are discarded in landfills along with MSW (ch. 7). Although OTA does not consider these wastes to be MSW per se, their management in this manner can pose potential risks for human health and the environment (e.g., groundwater and surface water contamination) and cause problems for MSW managers.

[2] This -Pie is not random. Cities and counties were selected to represent large and small Communities from all regions of the country (see chapter 2 for more details).

Box 3-B: *The EPA/Franklin Model*

The EPA/Franklin model uses a "materials flow" methodology to estimate MSW generation-it traces the flow of materials from production, through consumption, and on to disposal. The model begins with information about the historical production and consumption of materials and products (e.g., using data from the Department of Commerce and trade associations). These data are converted to waste generation estimates using assumptions about losses of materials in manufacturing, lifetimes of materials and products, recycling rates, and effects of imports and exports. Values are adjusted for products destroyed in use (e.g., cigarette paper) or diverted from the waste stream for long periods (e.g., library books). For materials like food and yard waste, values are based on sampling data from a range of sources.

Because the model relies on this "materials flow" approach, it generally does not use data measured at the points of generation (i.e., households, offices, stores) or management (i.e., landfills, incinerators, recycling facilities). Thus, the model does not predict how much the residential, commercial, and institutional sectors contribute to MSW, nor whether the generated waste actually ends up in recycling facilities, incinerators, or landfills.

What Does the Model Include and Exclude?

Some components of MSW are not included in the model, such as liquids, some packaging, and some nondurable items. According to the model's developers, these components might add 5 percent to the total estimates (12).

Liquids-One missing category identified by EPA and Franklin is liquids, including things such as inks, motor oil, paints, toiletries, and medicines. For the personal care products, the model only accounts for empty containers, and assumes that all contents are consumed or vaporized or that residuals are deposited into sewer systems. Motor oils are not included because about 60 percent of discarded motor oil is assumed to be recycled, leaving only about 660,000 tons ending up in landfills or incinerators (8, 9). For printing inks, about 825,000 tons were produced in 1987, of which perhaps 50 percent end up in MSW (26). * Including both inks and motor oil in the model would increase MSW by about 1 percent. Taken separately, this number is small, but it does indicate that the combination of several unaccounted-for waste categories could raise the estimated MSW rate by several percentage points, In addition, these types of products are often considered to contribute potentially toxic substances to MSW.

Packaging—Most packaging on imported goods is not accounted for, although the model does account for glass containers (e.g., for wine and liquor). One packaging company official estimates that the amount of imported packaging (e.g., glass, corrugated boxes, and other materials) amounts to about 2.5 million tons per year (2).

Miscellaneous Nondurables-This category includes disposable products such as diapers, foam cups, home-use bags and wrap, and trash bags. The amount discarded in 1986 was estimated to be about 2.8 million tons per year (10). Recent data suggest this estimate may be low. For example, diapers alone make up about 1 percent by weight of the material excavated from several landfills, equivalent to about 1.5 million tons per year.

Imported and Exported Products—This category needs additional study (13) because several imported and exported products are not accounted for:

- major appliances-only the estimates for microwave ovens account for imports and exports, because only this type of product had a relatively large portion of imports (i.e., net imports exceeding 5 percent of domestic shipments before 1984) (13); increases in imports of other appliances will not be reflected in MSW estimates for some time, since these products have lifetimes of up to 20 years;
- containers-only imports/exports of empty glass containers and glass bottles containing alcoholic beverages are counted; no adjustments are made for steel containers or aluminum containers and packaging;
- miscellaneous durable and nondurable goods;
- subassembled items-imported items for which final assembly occurs in U.S. plants (e.g., in the electronics industry), and exported parts for assembly abroad with the final product being reimported (e.g., the apparel industry), are not included; and
- goods and packaging carried by international travelers—the net difference between goods and packaging carried in by U.S. residents who travel abroad (12 million in 1986) (38) and goods carried out by visitors from other countries is not included.

[1] Although some ink used on products would end up as MSW, some weight loss & C to evaporation of solvent-based inks is expected. In addition, waste ink used by printers would end up in cleaning solvents (most of which would be disposed of into sewer systems) or cleaning rags (which would be sent to commercial launches).

als delivered to landfills was estimated to be 8.5 pounds per day. However, only 3.9 pounds per day was considered to be MSW as defined by the EPA/Franklin model. In this case, then, potential discrepancies among different estimates are caused primarily by the use of different definitions.

Even given these problems, the data in table 3-1 still are useful to illustrate that per-capita MSW generation varies widely among different cities and communities, in this survey between about 2 and 9 pounds per day. The data also can be compared—taking into account all the previously expressed caveats—with national estimates of per-capita generation. For instance, the average per-capita residential MSW generation in table 3-1 is 2.6 pounds, while the average per-capita generation for all MSW (i.e., residential, commercial, and institutional waste) is 4.5 pounds. In contrast, the EPA/Franklin model estimates that each person in the United States generated 3.6 pounds of MSW per day in 1986 and will generate 3.9 pounds per day in 2000. After accounting for recycling, the EPA/Franklin model estimated that the per-capita rate for the remaining discards was 3.2 pounds per day in 1986 and would be about 3.5 pounds per day in 2000 (10).

Problems in defining and differentiating MSW also appear in data collected at the State level. For example, OTA compiled MSW estimates available from 15 States that include over one-half of the U.S. population and calculated a per-capita rate of over 6 pounds per day. However, the utility of these data is questionable because State records generally do not differentiate between MSW and other commonly landfilled wastes (e.g., demolition and construction waste) (12).

Thus, the definition of MSW is an important issue to consider when evaluating estimates of local MS W generation. If decisionmakers need information on all the types of solid wastes that might need management (e.g., including construction and demolition debris), then the more encompassing per-capita estimates may be valid. On the other hand, if what is needed is information specifically about MSW as defined in this report, then these estimates are less useful than information about the generation of specific components of MSW (e.g., paper, plastics, and yard wastes). Information about individual components can be quite useful to communities trying to implement a strategy based on materials management (ch. 1). In either case, much more information is needed about the amounts and ultimate deposition of MSW and of materials such as construction and demolition debris.

The essential problem is that there is no standardized definition of what constitutes MSW, as well as no standardized methodology for collecting data on its generation (19). Each State and locality defines MSW differently and thus collects different statistics. If the data include wastes such as construction and demolition debris, they are difficult for planners to use. Because there is no standard way of classifying materials, many studies include categories such as "not elsewhere classified" or "other."

Another problem with available MSW data is that few studies have estimated the relative portions of MSW contributed by the residential, commercial, and institutional sectors. Yet this information has important implications for local MSW management. For example, curbside separation programs may be best suited for areas with a high proportion of single-family dwellings. Some studies include only residential wastes, while others include some or all of an area's commercial, institutional, and industrial wastes (table 3-l). Based on data in table 3-1 (and given the definitional problems), the residential MSW in the sampled localities ranged between 26 percent and 76 percent of total MSW, with an average of 48 percent.

In addition, some local studies have not fully accounted for potential changes in the per-capita rate and have made future projections solely on the basis of expected population growth. In one study, for example, the per-capita rate was held constant, and recycling (including comporting) and modular incinerators were assumed to be flexible enough to handle any growth in per-capita rates that might occur (33). In another study, the per-capita rate was estimated to grow by 0.34 percent per year to 2000 and then was held constant beyond 2000, with no explanation as to why the rate should be constant after that time (17).

