Chapter 4

MSW Prevention

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OVERVIEW

The Nation's current concerns about MSW arise from the increased visibility of several related problems: declining landfill capacity, overuse of virgin materials, and the presence of toxic substances in discarded products. One strategy to cope with these problems is to promote "MSW prevention. " OTA defines MSW prevention as activities that reduce the toxicity or quantity of discarded products before the products are purchased, used, and discarded.[1] Prevention should not be confused with waste management, which occurs **after** MSW is generated (ch. 1). Box 4-A discusses differences between prevention, recycling, and degradability.

There are two basic routes to MSW prevention—manufacturers can change the design of products and the way they are packaged, and consumers can alter purchasing decisions about existing products and the way they use and discard products (figure 4-l).

Two distinct characteristics of MSW need to be kept in sharp focus-toxicity and quantity (figure 4-l). To product manufacturers, reducing toxicity means eliminating or finding benign substitutes for substances that pose risks when they ultimately are discarded as MSW. Reducing quantity means changing the design of a product so that less MSW is generated when the product or its residuals are discarded.[2] From a consumer's perspective, both toxicity and quantity reduction involve deciding to buy products that reflect such changes. Quantity reduction also includes backyard comporting of yard wastes (i.e., within a household's property lines), since this eliminates materials that otherwise would be managed by the commercial or public sectors. Reduction also can include reusing an item without changing its form, structure, or function.

The motivation for promoting MSW prevention is strong and simple. The public is increasingly sensitive about potential human health and environmental risks associated with all MSW management methods. Reducing toxicity would make all management methods safer and help restore public confidence in waste management policies and programs. For example, reducing the amounts and types of organic chemicals in materials sent to landfills would mean less air pollution (e.g., from volatile organic chemicals) and less toxic leachate.

Reducing the quantity of discarded materials would mean that the useful life of existing and future waste management facilities could be extended and new replacement capacity could be developed at a slower rate. Currently, however, the amount of MSW generated in the United States increases by about 1 percent each year, a rate of increase that is expected to continue through at least the year 2000 (ch. 3). Overall population growth accounts for about two-thirds of the increase, but the average amount that each person generates (i.e., the per-capita rate) also has increased over the years. At the same time, available capacity for properly managing MSW is declining (chs. 1 and 7).

As reviewed in this chapter, some reductions in MSW toxicity and quantity already have occurred, and many more possibilities exist. With respect to toxic substances, the link between management problems and product design is clear, and manufacturers and EPA need to make stronger efforts to identify and reduce such substances. Identifying these substances and their major sources is not easy, however, especially given difficulties in estimating potential risks (chs. 5, 6, and 7), the thousands of products that are currently in commerce, and the functional purposes of the substances. Nevertheless, when such substances and sources are identified, then the feasibility and costs of developing products

[1] EPA uses the term "source reduction" (12, 91).

[2] Throughout this report, OTA's use of the term "products" includes packaging as well. The term "packaging" generally is used only when that subset of products is the focus of discussion.

Box 4-A—Prevention, Recycling, and Degradability

New products can be designed to make MSW management easier. Just as toxicity and quantity cart be considered when new products are designed, so can properties such as recyclability and degradability. If products are recyclable or degradable, less MSW might need to be sent to landfills or incinerators. Yet neither reduces the toxicity or quantity of MSW **before** it is generated. For this reason, OTA does not include recyclability and degradability as part of MSW prevention, a view shared by some other observers (e.g., 38). Instead, these two aspects of MSW are considered part of waste management.

Recycling, for example, occurs when an item is valued for its material content and the material is used to manufacture new items. However, recycling does not reduce MSW generation rates because it involves the separation, collection, and processing of materials **after they are** discarded. Although recycling is not a preventive measure, the link between the production/design portion of the MSW ''system and the ability to increase recycling is still important. As OTA pointed out in chapter 1, one key aspect of a materials management policy is to coordinate product manufacturing with the needs of management methods, in this case by designing products to be recyclable.

Similarly, degradable products do not decrease generation rates, although they can help reduce the visual problems and wildlife injuries associated with plastic litter (ch. 5). Degradable products generally are discarded into the MSW management system, where they end up in landfills. They may or may not degrade depending on the product and conditions at the landfill (chs. 5 and 7). Degradable products might even increase MSW generation rates in some cases. For example, some degradable plastic bags may require more polyethylene to have the same strength as non-degradable bags.

without the substances can be evaluated. Additional research is needed, however, to develop potential MSW prevention strategies, For example, independent testing of the toxic content of materials and development of non-toxic alternatives is needed (12).

It is difficult to target products for quantity reduction efforts. Many people assume that demands for convenience have caused the proliferation of packaging and single-use products, but this is only partly true. In many cases, the relative proportion of packaging in MSW actually has decreased, at least by weight.[3] Moreover, packaging performs critical functions such as decreasing food spoilage and preventing pilferage or tampering. Even the use of plastics, which is criticized by many people, may contribute to reduction in some cases (box 4-B). In addition, measuring quantity reduction is difficult because there are no standard methods for determining how much is generated (ch. 3).