Table 3-l-Selected Examples of MSW Generation Rates in U.S. Cities and Counties[a]

City/county	Amount of MSW (x 1,000 tons)	Type[b]	Percentage residential	Per-capita rate (pounds per day)
Albuquerque, NM	310	all	46	4.3
Austin, TX	178	?		2.1
Bannock County, ID	65	all	50	5.5
Boston, MA,	550	all	45	5.0
Charlotte, NC	225	R,C		3.3
Chattanooga, TN	286	all	58	9.4
Chicago, IL	2,200	R	50	4.0
Cincinnati, OH	213	R		3.2
Denver, CO	275-500[d]	all		3.1-5.7
Fairfax County, VA	1,039	?		7.5
Gwinnett County, GA	386	all	76	6.7
Hamburg, NY		all		2.1
Hillsborough County, FL	535	all	38	3.7
King County, WA	1,300	all		5.1
Los Angeles, CA	1,432	R		2.4
Marblehead, MA	19	all		4.6
Marion County, OR	216	?		5.7
Minneapolis, MN	160	R		2.5
Newark, NJ	325	R,C		5.4
New York, NY	7,500	?		5.8
Park County, MT	12	all		7.3
Peterborough, NH	3	all		3.3
Philadelphia, PA	1,700	all	51	5.8
Phoenix, AZ	1,200	all		7.0
Pinellas County, FL	1,160	?		7.5
Portland, OR	335	R		3.9
Prescott, AZ	52	?		5.7
San Antonio, TX	880	?		4.9
San Francisco, CA	967[d]	all		7.2
San Jose, CA	635	all		4.8
Seattle, VW	687	all	36	7.7
Shreveport, LA	307	all	26	7.8
Somerville, MA	36	all		2.2
Springfield, MO	200	all		7.8
Tulsa, OK	240	R,C		3.6
Waukesha County, WI	296	all	45	5.5
Yakima, WA	17	R		1.9

aThese data are from a survey of local solid waste management officials conducted by OTA from November 1988 to March 1989. Respondents were asked not to include construction/demolition debris, but some were unable to provide differentiated data.
bR=residential; C=commercial; I= institutional
CFor localities collecting all types of MSW and differentiating among residential commercial, and institutional MSW.
dIncludes both city and county.

SOURCE: Office of Technology Assessment 1989, *after K. Cox, Background Data on Municipal Solid Waste: Generation, Comrposition, Costs, Management* Facilities, State Activities (Takoma Park, MD: 1989)

How Fast Is the Per-Capita Rate Changing?

Although the national per-capita estimates are imperfect, they still provide useful approximations of how fast average per-capita generation rates are changing. Thus, acknowledging that the EPA/ Franklin model may somewhat underestimate total MSW generation, it is estimated that for the years 1970 to 1986 the per-capita MSW generation rate has increased 0.7 percent annually (10).[3]

Factors Affecting Per-Capita Generation

Reasons for the increasing per-capita rate are not clear, because many factors can affect per-capita generation in a given area. These include socioeconomic status, household size, demands for convenience, and degree of urbanization. As the following discussion indicates, this area clearly warrants additional research.

[3] Comparable data from earlier years are not available.

Socioeconomic Status-The effect of socioeconomic status on MSW generation is uncertain. A mid-1970s study in Texas found that income and urbanization were correlated with per-capita generation rates (34). Another study based on data from the 1970s reported that lower income households produced more residential wastes per capita than higher income households, although not for certain components such as newspapers and yard wastes (30).

One clear trend is that people in the United States have become more affluent, on average. One indicator is that disposable personal income, expressed in constant 1982 dollars, grew from $8,134 to $10,947 per person between 1970 and 1986 (38). This implies that we are buying more products of **all** types, which probably has at least some effect on MSW generation.

Household Size—Based on some limited studies, smaller households appear to produce more MSW per household member (28), and smaller households are becoming more common (38). From 1960 to 1986, the number of persons per household declined from 3.3 to 2.7 persons. This is partly because the portion of single people (i.e., never-married, widowed, or divorced adults) in the population increased from 28 percent in 1970 to 37 percent in 1986; during the same period, the number of single parents increased from almost 9 million to almost 13 million. These trends, in turn, contributed to an increase in the number of households from **63** million in 1970 to 88 million in 1986 (38).

Demand for Convenience—One common assumption is that demand for convenience has increased as the number of single-person households and the proportion of women in the work force have increased, and that this has led to a proliferation in packaging and single-use products. However, this may not be true. The proportion of packaging in MSW actually has been declining, at least by weight (see 'Product Categories' below). Single-use products are very common, but whether they have a significant impact on increasing per-capita rates is unclear. However, convenience as a substitute for time has certainly led to an increase in single-serving food products, Packaging for this type of product tends to be more wasteful than for goods with multiple servings (ch. 4).

Degree of Urbanization-The majority of the U.S. population lives in urban areas; the proportion increased from 64 percent in 1950 to 74 percent in 1980 (38). However, rural areas may have lower per-capita generation rates, at least for some MSW component For example, one study of MSW composition in a rural county concluded that the paper fraction was lower than expected because newspapers were published weekly instead of daily and because used paper tended to be consumed as fuel (27).

Comparison With Other Countries

In general, citizens in the United States often are considered to be more wasteful than citizens in other industrialized countries. However, the magnitude of any real differences is uncertain, as are the reasons for any such differences.

Most of the data on MSW generation in other countries suffer from the same problems as U.S. data, particularly differences in what types of wastes are included in the estimates. In addition, in the United States, post-consumer materials that are recycled are generally included in the definition of MSW. In contrast, Japan and many European countries (e.g., Sweden, Germany, Switzerland, Norway, and Spain) define MSW as including only those materials sent to waste treatment or disposal facilities (1 8). This definition excludes materials recovered for reuse, under the premise that these materials are resources and not wastes.

Data collection and record-keeping also vary widely among countries. In Japan, for example, almost all municipalities weigh MSW to the gram at landfills and incinerators; furthermore, data on the amounts of combustible and noncombustible materials are collected by each municipality and published annually by the national government (18). This type of effort is rarely practiced in the United States. National governmental agencies rarely aggregate the data that do exist. In most countries (including the United States), information on recycling is generally collected only for specific materials, by the industries that rely on those materials.

Nevertheless, some data from countries that tend to have better record-keeping are presented in table 3-2. Based on data from the early to mid- 1980s, for example, citizens in Sweden generated an estimated

Table 3-2—Estimated MSW Generation Per Capita in Different Countries (pounds per person per day)

Country	Gross discards[a]	Net discards[a]	Year
United States	3.6	3.2	1986
West Germany	—	2.6	1984/85
Sweden	—	2.4	early to mid-1980s
Switzerland	—	2.2	—
Japan	—	3.0	1987

[a]Gross discards refer to total MSW generation, net discards refer to MSW remaining after recycling but prior to energy recovery,

SOURCES: Franklin Associates, Ltd., *Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988),* report prepared for U.S. EPA, Office of Solid Waste and Emergency Response (Prairie Village, KS: 1988, G. Goosmann, "Municipal Solid Waste Management in the Federal Republic of Germany," pp. 118-126 in *A Se/act/on of Recent Publications (Vol. 2),* Federal Environmental Agency, Federal Republic of Germany (Berlin 1988); A.J. Hershkowitz, *International Experiences in Solid Waste Management,* contract prepared for U.S. Congress, OfficeofTwhnology Assessment (Elmsford, NY. Muncipal Recycling Assoaates, Inc., 1988; Clean Japan Center, "Waste Volume on the Rise and Measures Against It," *C/can Japan* 14:6-10, February 1989.

2.4 pounds of MSW per person per day after recycling. Japan appears to have had a similar rate at that time (18), but recent data indicate that the per-capita rate after recycling rose to 3.0 pounds per day in 1987 (5). This is close to the EPA/Franklin estimate for the United States of 3.2 pounds per day after recycling. Another study reported that several nations (e.g., Australia, Bulgaria, Canada, Hungary, New Zealand, Republic of Korea) have generation rates similar to the U.S. rate, at least based on data from the United Nations, the Organisation for Economic Cooperation and Development, and national sources (47); however, OTA considers comparisons based on these data to be tenuous because of differences in definitions and data collection techniques. No studies have been conducted to critically analyze the relationships between per-capita generation rates in different countries and per-capita income, land availability, social attitudes, or other factors.

MATERIAL AND PRODUCT COMPOSITION

Most MSW data are collected in terms of weight of materials (e.g., tons of glass), not in terms of volume or toxicity. Weight data are useful for some decisions; for example, prices for secondary materials are usually based on weight. On the other hand, weight data do not necessarily provide the information needed to assess the feasibility of waste reduction, particularly to help identify appropriate targets for government action. The volume of materials that enter the MSW stream often is a more useful measure for decisionmakers, particularly when assessing collection capabilities and landfill capacity.

Estimated MSW Proportions By Weight

Materials

Studies around the country show similar trends in the proportions of some materials in MSW. For example, data compiled by OTA from nine studies and another compilation of data from 40 studies (table 3-3) indicate that the largest categories of materials in MSW by weight are paper and yard wastes. However, there is substantial variation within the studies. In the nine studies, the proportion (by weight) of yard waste ranged from O to 39 percent, while paper ranged from 30 to 46 percent. Data from the 40 studies show similar trends, although the ranges were somewhat higher for paper (36 to 55 percent). These data also are similar to estimates from the EPA/Franklin model.

Some of the wide variation in the estimates can be attributed to differences in sampling and definitions. Other possible causes of variability include location, socioeconomic conditions, and seasonality. The effects of seasonality, for example, are most visible in the amount of yard waste produced, particularly in the Northeast and other temperate zones. The greatest amounts of yard waste in these areas are generated in the fall or spring, and the least in winter (ch. 5). Seasonal tourism and the presence of nonresident university populations also influence the seasonal composition of MSW.

The EPA/Franklin model estimates the weights of different materials in MSW (table 3-4). These estimates must be interpreted carefully (box 3-B), but they do indicate that the proportions of materials and products present in the MSW stream after recycling have changed over time. Paper and plastics, in particular, have been increasing rapidly.

Even after recycling, paper and paperboard products comprise the largest category of materials in

Table 3-3-A Comparison of Estimated Percentages of Different MSW Components, by Weight

	9 studies		40 studies	
Material	Mean	Range	Mean	Range
Total paper	38.8	29.9-45.9	46.7	36.5-54.7
Newspaper	6.3	4.3-8.1		
Corrugated	7.9	4.7-13.1		
Mixed	21.9	19.6-25.2		
Magazines	0.7	0.7		
Total metal	4.9	1.5-9.4	8.5	4.0-14.7
Aluminum cans	0.9	0.8-1.0		
Miscellaneous aluminum	0.7	0.2-1.6		
Other non-ferrous	1.0	0.0-3.4		
Total glass	7.8	3.6-12.9	8.4	6.0-13.7
Glass containers	6.4	6.1-6.6		
Total plastic	8.8	5.3-12.6	5.3'	2.0-9.0'
Plastic film	3.1	3.1		
Plastic containers	0.9	0.7-1.0		
Yard waste	18.2	0.0-39.7	9.5	0.4-25.0
Food waste....	14.7	1.3-28.8	7.8	0.9-18.2
Wood	2.6	0.7-8.2	2.6	0.5-7.0
Textiles	3.4	1.1-6.2	3.3	0.7-5.0
Rubber	0.4	0.0-1.0	— c	— c
Diapers	—	—	1.5	0.5-2.9
"Note elsewhere classified"	9.2	3.8-16.6	—	0.5-10.0

aCompiled from 9 local studies that did not have more than 10 percent (on average) of MSW in the "Not elsewhere classified" category (6).

bCompiled from 40 local studies (20) whether these studies were selected on the basis of the same criteria (i.e. less than IO percent in the "Not elsewhere classified" category) as the 9 local studies is unknown.

cPlastic, rubber, and leather were compiled together.

SOURCE: Office of Technology Assessment 1989, after K.Cox, *BackgroundDataon Municipal Solid Waste: Generation,* Composition, Costs, *Management* Facilities, State Activities (TakomaPark, MD: 1989); R.N. Kinman and D.K. Nutini, "Household Hazardous Waste in the Sanitary Landfill:' *Chemical TIMES & TRENDS* 11:23-29 and *39-40,1988.*

Table 3-4-EPA/Franklin Model Estimates, by Percent by Weight, of Materials and Products in MSW[a]

	After materials recovery			Before materials recovery
	1970	1986	2000	1986
Materials:				
Paper and paperboard	32.4	35.6	39.1	41.0
Glass	11.1	8.4	7.1	8.2
Metals	12.0	8.9	8.5	8.7
Plastics	2.7	7.3	9.2	6.5
Rubber and leather	2.7	2.8	2.3	2.5
Textiles	1.8	2.0	2.0	1.8
Mod.	3.6	4.1	3.6	3.7
Food wastes	11.4	8.9	7.3	7.9
Yard wastes	20.6	20.1	19.0	17.9
Miscellaneous inorganic	1.7	1.8	1.9	1.6
Products:				
Durable goods	12.4	13.6	13.6	
Nondurable goods	19.0	25.1	28.1	
Containers and packaging	34.9	30.3	30.0	
Other wastes (food, yard, miscellaneous inorganics)	33.6	30.8	28.1	

aIn all cases, estimates are for percentages before energy recovery during incineration; materials recovery refers to recycling of secondary materials.

SOURCE: Franklin Associates, Ltd., *Characterization of Municpal Solid Waste in the United States, 1960-2000, report* prepared for U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response (Prairie Village, KS: 1988).

MSW (36 percent). The second largest category by weight is yard and food wastes, which represent over one-fourth of MSW, although this proportion has declined steadily. Plastics comprise a small but rapidly growing category, with an expected increase to 9 percent by 2000. Glass, non-ferrous metals, rubber, textiles, leather, and wood have changed little over time, while ferrous metals have declined somewhat, Among recycled materials, paper and paperboard represented over 86 percent of the total amount recycled in 1986; glass and metals represented 6.5 and 5.9 percent, respectively (10).[4]

Product Categories

The EPA/Franklin model also provides estimates of the proportions of different *product* **categories**, again after recycling (table 3-4). In 1986, durables (e.g., furniture, tires, appliances) were estimated to make up about 14 percent of MSW, nondurable (e.g., newspapers, tissue paper, clothing) about 25 percent, and containers and packaging, the largest category, about 30 percent (which represents a slight decline from estimates for earlier years). According to these data, the nondurable category has grown the fastest, and it will continue to grow through 2000, although at a slower rate. The percentages of durable products and of containers and packaging. are expected to remain about the same through the year 2000.