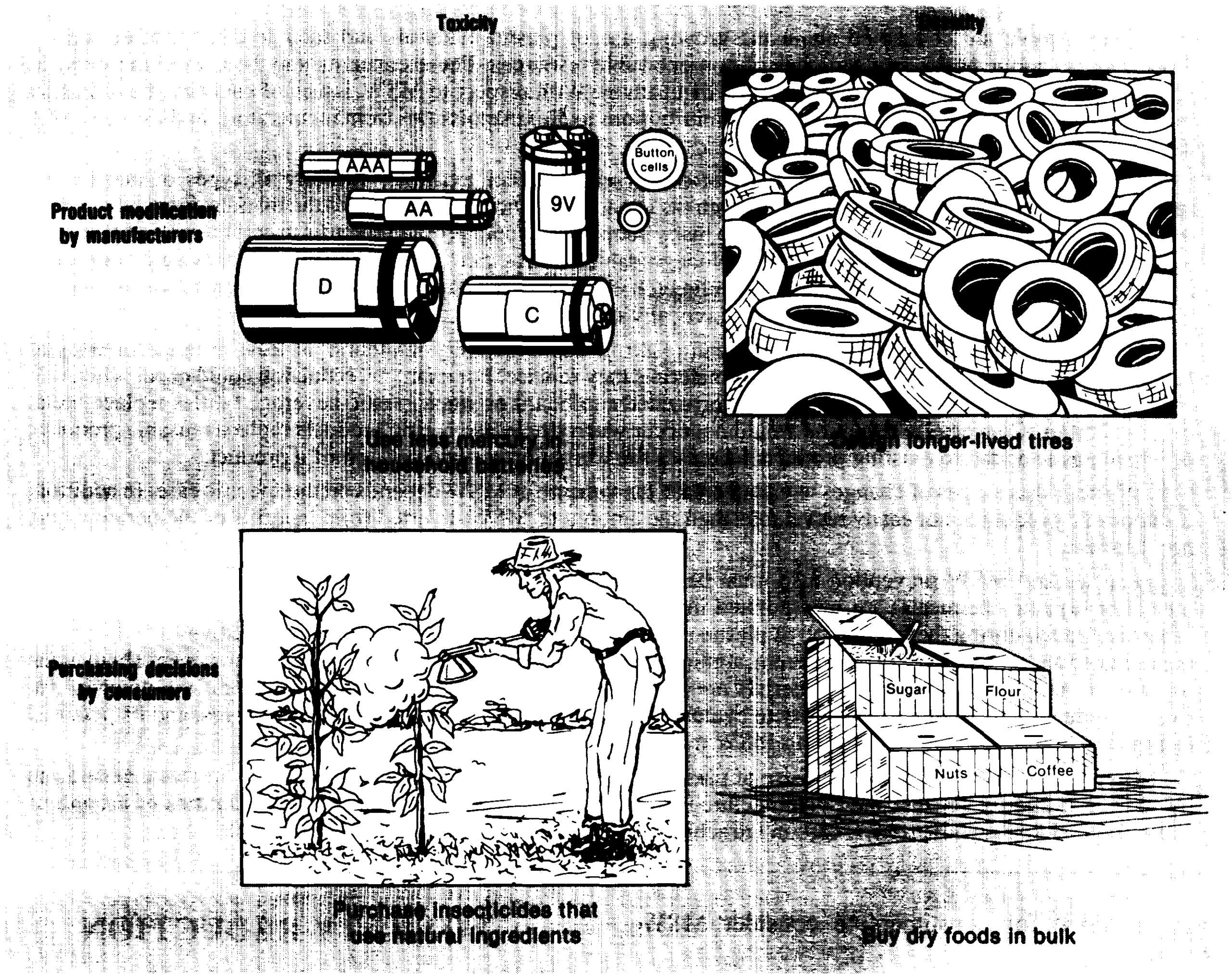
Even so, there are some obvious opportunities to reduce the quantity of MSW. These include reducing some packaging (e.g., multi-material packaging, which makes recycling difficult), some uses of paper (e.g., in direct mail advertising, oversized newspapers), and single-use products (e.g., diapers). In addition, yard wastes make up a large portion of MSW in many areas (ch. 3) and efforts to increase backyard comporting could be important.

The major problem associated with MSW prevention is that MSW generation itself is a social phenomenon tied to social customs and personal preferences and lifestyles. Reducing the quantity of MSW generated will require changes in the attitudes of most Americans. This can only occur if producers and consumers assume joint responsibility for MSW generation, and it will involve changes in manufacturing design practices and in consumer purchasing decisions.

These changes would likely have positive and negative economic and social effects. As noted above, the potential benefits are attractive. Reducing toxicity would make MSW management safer and could have economic benefits associated with a decrease in cleanup costs of future hazardous waste sites. Reduced MSW quantity could lower the rate at which landfills are reaching capacity and possibly the rate at which costs for consumers and communi-

[3] The estimated weight of all containers and packaging in MSW declined from 35 percent in 1970 to 30 percent in 1986; while more packaging may be entering the MSW stream, lighter materials such as plastics and paper have been replacing heavier materials such as glass and metals (ch. 3). Little information is available on the volume of packaging. Based on limited data from excavations at landfills (ch. 3), the volume of plastics stayed relatively constant during the last 15 years, the volume of paper packaging increased slightly, and the volume of glass and metal decreased.

Figure 4-l-Routes to MSW Prevention



SOURCE: Office of Technology Assessment, 1989

ties are rising. Negative effects are possible, however, and they are likely to be unevenly distributed throughout society. For example, quantity reduction could affect employment, tax revenues, and the gross national product in unpredictable ways because about 70 percent of MSW consists of manufactured goods. Quantity reduction also could have negative economic impacts on some recyclers, although whether such effects would be enough to significantly affect recycling operations is unknown. For example, a change in battery components could affect recycling systems whose intent is to collect and sell specific metals.

Given these obstacles, it is uncertain just how much MSW prevention, particularly in terms of reducing quantity, will be achieved in the long-run. However, it is a certainty that little will be accomplished if the Nation maintains its current MSW practices. Although manufacturers have an economic incentive to reduce production and materials costs, they have little incentive to consider the ultimate costs for disposal of their products. Unless products or materials are available that perform well and have costs comparable to existing maw-ids, manufacturers are unlikely to adopt alternatives in the absence of incentives (12). Similarly, there is

Box 4-B—Does Shifting to Plastics Mean MSW Prevention?

Many people are concerned about the growing use of plastic materials and their long-term effect on the environment, public health, and supplies of nonrenewable resources. These concerns may be caused more by the visibility of their use rather than the materials themselves. With respect to MSW, issues of concern about plastics include non-recyclability, non-degradability, contributions to dioxin emissions from incinerators, and use of landfill capacity.

Questions about plastics in MSW are not easily resolved. For example, virtually all types of plastics are recyclable from a technical perspective, although the capacity for such processing and the markets for products may be limited. Degradable plastics are appealing to many people and would provide benefits to certain sectors of society (e.g., corn growers if the use of cornstarch in biodegradable plastics increases), but there are unanswered questions about their effects on the environment and recycling (ch. 5). Similarly, issues concerning the contribution of plastics to dioxin emissions cannot be answered unequivocally (ch. 6).

Even so, switching to plastic materials can result in MSW quantity reduction, at least in terms of **weight,** because plastics generally are lighter than the materials they replace. For example, reduction could occur when thin plastic "shrink-wrap" films replace thicker corrugated cardboard or when plastic beverage bottles replace metal or glass bottles. Conversely, reduction would not occur when single-use plastic products replace reusable products, or when plastic added to existing products increases the weight or volume per unit of a product.

Whether these types of changes would decrease the **volume** of MSW depends on the specific case. In addition, if the plastic product is not easily recyclable, then the amount of MSW diverted from landfills or incinerators may not decrease.

Plastics and MSW prevention also must be considered in the context of toxicity. Different additives (e.g., metals or organic chemicals) are incorporated into polymer matrices during the production of plastic resins and others are added during the fabrication of plastic products (ch. 5). In fact, the variability of additives is what allows these materials to be tailored to different applications. There are unanswered questions, however, about what happens to additives when plastic materials are recycled, incinerated, and landfilled. To assess the potential for toxicity reduction, it would be necessary to evaluate each individual plastic material, its additives, and its potential health and environmental effects during MSW management.

On a broader scale, however, the use of plastics may not contribute to overall reductions in waste generation by society, primarily because their manufacture is associated with the generation of large quantities of hazardous waste (e.g., chlorinated benzenes, carbon tetrachloride, methylene chloride, trichloroethylene).

little incentive for consumers to consider MSW prevention.

The potential benefits of both toxicity and quantity reduction suggest that a concerted effort to promote prevention is worth starting today. There is a limit to what local and State governments can do to provide such incentives (chs. 1 and 8). The Federal Government, however, can provide strong leadership, actions, and positive incentives for MSW prevention efforts. Without Federal involvement, success is unlikely. This chapter discusses issues associated with MSW toxicity and quantity reduction, examples of successful changes, and some of the opportunities that different consumers can attempt. Current Federal and State activities related to MSW prevention are discussed in chapter 8, and policy options are discussed in chapter 1.

TOXICITY REDUCTION

Toxicity reduction refers to changing the design of products prior to manufacturing so they contain fewer or none of the substances that pose risks when those products become part of the MSW management stream. Toxicity reduction also can occur when products with toxic substances last longer. However, lowering the toxicity of a product by half would not be considered toxicity reduction if the change means that the product's lifetime is also cut in half.

Reducing the toxicity of MSW is an approach that emerged out of policies regarding industrial hazardous waste reduction (75, 77). The dynamics for MSW prevention efforts are different, however, primarily because the generator of a **product** with a toxic component is **not** responsible for its disposal, which is the opposite of the case for most generators of industrial hazardous waste. In principle, reducing the toxicity of MSW can decrease MSW management costs and exposure problems at all points in the lifecycle of a product, from point of manufacture to point of ultimate disposal or management. If the substances in MSW that pose the greatest risks to humans could be identified and removed from or substantially reduced in products, then those items would be safer.

What and Where Are Toxic Substances?

To identify substances and product.. for toxicity reduction efforts, information is needed about the types and amounts of toxic substances in MSW, which products contain significant quantities of them, and potential for exposure and toxic dosage during MSW management. With this information, specific substances and products could be targeted for initial reduction efforts.

Some toxic substances are known to pose human health and environmental problems (e.g., lead and benzene), and some can degrade machines and equipment. However, the state of our knowledge about potentially toxic substances in MSW is uncertain. Little is known about the distribution of toxic substances in various products. what exposures during or after MSW management are sufficient to cause problems, and what relative risks these substances pose when different MS W management systems are used.

An initial way to screen the universe of substances is to use existing regulatory lists. In addition, two general sources of information can be used to link particular toxic substances with products: 1) analyses of materials "flow," usually done for other purposes, that inventory substances from their origins to their end use; and 2) local household hazardous waste collection programs around the country, which collect discarded products containing hazardous substances.

Existing Regulatory Lists

Existing regulatory lists of toxic substances provide an initial basis of information about the extent of toxic substances. Several lists exist in environmental laws or regulations. For example, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) defines hazardous substances; the Resource Conservation and Recovery Act (RCRA) defines hazardous wastes; the Clean Water Act defines priority toxic pollutants; and the Clean Air Act defines hazardous air pollutants.[4]

This information has limitations. For example, many suspect chemicals are likely to exist that are not listed. In addition, hundreds of new chemicals are introduced into production and commerce by industry each year.

Obviously, it is impossible to analyze at one time the potential harm of hundreds of chemicals, nor could the Federal Government implement any toxicity reduction program that encompassed all substances at once. The lists simply provide a guide to potential and sometimes actual toxicity. **The Federal Government needs to determine where its efforts in promoting the reduction of toxics in MSW should be concentrated.** EPA reached the same conclusion (91).

Materials Flow Inventories

Complete studies of how a given substance is used and flows through society are limited. With respect to MSW, most of the available information deals with metals.