These major categories also are broken into smaller subdivisions (9, 10). Among *containers and packaging*, for example, beverage containers made up between 6 and 11 percent of MSW by weight in 1986, with glass containers being the largest component. These data were analyzed to estimate the percent change of a product in MSW for a given period. Product categories expected to increase by more than 10 percent through 2000 include:

- furniture and furnishings,
- books and magazines,
- office papers and commercial printing papers,
- beer and soft drink cans,
- aluminum foil and closures,
- corrugated boxes, and
- plastic containers and other plastic packaging.

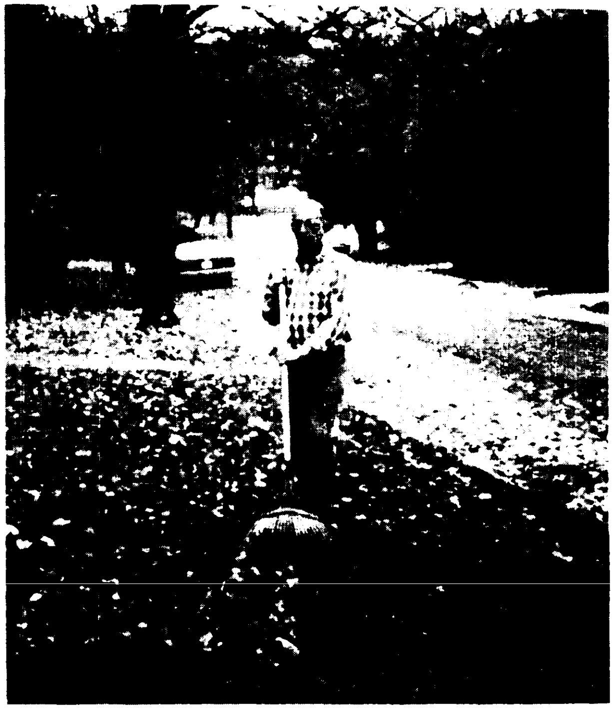


Photo credit: Office of Technology Assessment

The second largest category by weight of materials in MSW is yard waste (including leaves, grass clippings, weeds, and prunings). Properly controlled comporting of the wastes yields high-quality compost. Separating yard wastes from other MSW helps reduce leachate generation at landfills and nitrogen oxide formation at incinerators.

For example, beer and soft drink aluminum cans are expected to increase by 14 percent from 1990 to 1995, while all aluminum is expected to increase by 18 percent. Additional information on product trends, including containers and packaging, is discussed in chapter 4.

Technological changes have caused some change in the nature of MSW. For example, the portion of office and commercial printing papers (e.g., computer printouts, high-speed copier products, direct mail advertising) in MSW increased from an estimated 3.4 percent in the 1970 to an estimated 6.1 percent in 1984 (9). Plastic containers and packaging and disposable packaging associated with micro-

[4]Other data tend to confirm these trends. One study reported data based on over 2000 samples of residential MSW collected from Tucson households between 1978 and 1988 (44). Plastics increased from 5 percent to 10 percent by weight, presumably reflecting the increasing use of plastics in place of glass and metal containers. Paper increased from 30 percent to 35 percent, possibly reflecting increases in direct mad advertising and home computer output.

Photo credit: W. Johnson

Corrugated cardboard comprises about 7 percent of MSW by weight. About 40 percent of the waste paper exported from the United States is old corrugated cardboard, in high demand because of its strong softwood fibers.

wave frozen foods also have increased (43). In some cases, these have replaced other previously used materials, so the net change is difficult to assess. Within the containers and packaging category, for example, heavier materials such as glass and steel have been declining, in part because they are being replaced by lighter materials such as aluminum and plastics. The use of multi-material packaging (e.g., multiple layers of plastics, foil, paper; metal caps; and paper or foil labels) also appears to be increasing. This type of packaging tends to be lighter than previous packaging, but it also is harder to recycle.

Landfill Excavation Data by Volume and Weight

Information from landfill excavation studies being conducted by ''The Garbage Project" at the University of Arizona (29, 35) is significant because it includes data on both the volume and weight of materials, and some of the data illustrate changes in the waste stream during the last 20 years. The data must be interpreted carefully, however. The studies have only been conducted at a few landfills to date. Moreover, the data only refer to the volume and weight of materials present when the landfills were excavated, not to the amounts that originally entered the landfill or that might have been recycled or incinerated instead.

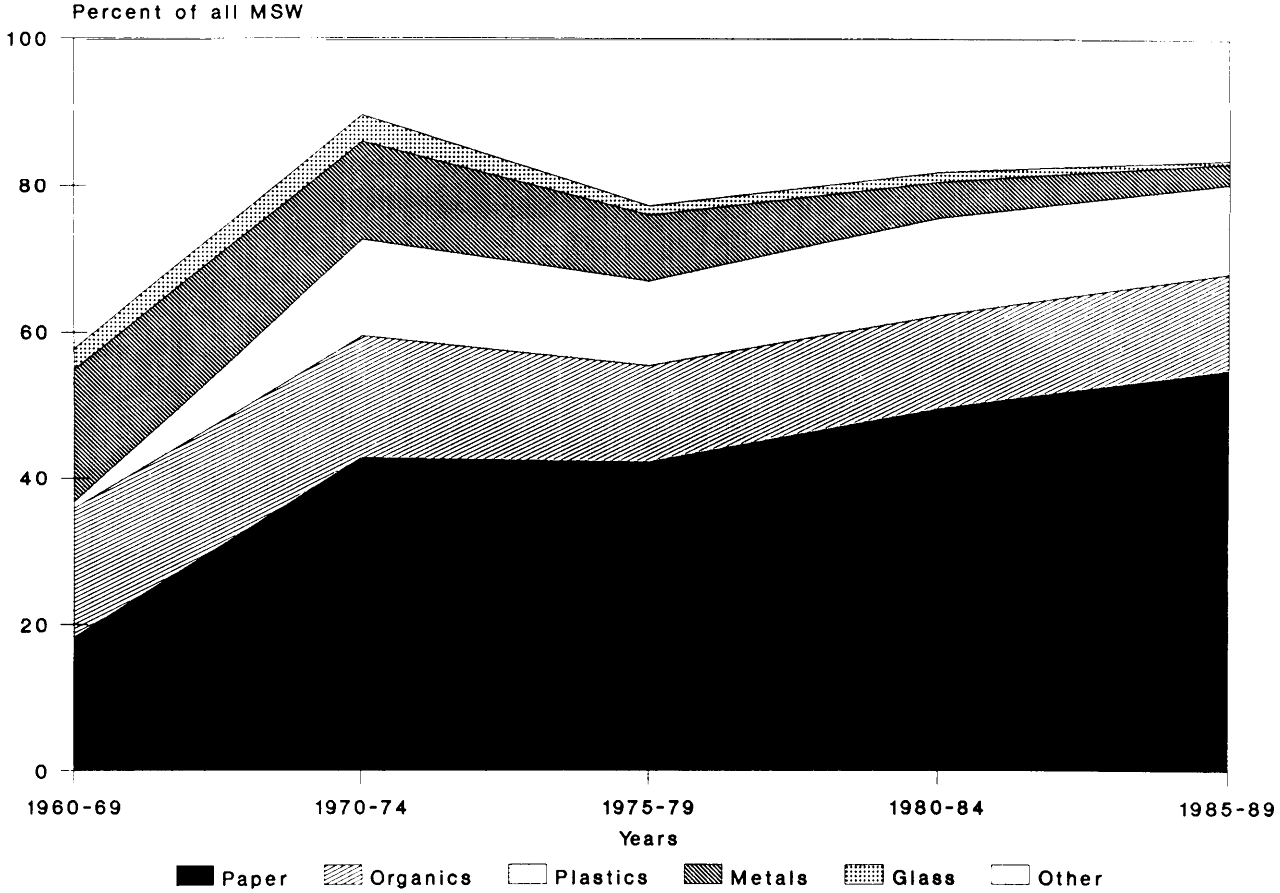
Photo credit: Office of Technobgy Assessment

Newspapers comprise the largest single item excavated from landfills. About 23 percent of the newsprint manufactured in the United States is made from waste paper, almost all of which is old newspapers (ONP). Supplies of ONP have increased because more communities now collect it, but by late 1988 some communities were paying waste paper dealers to take collected ONP.