Data on Metals--Three heavy metals that are generally recognized as toxic to humans are cadmium, lead, and mercury. These are used in many products (92):

- cadmium-metal coatings and platings for white goods; rechargeable household batteries; electronics and fasteners; color pigments for plastics, paints, printing inks; heat stabilizers in plastics;
- lead-rustproofing paints; wire and cable insulation, for electrical stability; bottle caps; contact base of incandescent light bulbs; and
- mercury-fluorescent lights, batteries, power control switches for lights and thermostats, mildew-proofing paints.

[4] The words toxic and hazardous are not used here in their legal or regulatory technical sense. Instead they are used to refer to materials that are harmful when people are exposed to them in sufficient concentrations.

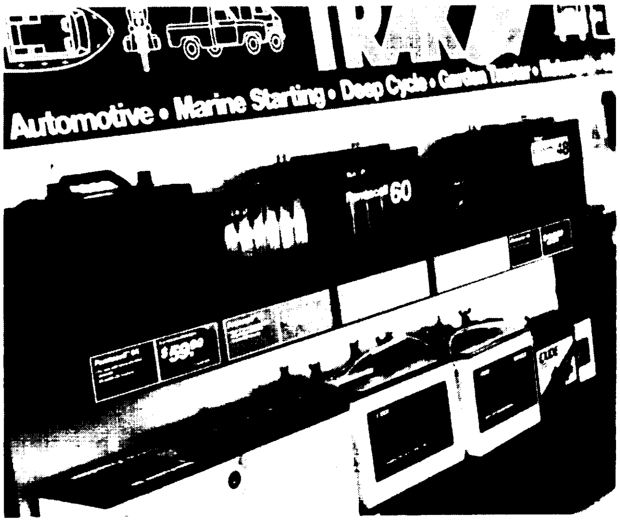


Photo credit: Office of *Technology Assessment*

Lead is used in many products, including lead-acid automobile batteries, consumer electronics, paints and inks, some food packaging, and light bulbs. Most led-acid batteries are recycled, but these batteries still account for about 65 percent of the lead present in MSW after recycling.

Table 4-1-U.S. Consumption and Demand for Lead, Cadmium, and Mercury

End use	Tons	Percent
Mercury demand by end use, 1983:		
Electrical	1,024	55
Caustic soda and chlorine	306	16
Paints	230	12
Instruments	94	5
Dental supplies	61	3
Other	153	8
Cadmium demand by end use, 1983		
Coating and plating	1,410	34
	1,120	27
Pigments	660	16
Plastic stabilizers	620	15
Other	330	8
Lead consumption by class of product, 1986:		
Storage batteries	940,899	76
Metal products	160,949	13
Other oxides	76,619	6
Gasoline additives	31,452	3
Other	29,663	2

SOURCES; U.S. Department of the Interior, Bureau of Mines, *Mineral Facts and Problems 1985 Edition,* Bulletin 675 (Washington, DC: 1985); U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbook* (Washington, DC: 1986).

They also can be found in trace quantities in some products. For example, printing inks classified as non-lead-based can still contain lead in trace concentrations below 600 ppm.

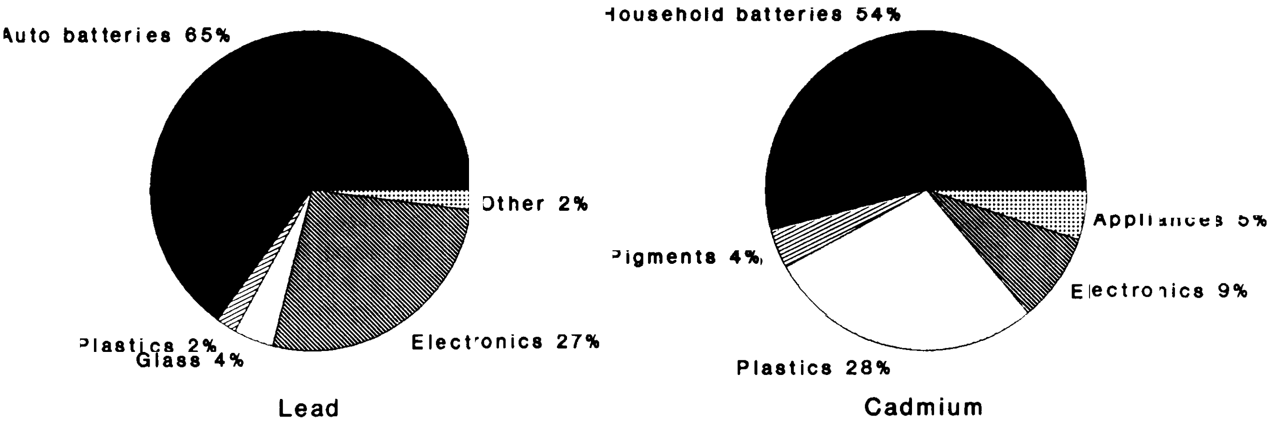
The Bureau of Mines estimated how these metals are distributed among all end uses (table 4-l). In 1983, most cadmium (34 percent) was used in coating and plating; the second largest use was batteries (27 percent in 1983), which are expected to top the list in the year 2000. Cadmium use in plastics as a pigment and sometimes as a stabilizer is expected to grow to third place in 2000. Mercury end uses in 1983 were primarily electrical (55 percent).

One materials flow analysis on lead and cadmium specifically analyzes metals in MSW (29). Lead-acid batteries (primarily from automobiles) accounted for 65 percent of the lead after recycling, while consumer electronics (e.g., TVs, radios, and VCRs) accounted for 27 percent (figure 4-2). Nickel/cadmium household batteries are the largest source of cadmium, accounting for an estimated 52 percent, while plastics contribute 28 percent. Along with the Bureau of Mines data, this information indicates that automobile batteries are the major source of lead in MSW, while household batteries are major sources of mercury and cadmium, and plastics are major sources of lead and cadmium, as well. One European study found that household batteries contributed the highest fraction of mercury, cadmium, zinc, and manganese in urban waste (55).

Little analysis of the contents of packaging has been conducted, but most of the materials used in packaging (i.e., paper, plastics, steel, glass) may be sources of toxic substances, particularly metals (28). Sources of lead in packaging include solder in steel cans, paint pigments, ceramic glazes and inks, and plastics. Sources of cadmium include the coating and plating on metals and pigments in some plastics. There also are many other additives in plastics (ch. 5).

Data on Organic Chemicals—Synthetic organic chemicals are used intentionally in many common consumer products-e. g., toluene in inks, formaldehyde in particle board and glues, chlorobenzene in cleaners, and methylene chloride in spray propellants (92) (also see ch. 3). The production of these chemicals has proliferated since the 1940s because of technological changes in invention and mass production. Relatively little information is available,

Figure 4-2—Distribution of Lead and Cadmium in Products



SOURCE: Franklin Associates, Ltd., *Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000, Executive Summary and Chapter 1*, Final report prepared for the U.S. Environmental Protection Agency, Municipal Solid Waste Program (Prairie Village, KS. January 1989).

however, on the end uses of organic chemicals in different products.

Determining which products are major sources of particular organic chemicals will involve substantial research. Other questions about organic chemicals need to be considered. Should chemicals used as ‘‘active” and “inert” ingredients in pesticides be counted?[5] How should the chemical form of the substance, exposure. and dosage be accounted for? In addition, obtaining information on particular ingredients can sometimes be difficult because of proprietary considerations. Still, existing regulatory lists at least provide some insight into usage of these chemicals.

Household Hazardous Waste Lists

EPA defines “household hazardous waste” as products discarded from residences which contain substances already regulated under RCRA as an industrial hazardous waste (89).[6] Over 100 substances classified as hazardous under RCRA are found in common household products (ch. 3). Although the list in chapter 3 is not comprehensive, it indicates the wide range of products that contain hazardous substances.[7] EPA also has compiled similar lists (89). One list covers household hazardous wastes; a second lists “household items that may be hazardous. ” EPA cautioned that not every commercial product of the general types listed contains the specific component.

Lists of these products also have been compiled by local or State organizations for use by consumers. Their formats vary widely. Most lists include categories such as automotive products (e.g., oils, batteries); cleaners (e.g., detergents, drain and oven cleaners); paints and polishes; pesticides and insecticides; and miscellaneous. One list gives each category a toxicity rating (39). Its rating system may be too simple because of the wide range of products and product compositions in each category, but it does provide consumers with some information about relative toxicity. Another example is a‘ Household Hazardous Waste Wheel” (19). This educational tool lists 36 types of products in four categories (house, auto, pesticides, and paint products) and identifies hazardous ingredients and their properties, management methods, and alternative products.

[5] Inert ingredients are inactive chemicals that facilitate the effects of active ingredients. They include solvents such ss water, baits for attracting pests, dust carriers such as clay or talc, tillers, wetting and spreading agents, propellants, and emulsifiers (10). EPA groups them into four lists, the first of which, for example, contains 57 of the most toxic inerts currently used in products.

[6] However, no Federal regulations exist for household hazardous wastes.

[7] The list does not include many pesticides, and it is restricted to hazardous wastes as defined by RCRA.

Some European lists of household hazardous waste contain items rarely found on U.S. lists. In West Germany, for instance, the product groups defined as household hazardous waste include fluorescent tubes and medicines (34).

Chapter 3 includes some data on the frequency at which these products (excluding automobile batteries) appear in residential MSW. For example, household maintenance and cleaner products are estimated to make up almost half of the household hazardous wastes discarded from residences.

Examples of Toxicity Reduction

Product reformulation is an ongoing process in industry, occurring continually for safety and market reasons. Various examples show that industry can use its creativity to develop new alternatives and reap spin-off rewards without loss of competitive position or jobs. For example, the use of chlorofluorocarbons (CFCs) as propellants in most aerosols was banned by EPA and the Food and Drug Administration in 1978 (22). Initially, the void was filled by hydrocarbons, which already were used in about half of the aerosol market and in pump sprays. The change also resulted in expanded commercial development of new products, new ways of applying materials, and new technology. More recently, plastics manufacturers are moving to eliminate the use of CFCs in the foam polystyrene used in fast-food packaging (ch. 5).

Investments in research and development on the reformulation of products is expensive and time-consuming, however. For example, according to the vice president of research and development at one company, approval of one pesticide for home use can sometimes take 10 to 15 years and cost $10 million (22).

In addition, many manufacturers argue that their products are unsafe only when they are mishandled and improperly discarded. For example, the Chemical Specialties Manufacturers Association argues that chemical specialty products, which often are included on household hazardous waste, are formulated to maximize their safety during use and minimize potential environmental effects (9).[8] To promote proper use of these products, the Association is supporting a program called 'Disposal: Do It Right," run by the Household Products Disposal Council. This group distributes information about the safety of chemical products and how to properly use and dispose of them.

Some manufacturers have made changes in the composition of products that ultimately become MSW. Some cases involve substances whose toxicity, given sufficient exposure and dosage, is undisputed, such as lead, mercury, and cadmium. For example, lead in exterior house paints has been replaced with titanium and zinc pigments (85) and the use of lead soldering in food cans has declined from 90 percent of such cans in 1979 to about 20 percent in 1986 (84). Box 4-C highlights another example, where Polaroid eliminated mercury in camera batteries by redesigning the battery.[9] Two other examples--efforts to reduce the use of lead in printing inks and the use of mercury in household batteries in general—are discussed below.

Organic chemicals also can be the targets of toxicity reduction efforts. For example, perchloroethane has been replaced with a water-based solvent in Dow's Spray 'n Wash product (7). Another example—Safer, Inc., which produces nontoxic garden insecticide products—is highlighted in box 4-D.