Figure 3-1 presents volume data for different materials excavated from studied landfills. According to the investigators, the major variability in these measurements is within different sections of landfills, not between landfills, regardless of the type of climate (28). This is because the major source of moisture in the studied landfills has been the garbage itself, not rainwater or groundwater.

Paper and paper products have increased steadily and now comprise approximately 55 percent by

Figure 3-1—Average Volume (by percent) of Materials Excavated From Landfills



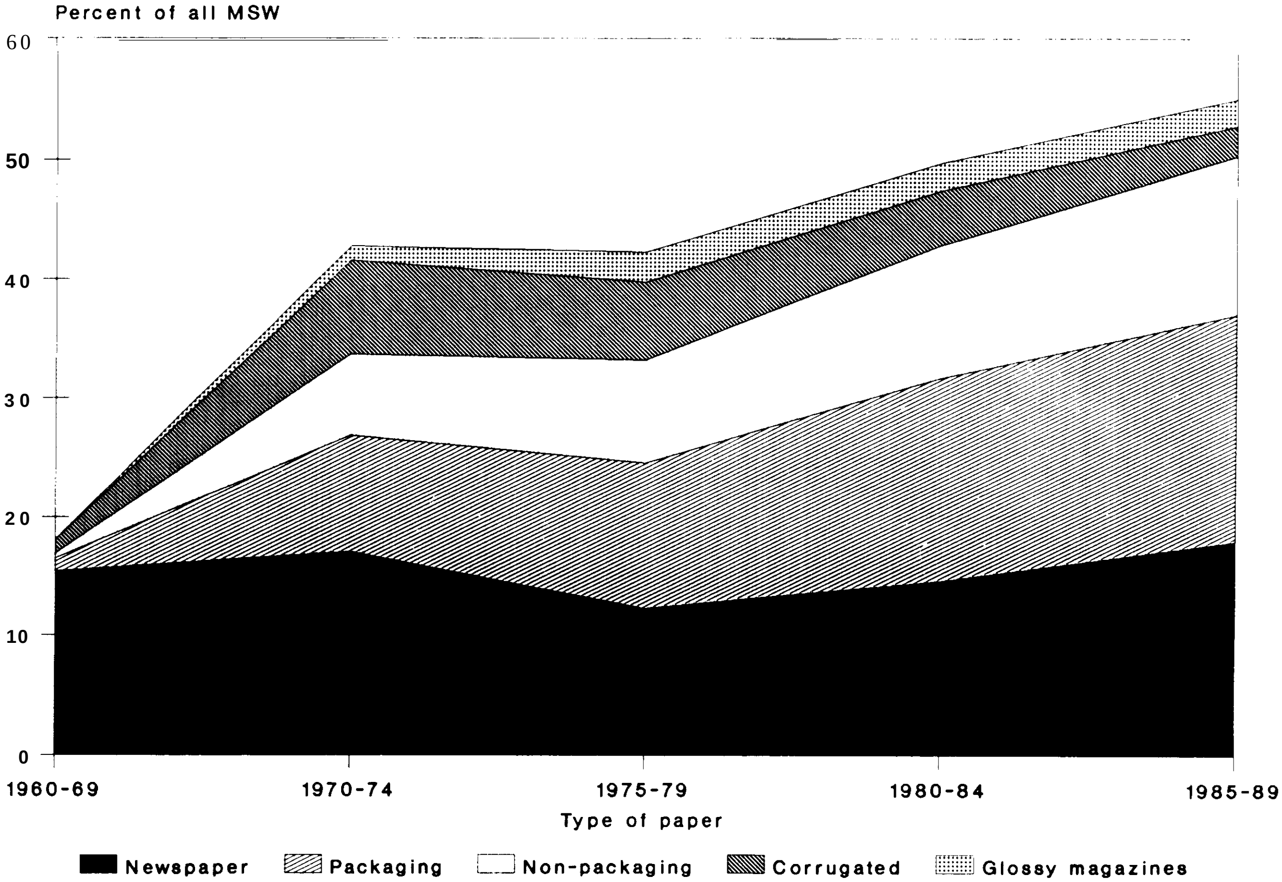
SOURCE: W.L. Rathje, University of Arizona, personal communication, February 1989.

volume (and almost one-half by weight) of the materials excavated (figure 3-1). While the volume of plastics increased in the early 1970s, it has remained essentially unchanged since the early 1970s, hovering around 12 to 13 percent. By weight, plastics comprise about 7 percent of landfilled MS W, thus indicating that they take up more volume than weight measurements alone might suggest. Not surprisingly, denser materials such as glass, rocks, and ferrous metals comprised a smaller percentage by volume than by weight.[5] During the last 20 years, the volume of glass has declined to less than 1 percent. The volume of metals has declined from 18 percent in the 1960s to about 3 percent today; the decline is probably due to use of lighter metals, increased recycling of aluminum beverage cans, and replacement of some metals by plastics. Overall, the weight of MSW may be increasing more slowly than is its volume because of these types of changes (10).

Paper used for packaging has increased steadily to comprise 19 percent of landfilled MSW, and paper used in nonpackaging (e.g., computer paper, printing and writing paper other than newsprint and glossy magazines) has risen to 13 percent (figure 3-2). Newsprint has risen recently to about 18 percent by both volume and weight, and it comprises the largest

[5] The density of some MSW components also is affected by many factors between the points of generation and disposal, including exposure to weather and variation in levels of compaction during handling and transportation.

Figure 3-2—Average Volume (by percent) of Types of Paper Excavated From Landfills



SOURCE: W.L. Rathje, University of Arizona, personal communication, February 1989.

single-item product in the landfills. In contrast, corrugated cardboard has declined from a peak of 6 percent in the early 1970s to less than 3 percent today.

These landfill excavation studies have generated interesting information about several components of MSW that have drawn public and media attention: plastics, fast-food packaging, and disposable diapers. Aside from finding that the volume of plastics has remained constant since the 1960s, the investigators also found, on the basis of limited sampling, that most plastic beverage containers compress under the pressure of overlying materials. This is different than glass bottles, of which more than half are found intact (28). Although the overall volume of plastics has remained constant, the relative amounts of film and rigid plastic products have fluctuated, without any discernible trend.