Often these types of substances are the focus of attention from environmental and public health interest groups, or potential targets of government regulations or bans. The household battery industry's voluntary program to reduce mercury, for example, is at least in part a response to questioning and concerns expressed by environmentalists and public health interest groups (60). In other cases, changes have been made more quietly.

Lead-Based Inks

Printing inks traditionally have contained lead. During the last 10 to 15 years, however, manufacturers and users of these inks have reduced the use of lead in response to customer pressure, concerns about employee health, technological changes, and concerns about industrial wastes. For example,

[8] Members of the Association manufacture, for example, detergents, disinfectants, deodorants, hair spray, waxes and polishes, roach killers, garden pesticides, and automotive products.

[9] OTA's highlighting of particular brand-name products does not in any way imply endorsement of those products.

Box 4-C—Polaroid's Mercury-Free Battery For Film Cassette

Household batteries are one of the most common contributors of mercury in MSW, and the popularity of cameras using small "button"' batteries has increased the potential for MSW problems from this source. The Polaroid Corp. has conducted extensive research to reduce the mercury content of its camera batteries. Special to the Polaroid case, however, is the fact that the battery providing power to run the camera's electronics, optics, and film transport is built into the film cassette itself. Thus, each time an empty film cassette is discarded, a battery is discarded as well. The system uses a carbon/zinc battery.

Part of Polaroid's motivation in developing reduced-mercury batteries was market-generated. Polaroid already had decided to reduce mercury in its products when, in 1986, the Swiss government issued regulatory requirements on household batteries. The requirements set limits on allowable concentrations of metals in various household batteries and required labels on batteries exceeding the limits to warn consumers to dispose of them separately because of concerns about the emission of metals from MSW incinerators. Although Switzerland accounted for only 1 percent of the company's market, the Swiss regulations are typical of guidelines being developed in other countries.

In early 1987, Polaroid was producing some batteries with 50 percent less mercury and by fall of that year all Polaroid batteries met this goal; mercury levels were reduced from 0.18 to 0.09 percent by weight. Other adjustments were still necessary, however, to meet the Swiss standard (i.e., combined weight of cadmium and mercury in carbon/zinc batteries not to exceed 0.025 percent). In April 1988, mercury was eliminated from all new Polaroid batteries and in 1989 new Polaroid film cassettes sold throughout the world will contain mercury-free batteries.

Polaroid's complete conversion to mercury-flee batteries took about 2 years; the cost of the research, development, and conversion reached several hundred thousand dollars. The relatively short time involved is somewhat misleading, however. Years of previous research set the stage for the conversion. Some side benefits were generated as well: for example, the new battery eliminated some of the costs previously needed to protect workers from mercury, reduced some waste treatment costs, and enhanced the potential to recycle battery components. These cost savings are expected to offset development costs in about 3 years.

SOURCE: H. Fatkin, Health, Safety & Environmental Affairs, Polaroid Corp., personal communication, August 1988 and February 1989.

printers of corrugated and kraft paper have reduced the use of lead pigments and shifted to water-based inks to eliminate the generation of hazardous wastes from the cleaning of press equipment and to comply with air emissions regulations for volatile organic chemicals (12). Companies such as Procter & Gamble have eliminated the use of metal-based inks for printing on packaging.

According to the National Association of Printing Ink Manufacturers (NAPIM), pigments with heavy metals such as lead are not widely used in printing ink today (47). In the mid-1970s, the American Newspaper Publishers Association (ANPA) prohibited the use of lead pigments in ANPA-approved newspaper inks and developed a logo to identify acceptable inks.[10] According to ANPA, most newspapers in the United States request inks carrying this logo (13, 47).

Lead is the dominant heavy metal used in chrome yellow and molybdate orange pigments; about 60 percent of the weight of these pigments is lead. NAPIM estimated that these two pigments comprised only 0.4 percent (3,300 tons) of all the printing ink produced in the United States in 1987. According to NAPIM, cadmium-based pigments are used only in inks where extreme chemical resistance is required (e.g., labels on acid bottles). NAPIM also contends that use of lead-based orange and yellow inks can be further reduced by using organic pigment substitutes, when exact color matches, opacity, and/or light fastness are not required properties in the printed product.

Household Batteries

Household batteries use several metals in their electrode systems (table 4-2), of which mercury and cadmium are of greatest concern. Data from the

[10] "Non-lead based" inks still can legally contain lead in concentrations below 600 ppm, however.

Box 4-D-Safer, Inc., Alternatives to Petrochemically Based Pesticides

In the mid- 1970s, two scientists in Canada began studying the use of naturally occurring fatty acids in killing specific insect pests. In 1978, these scientists formed Safer, Inc., a privately held company that is a developer and marketer of pesticides and plant-care products.

According to the company, its fatty-acid based pesticides products are specific to the targeted pest, degrade rapidly, and are 8 to 93 times safer (in terms of toxicity) than some commonly used petrochemically based pesticides. As such, they would be likely to have fewer of the disadvantages associated with the petrochemically based pesticides—indiscriminate effects on pests as well as beneficial insects (e.g., pollinating honeybees), birds, and pets; other environmental hazards such as water pollution; health hazards posed to persons applying the chemicals; and the development of pest strains resistant to the chemicals. However, they may take longer to achieve their desired effects than do the petrochemical pesticides. In addition, they are too expensive to be used commercially; the homeowner market is the largest market for Safer's products at this time.

Like the petrochemically based pesticides, Safer's pesticides are subject to EPA regulations under the Federal Insecticide, Fungicide, and Rodenticide Act. Because of the nature of the products, however, Safer's pesticides usually must undergo only the first of three levels of required testing; occasionally, a product will be reformulated if it is found to cause unacceptable skin irritation.

In addition to its these pesticides, Safer is exploring microbiological and biotechnological approaches to pest control. The company expects demand for these types of products to increase for at least three reasons: growing consumer awareness of the hazards associated with the use of petrochemicals, increased regulation of the pesticides, and initiatives such as California's voter-approved Proposition 65, which requires manufacturers to prove that substances used in products are not toxic. Safer is trying to develop markets with landscape companies, nurseries, and other commercial outlets, as well as in agricultural operations.

SOURCE: M. Goldberg, Safer, Inc., personal communication, August 1988.

National Electrical Manufacturers Association (NEMA) show that mercury use in household batteries is declining (figure 4-3), despite an overall increase in the number of batteries produced.[11] In 1983, 753 tons of mercury were used in U.S. production of household batteries, of which 49 tons were used in mercuric oxide button cells. This represented about 40 percent of all end uses of mercury (table 4-1).[12] NEMA estimates that in 1989, 168 tons of mercury will be used, a decline of 78 percent from 1983, with about 31 tons to be used in button cells.[13]

Thus, depending on the total amount of mercury used in the United States in 1989, household batteries might account for less than 20 percent of total consumption, although they still could be the major source of mercury in MSW. In addition, if the concentration of mercury per battery reaches some lower limit and overall battery sales continue to rise, then the total contribution of mercury could begin to rise again. This might be tempered by a shift toward rechargeable cadmium/nickel batteries and lithium batteries, but cadmium and lithium pose problems of their own (e.g., lithium is reactive with water).

Household batteries are changing in other ways. The service life of alkaline batteries has increased by up to 30 percent in recent years (48). Alkaline batteries have longer service lifetimes than do carbon/zinc batteries, and consequently their market share continues to increase while that of carbon/zinc batteries continues to decrease.

Changes in consumer electronic products also have had a large effect because they require more batteries and longer service lifetimes, as well as batteries of reduced dimensions. This has increased

[11] Mercury historically has been a component of batteries that use zinc as the negative electrode material. It reduces the tendency of zinc to react with other battery components. Information on recycling household batteries. including Japanese and European experiences, is discussed in ch. 5.

[12] In comparison, natural sources of mercury may be greater. The World Health Organization (96), for example, estimated in the mid- 1970s that about 30,000 metric tons of mercury were deposited annually in rain. Of course, those amounts were dispersed over the entire global surface.

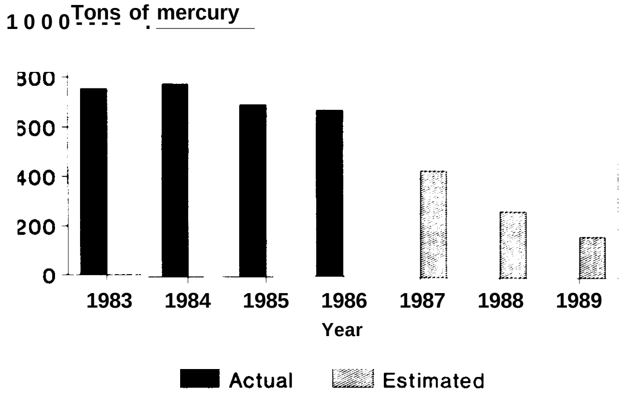
[13] Mercuric oxide button batteries are being replaced slowly by newer systems such as zinc/air batteries.

Table 4-2-Electrode Systems of Common Household Batteries

Battery type	Electrode system
Cation/zinc.	Zinc, manganese dioxide, and either zinc chloride or ammonium chloride
Alkaline/manganese . .	Zinc, potassium hydroxide, and manganese dioxide
Mercuric oxide	Zinc, potassium hydroxide, and mercury oxide
Silver oxide	Silver oxide and either potassium hydroxide or sodium dioxide and zinc
Zinc/air	Zinc, potassium hydroxide, and oxygen
Nickel/cadmium	Cadmium hydroxide, potash lye, and nickel hydroxide
Lithium	Lithium and one of manganese dioxide, carbon monoflouride, bismuth trioxide, thionyl chloride, or sulfur dioxide

SOURCE: Organization for Economic Cooperation and Development, *Fate of Small Quantities of Hazardous Waste,* Environmental Monographs No. 6 (Paris: August 1986).

Figure $3-Trends in Use of Mercury in Household Batteries in the United States



SOURCE: National Electrical Manufacturers Association, personal communication, February 1989.

batteries and longer service lifetimes, as well as batteries of reduced dimensions. This has increased the use of rechargeable batteries, which cost more and require a recharger but which can be used hundreds of times (44). Rechargeable batteries are most often used as built-in components in appliances. Currently, most are nickel/cadmium batteries, and NEMA estimates that 75 to 80 percent of the nickel/cadmium batteries used by consumers are built into and sealed inside of appliances. This means, however, that when these products are discarded, most of the cadmium in the batteries is also discarded.[14] Rechargeable lithium batteries are not expected to begin displacing nickel/cadmium batteries for several more years. Another development is the potential commercialization of plastic casings on household batteries (44).

As batteries change, the evaluation of whether or not toxicity reduction is occurring has to be assessed on the basis of the toxicity of the substitute materials. Lithium batteries do not contain cadmium, mercury, or lead, but lithium compounds are reactive with water and they can affect the nervous system. Zinc/air batteries contain mercury, but in smaller amounts than the mercuric oxide ones they replace. Information about substitute materials for mercury is proprietary, however, and this makes evaluations of toxicity reduction difficult.

Consumer Purchasing Decisions

Consumers have the option to make purchasing choices about products on the basis of toxicity. Not surprisingly, public opinion favors the opportunity to purchase products that pose fewer potential risks when discarded. In a 1987 survey conducted in Massachusetts, 95 percent of the respondents wanted manufacturers to develop substitute nonhazardous products (71). Over three-fourths (77 percent) preferred this to redesigning the original product to have a lower concentration of the toxic substance in question.