Fast-food packaging comprised only 0.3 percent, by both weight and volume, of the excavated material. Diapers were less than 1.0 percent by volume and by weight, on average. In contrast, a different study indicated that single-use disposable diapers make up 3.5 to 4.5 percent by weight of all MSW generated at residences and up to 2 percent of all MSW (22).[6] This difference may not be surprising, since the materials in the landfill excavations generally represented a combination of residential, commercial, and institutional MSW.

[6] About 18 billion single-use diapers were purchased in the United States in 1988 (22). About two-thirds of a disposable diaper is made of cellulose, a component of wood (and paper) that is degradable under proper conditions; the remainder is mostly plastic (e.g., polyester or polypropylene liners, polyethylene backsheets or outer layers).

CHEMICAL COMPOSITION

Basic Chemical Composition

MSW consists mostly of water, various elements (e.g., carbon, hydrogen, oxygen, chlorine, and nitrogen), and incombustible materials (e.g., glass, metals, ceramics, minerals, clay, and dirt) (16). In addition, various trace metals and organic chemicals can be present, but little aggregated information exists on their concentrations in MSW prior to recycling, incineration, or landfilling.

One chemical of particular concern is chlorine because it can be involved in the formation of dioxins and other chlorinated organics, as well as hydrogen chloride, during incineration (ch. 6). The major sources of chlorine in MSW appear to be paper and plastics. In Baltimore County, Maryland, for example, paper was estimated to contribute 56 percent of the total chlorine in the combustible portion of MSW; in Brooklyn, New York, plastics contributed an estimated 52 percent (4).

Chlorine is used directly to make certain products, such as PVC plastics and insulation and textiles. Chlorine is also used to bleach pulp for paper-making. In the pulping process, chemicals remove roughly three-fourths of the lignin (which makes up about half of wood), and bleaching removes the rest. Elemental chlorine (as a gas) has been the preferred bleaching chemical because it is cheaper, effective in dissolving lignin while maintaining the strength of the pulp, and can achieve higher-brightness paper than alternative bleaches. The alternatives, which include hypochlorite, chlorine dioxide, peroxide, and oxygen, generally are less efficient and more expensive than chlorine gas.

Combustibility

Some components of MSW are combustible—organic materials such as paper, plastics, textiles, rubber, and wood. The organic fraction of MSW was estimated to be about 81 percent by weight in 1986 (10). It appears to be growing slowly, primarily because the portions of paper and plastics in MSW also are growing.

One measure of MSW that is related to combustibility is "higher heating value" (HHV), or the number of Btu of energy that could be produced per unit of MSW. In general, MS W can generate from 4,5(K) to 6,000 Btu per pound. The average Btu value of MSW may be increasing because both plastic and especially paper, which have increased over the last 10 years, have high Btu values (figure 3-3). Paper wastes comprise a large portion of MSW and thus contribute much of its average total HHV. Food and yard wastes both have low Btu values, while inorganic materials such as metals and glass have no Btu value.

However, MSW is not homogeneous, either in its Btu values or its composition, between different locations or even over short periods at the same location. For example, combustibility can vary drastically because the portion of yard wastes can more than double during certain seasons. Yard wastes have high moisture content and low Btu values, so the overall HHV of the MSW decreases during summer and fall, when large amounts of yard waste are generated. Moisture content is also important because it affects the stability of the combustion process (16) and combustion efficiency during ''cold starts" of an incinerator (ch. 6). In addition, evaporating moisture during the initial stages of combustion requires the use of energy and thereby affects operating costs.

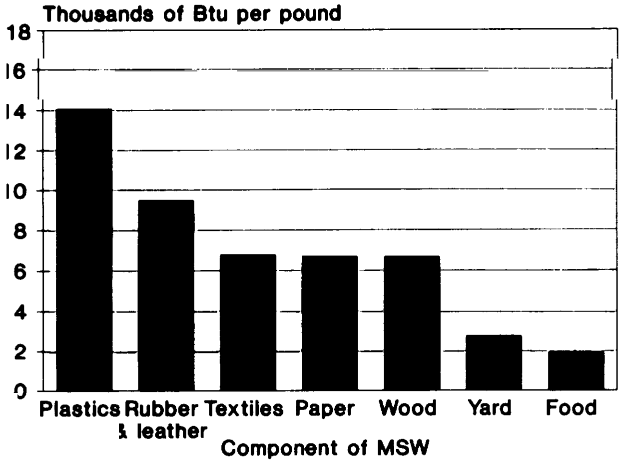
Removing particular materials from MSW prior to incineration (e.g., through source separation) can affect combustibility.[7] For example, removing yard wastes and inorganic recyclable such as glass and metals can reduce moisture and increase average HHV. In contrast, removing paper and plastics lowers HHV and increases moisture content. The net effect will depend on exactly what is removed,

Degradation

Some of the materials (e.g., paper and yard wastes) in MSW decompose or degrade, while others do not. In general, the rate of decomposition depends on local landfill conditions, such as temperature, moisture, oxygen levels, and pH (ch. 7). In theory, a large portion of MSW should eventually decompose because it tends to have a high level of degradable carbon. For example, one study estimated that degradable carbon comprised 34 to 59 percent of MSW (24). Another study estimated that

[7] The potential trade-offs between recycling and incineration of different materials are also discussed in chapters 1 and 6.

Figure 3-3--Relative Btu Values per Pound for Materials in MSW



SOURCE: Franklin Associates, Ltd., *Waste Paper, The Future of a Resource 1980-2000*, prepared for the Solid Waste Council of the Paper Industry (Prairie Village, KS: December 1982).

paper products and textiles were composed of about 40 percent degradable carbon, while yard and food wastes were composed of less than 20 percent carbon (3).

The landfill excavation study, however, has revealed some interesting insights about decomposition. In these landfills, paper products in particular, but also food wastes, have not degraded rapidly; in fact, it appears that degradation in general may be slow (29). For example, newspapers that were still readable after years of burial were found in all of the studied landfills. Paper and food waste excavated from part of one landfill were in the same condition as similar materials buried 5 to 10 years earlier in another part of the landfill.

Toxic Substances and Household Hazardous Waste

When MSW is landfilled, incinerated, or recycled, some of the composite metals and organic chemicals have the potential to harm public health and the environment (chs. 5, 6, 7). These are often called toxic or potentially harmful substances, although their potential effects on health and the environment depend on rates of exposure and dosage, sensitivity of exposed individuals, and other factors.

Toxic Substances in MSW

Many potentially harmful metals and organic chemicals are components of products and packaging that are used at residences and offices and then discarded as MSW. Available data focus on three metals-mercury, lead, and cadmium. For example, mercury is a component of most household batteries, as well as fluorescent light bulbs, thermometers, and mirrors. Sources of lead include solder in steel cans and electronic components, automobile batteries, paint pigments, ceramic glazes and inks, and plastics. About two-thirds of all lead in MSW (after recycling) is estimated to be from automobile batteries (1 1). Cadmium is found in metal coatings and platings; rechargeable household batteries; pigments in plastics, paints, and inks; and as a heat stabilizer in plastics. Nickel/cadmium batteries are the largest source, accounting for an estimated 52 percent after recycling, and plastics contribute about 28 percent.

The **noncombustible** portion of MSW is estimated to contain 98 percent of the lead and 64 percent of the cadmium (1 1). This suggests that separating noncombustible materials from MSW that is to be incinerated would be likely to reduce the amounts of these metals in emissions and ash (see ch. 6). Furthermore, because plastics account for an estimated 71 percent of the lead and 88 percent of the cadmium in the remaining combustible portion of MSW, efforts to manufacture plastic products without these metals also might help reduce amounts of these metals in emissions and ash. The toxicity issue is discussed in more detail in chapter 4.

Household Hazardous Wastes

Household hazardous wastes (HHW) are discarded products that contain potentially toxic substances, but that tend to be stored at residences for relatively long periods of time before being discarded.[8] Although there is no standardized definition of what products and materials comprise HHW, they generally include common household items such as cleaning products, automobile products, home maintenance products (e.g., paint, paint thinner, stain,

[8]The term "household hazardous wastes" is not used here in the legal sense of being a hazardous waste as defined in RCRA, although some of the substances in such wastes maybe classified as hazardous in RCRA (see ch 8).

varnish, glue), personal care products, and yard maintenance products (e.g., pesticides, insecticides, herbicides). In most cases these items are not hazardous while in storage, or during use if properly handled, but they may release potentially toxic substances after they have been discarded.

More than 100 substances that are listed as RCRA hazardous wastes are present in household products (table 3-5). The substances include metals (e.g., mercury, lead, silver) and organic chemicals (e.g., trichloroethylene, benzene, toluene, parathion).

Several studies have looked at the amounts of HHW generated. In two communities, Marin County, California, and New Orleans, Louisiana, HHW from single-family dwellings was sorted and weighed (42). Between 0.35 and 0.40 percent of the total MSW was considered hazardous, and each household threw away an average of 50 to 60 grams of HHW each week.[9] Other studies in Albuquerque, New Mexico, and the Puget Sound area in Washington reached similar conclusions: in general HHW comprises less than 1 percent of MSW (25, 41). Data from Los Angeles County, California, Portland, Oregon, and several localities in Michigan indicated that the quantities of actual constituents of concern were even lower, less than 0.2 percent (20). This has led some analysts to conclude that placing HHW in landfills is not a problem (20). However, the extent to which HHW contributes to environmental problems at landfills is unclear. Given the total quantity of MSW generated each year, even the apparently low proportion of 0.2 percent would mean that about 300,000 tons of potentially toxic substances in HHW are discarded each year.[10] Yet, when spread among thousands of facilities, the potential impacts should be lessened.

Data from residences in several areas (Tucson and Phoenix, Arizona; Marin County, California and New Orleans, Louisiana) have been compiled to indicate which HHW products were most commonly discarded; the data include containers but exclude automobile batteries (45). The largest category was household maintenance products, making up 37 percent by weight. Household batteries contributed 19 percent, cosmetics 12 percent, household cleaners 12 percent, automobile maintenance products 11 percent, and yard maintenance products 4 percent. About 80 percent of the automobile products was motor oil. Socioeconomic status appears to affect the types of HHW generated. Households in higher-income neighborhoods discarded more pesticides and yard products than did lower-income neighborhoods; cleaning materials were more common in middle-income neighborhoods; and automobile maintenance products were more common in lower-income neighborhoods (31, 45).

One study at a California landfill indicates similar trends (20). Two thousand fifty-six containers of HHW (whether empty or with residue) received at the landfill were sorted and counted. Of the six categories of containers, 40 percent had household and cleaning products; 30 percent automotive products; 16 percent personal products; 8 percent paint and related products; 3 percent insecticides, pesticides, and herbicides; and 4 percent were other products considered hazardous.

The effects of a one-day collection program for HHW in Marin County on subsequent generation of HHW raise an intriguing dilemma (31). Two months after the collection day was held, the amount of HHW in the normal MSW pickup was twice as high as it was before the collection day. This suggests that the educational effect of the collection day was short-lived or, as seems more likely, that people did not want to keep HHW around after they learned about it. If the latter proves true, regular collection days would be needed to keep HHW out of the normal MSW collection system. Chapter 8 discusses HHW programs in more detail.

Other Sources of Toxic Substances

Household products and materials in landfills and incinerators are not the only sources of potentially harmful chemicals in MSW. Under RCRA, businesses that generate less than 100 kilograms of hazardous wastes per month are allowed to deposit them in solid waste landfills (including municipal landfills) or have them burned in MSW incinerators (36, 37). These businesses are known as "very small

[9] These data refer to the weight of that portion of the waste that contains the hazardous ingredients, not including contaminated containers or other contaminated articles such as paint brushes and oil-soaked rags. Thus, they probably underestimate total amounts.

[10] Many hazardous household products also are emptied into sewer systems (40). When household cleaners are used, for instance, the product is washed down the drain and ends up in municipal sewage treatment plants.

Table 3-5-Examples of Hazardous Ingredients in Common Household Commodities[a]

Ingredient	Types of products found in
Acetic acid	household cleaners (starch powder), adhesives (microfilm)
Acetone	adhesives (film, microfilm, model, fishing rod, shoe, plastics, fabric, china solvent, canvas), pet maintenance (soaps), cosmetics (nail polish)
Acrotein	pet maintenance
Acrylic add	adhesives
Aldicarb	pet maintenance
Aldrin	pet maintenance
Aniline	cosmetics (perfume), stain (wood)
Arsenic (Ill) oxide	paint (non-latex anti-algae)
Arsenic (V) oxide	paint (non-latex anti-algae)
Arsenic acid....	pet maintenance
Aziridine	pet maintenance
Benzene	household cleaners (spotremover, degreaser, destainer, oven cleaner), stain, varnish, adhesives, cosmetics (nail polish remover)
Butyl alcohol	engine treatment (degreaser)
Cadmium	household batteries, paints, photographic chemicals
Carbon tetrachloride	household cleaners (degreaser, destainer)
Chloral (hydrate)	cosmetics (hair treatment)
Chlordane	pet maintenance (flea powders)
Chlorinated phenols	paint (latex)
Chlorobenzene	household cleaners (degreaser, destained)
Chloroform	household cleaners (lipstick spot remover), pet maintenance (mange drug)
Chromium	paint (wood preservative), photographic chemicals
Creosote	pet maintenance (repellent)
Cresol	household cleaners (disinfectant), engine treatment (degreaser)
Cresylic acid	engine treatment (degreaser)
Cyclohexane	adhesives
DDD	pet maintenance (dips)
DDT	pet maintenance
Dibutyl phthalate.	paint (non-latex plasticizer), adhesives (builder's, model, vinyl wood glue, thermoplastic, china water emulsion, china solvent), cosmetics (nail polish)
m-Dichlorobenzene	household cleaners (disinfectant)
o-Dichlorobenzene	household cleaners (disinfectant, toilet bowl cleaner)
p-Dichlorobenzene	household cleaners (disinfectant, toilet bowl cleaner, air sanitizer, air deodorant)
1,2-Dichloroethane	household cleaners (rugs, upholstery, tar remover)
1,2-Dichloroethylene	household cleaners (rugs, upholstery), polish (shoe)
2,4-Dichlorophenoxyacetic acid (2,4-D)	pet maintenance, insect repellants
1,2-Dichloropropane	household cleaners (tar remover, wax, wax remover
1,3-Dichloropropylene	household cleaners (wax)
Dieldrin	pet maintenance
Diethyl phthalate.	paint (non-latex plasticizer) adhesives (fabric, metal), polish (metal)
Dimethoate	pet maintenance
Dinoseb	pet maintenance
1,4-Dioxane	adhesives (film)
Disulfoton	pet maintenance
Endosulfan	pet maintenance
Endrin	pet maintenance
Ethanol	household cleaners (dish detergent disinfectant)
Ethyl acetate	household cleaners (spot remove~degreaser/destained), paint (lacquer thinners), adhesives (film, leather, fabric, china, model glue), cosmetics (nail enamel)
Ethyl ether	engine treatment (degreaser)
Ethylene dibromide	engine treatment (fuel additives)
Ethylene dichloride	household cleaners (carpet cleaner/deodorizer), engine treatment (degreaser, fuel additives), adhesives (film)
Ethylene oxide (condensate)	household cleaners (disinfectant)
Ethylidene dichloride	adhesives
Formaldehyde	household cleaners (starch, disinfectant, air sanitizer), polishes (shoe, plastic), adhesives (gum arabic, library paste, waterproof glue)
Heptachlor	pet maintenance
Hexachlorobenzene	household cleaners (disinfectant)
Hexachloroethane	insect repellents
Hexachlorophene	cosmetics (cleansing creams, conditioning cream, face mask)
Lead	stain/varnish, automobile batteries, paint

Table 3-&Examples of Hazardous Ingredients in Common Household Commodities[a]--Continued

ingredient	Types of products found in
Lead acetate	cosmetics (haircoloring)
Lindane	pet maintenance (seeps, sprays, dips)
Mercury	household cleaners (disinfectant), paint (non-latex anti-algae, Iatex), household batteries
Mercury fulminate	household cleaners (disinfectant)
Methanol (methyl alcohol)	engine treatment (degreaser, antifreeze/coolant), adhesives (film), household clean-ers(rust and ink remover), (degreaser), stain/varnish, cosmetics (nail polish)
Methoxychlor	household cleaners (air sanitizer), pet maintenance (powders, dips, soaps, sprays)
Methylene chloride	household cleaners (air sanitizer, oven cleaner, tar remover), engine treatment (degreaser), paint (anti-corrosion non-latex), stain/varnish, adhesives (air filter, film)
Methy ethyl ketone	household cleaners (degreaser), adhesives (film, microfilm, fishing rod, china (butan-one) solvent), cosmetics (nail polish)
Methyl isobutyl acetone	adhesives (china solvent, microfilm)
Methyl methacrylate	cosmetics (nail polish), adhesives (dental plate)
Methyl parathion ... ,	pet maintenance
Naphthalene	household cleaners (glass cleaner, carpet cleaner/deodorizer, air sanitizer, air deodorant)
Naphthalene, 2-chloro	household cleaners (glass cleaner)
1,4-Naphthalenedione	household cleaners (glass cleaner)
1,4-Naphthaquinone	household cleaners (glass cleaner)
1-Naphthylamine	household cleaners (glass cleaner)
2-Naphthylamine	household cleaners (glass cleaner)
2,7-Naphthalenedisulfonic acid	household cleaners (glass cleaner)
Nitrobenzene	polish (shoe)
Parathion	pet maintenance
Pentachlorophenol	household cleaners (starch), pet maintenance, adhesives (dental plate), paint (wood preservative)
Phenols	adhesives (gum arabic, dextrin, flexible glue), household cleaners (pine oil, disinfectant), paint
Phenyl mercuric acetate	polishes (shoe), household cleaners (starch, disinfectant)
Phorate	pet maintenance
Phosphoric acid	household cleaners (spot remover, glass cleaner, disinfectant, degreaser), polish (auto)
Phthalates	adhesives (microfilm), polish (metal)
Propane	paint (latex)
Resorcinol	cosmetics (hair coloring and tonics)
Selenium	photographic chemicals
Silver	household batteries, photographic chemicals
Silvex	pet maintenance
Sodium o-phenylphenate	adhesives (library paste)
Sulfuric acid....	household cleaners (toilet bowl cleaner)
Sulfuric acid, thallium salt	polishes (metal)
Tetraethyl lead	engine treatment (fuel additives)
Toluene	household cleaners (spot remover, degreaser), lubricating oil (all-purpose, brake/clutch/ hydraulic fluid, motor oil), paint (latex, lacquer thinners), adhesives (microfilm, plastic, leather, fabric, rubber), cosmetics (nail polish)
Toxaphene	pet maintenance (dips), insect repellents
1,1,1-Trichloroethane	polishes (general, shoe), adhesives (contact cement), household cleaner (oven cleaner, rugs, upholstery)
1,1,2-Trichloroethane	polishes (shoe)
1,1,2-Trichloroethylene	engine treatment (fuel additive), household cleaners (degreaser/destainer, carpet cleaner/deodorizer, rugs, upholstery)
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	pet maintenance
Trichloromonofluoromethane	household cleaners (air sanitizer)
Warfarin	pet maintenance
Xylene	transmission fluid, engine treatment (degreaser), paint (latex, non-latex, lacquer thinners), adhesives (microfilm, fabric), cosmetics (nail polish)

aDetermination as hazardous based on 40 Code *of Federal Regulations 261.*

SOURCES: Based on U.S. Environmental Protectlon Agency, Sources *of Toxic Compounds in Household Wastewater,* EPA 600/2-80-128 (Cincinnati, OH: August 1980) (39); D.C. Wilson and W.L. Rathje, University of Arizona, The Garbage Project, personal communicatlon, March 1989 (compilation of data from refs. 15, 32, and 35).

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quantity generators" and include vehicle maintenance shops (which handle lead-acid car batteries and used motor oil), drycleaners, pesticide application services, and others (10,37). One study estimated that there are about 450,000 very small quantity generators in the country and that they generate about 197,000 tons of hazardous waste annually (l). How much of this waste is sent to MSW landfills and incinerators is unknown. Even if all of it is discarded at MSW landfills, it would represent much less than 1 percent of all landfilled waste; however, it does contain toxic substances, and about one-fourth of all MSW landfills accept such wastes (ch. 7).

In addition, some nonhazardous industrial wastes are discarded in MSW landfills (ch. 7). Although most nonhazardous wastes currently are managed ''on-site," pressure to send them to off-site landfills may increase in the future if regulations guiding on-site management become more stringent.

It also is important to note that some of the materials in MSW are not always handled by MSW management methods. For example, liquid cleansers may be washed down the drain and into the municipal sewage treatment system (40). Pesticides (e.g., from spraying lawns) can be carried by rain into storm drains, which generally discharge into surface waters. Pesticides also can be dumped on the ground or into sewers, or stored at home.

RESEARCH NEEDS

Although this chapter is filled with statistics, the data base available about MSW is actually quite limited and quite uncertain. There is general consensus that total MSW generation in the United States is increasing. But translating this broad conclusion into guidance for local decisionmakers is difficult. Communities need better information about local conditions and better ways to collect that information. The States and the Federal Government could benefit, too, from better information as they work to develop wise MSW policies.

Additional research is needed on many topics related to MSW generation. The Federal Government, for example, could sponsor or conduct research on many of these topics, including:

- standardized definitions of MSW;
- standardized data collection and reporting methods;
- why and how MSW generation and composition vary among communities and in relation to demographic and socioeconomic factors;
- amounts and composition of MSW produced by residential, commercial, and institutional sectors;
- amounts of other nonhazardous wastes sent to MSW management facilities (including, but not limited to, construction and demolition debris);
- the relationship between weight and volume;
- degradation rates in landfills; and
- compilations of existing generation and composition studies.

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