Making wise purchasing decisions, however, is not easy. For instance, many household cleaners are considered to be potential household hazardous wastes, but a glance at cleaners in any store will confuse even knowledgeable consumers. Some products contain no information about their contents. Some have cautions about proper use of the product and warn against direct contact, implying toxicity. Other products contain a long list of chemicals that to most consumers is “chemical mumbo jumbo. ”

Lists of household hazardous wastes are one source of information about alternative products. Consumers armed with these types of lists can make better decisions about the products they bring into their homes than they can by relying on current

[14]NEMA estimates that collection programs for cadmium batteries that are not sealed inside appliances would account for less than 5 percent of all cadmium consumed in the United States (48).

labeling information. Developing effective methods to convey toxicity information on product **labels would be of great use to consumers willing to change their purchasing patterns.**

Another example of a choice available to consumers, if they were given adequate information, concerns bleached (i.e., white) and unbleached paper products. Small quantities of dioxin have been found in wastewater from the bleaching of wood pulp necessary to make white paper. Informed consumers might opt to buy common products (e.g., paper plates, coffee filters, tissue, and sanitary papers) made from unbleached paper, regardless of their brownish color, if they knew this fact. In Sweden, gift wrapping paper, coffee filters, and other products made from unbleached paperboard are now available. However, this trend is occurring at least in part because unbleached board is stronger and cheaper than bleached paper and often is not a visible component of packaging.

QUANTITY REDUCTION

In essence, reducing the quantity of the Nation's MSW involves changing the nature of many common products, including packaging. It can occur, for example, if the lifetime of a product is held constant while its weight or volume is reduced, or if weight or volume are held constant while the lifetime is increased.[15] In addition to products, materials such as yard wastes can also be the focus of prevention efforts (i.e., through comporting in residential backyards).

Discussions about quantity reduction often focus on packaging, which makes up about 30 percent of all MSW by weight. OTA believes, however, that attempts to reduce MSW should consider all components in the MSW stream, rather than only packaging. For example, paper and paperboard products make up over one-third of MSW by weight, and much of this is not packaging. Yard wastes comprise another 20 percent or so on average, and more so in certain areas or at certain times of the year (chs, 3 and 5). In fact, given the changes in social attitudes and behavior that are required, it seems likely that quantity reduction will best be achieved through many small cumulative changes in product design and consumer behavior. This approach is more likely to have greater impact than focusing only on packaging because no one product or industry group is singled out for undue attention.

Measuring changes in MSW generation will be difficult, given current definitions and methodologies (chs. 1 and 3). Small changes in generation rates are likely to be masked by sampling errors and natural fluctuations. In addition, it is not always obvious what constitutes quantity reduction.

The information needed to make decisions about which products to target for reduction efforts is complex. Useful information would include:

- types, composition, and amounts of products being produced;
- how consumption of products is changing over time;
- why certain products are purchased and who buys them;
- feasible alternatives to current products;
- consumer behavior after products are purchased;
- disposal costs relative to product durability and toxicity; and
- full costs of disposable and reusable products.

Obtaining such complex data is difficult. Cost estimates must account for use of energy and materials, labor, waste management, and equipment. And these must be considered over the entire lifecycle of a product, from virgin material extraction or secondary material recovery, through processing, manufacturing, and use for final products.

Deciding What Products and Materials to Target

If the Federal Government develops policies to emphasize MSW quantity reduction, it will have to decide how to measure reduction and which products and materials to target. This section discusses: 1) difficulties in measuring quantity reduction; 2) national estimates regarding products in MSW; and 3) factors influencing producer and consumer decisions.

[15] In addition, the effect of such changes on the toxicity of the products must be considered.

Measuring Quantity Reduction

One critical question is how to measure a reduction in quantity. Small changes in MSW generation are difficult to detect because of problems stemming from the different definitions and sampling methodologies used in studies of MSW generation (ch. 3). Any sampling methodology, no matter how standardized, also is subject to sampling error, and this source of variability can sometimes overwhelm detection of real changes.

A related problem concerns measuring MSW by weight versus volume. Most MSW analyses, including the EPA/Franklin model (ch. 3), are based on weight, yet MSW volumes may change independent of weight. The use of lighter but higher volume materials appears to be increasing, for example, in the case of plastics replacing glass containers. Volume data are more important than weight data for some MSW management decisions (e.g., for estimating landfill capacity) and thus are important for quantity reduction efforts. However, comprehensive data on the volumes of products and materials simply are not available.

The degree to which materials can be compacted also complicates the interpretation of data about MSW quantity. The volume of MSW depends at least in part on its compactability and the degree to which it is actually compacted. As noted in chapter 3, there is some evidence that plastic bottles are more readily compacted in landfills than are glass bottles. The design of collection vehicles also is usually based on volume capacities, but vehicles using public roadways can be limited by their total tonnage.

Another factor to consider is whether reducing a product's residuals that become MSW causes any change in the overall amount of waste generated in its production. For instance, improvements in packaging have decreased food spoilage and thus decreased food wastes, but it is possible that the production of the packaging itself causes an increase in industrial waste generation.

No matter what type of strategy is pursued, there obviously are many factors to consider. Some criteria to help target products for quantity reduction might include (94):

- the amount and scarcity of feedstock materials and energy required for manufacture;
- the volume of a product and its manufacturing byproducts that will have to be discarded;
- the difficulty and environmental impact of disposing of a product and its manufacturing byproducts;
- the useful life, reusability, or recyclability of a product; and
- the availability of alternatives.

These are reasonable criteria, yet their very nature indicates just how difficult it is to evaluate the potential for quantity reduction,

National Estimates About Products in MSW

The EPA/Franklin model (ch. 3) estimates the portions by weight of different categories of products in MSW. It indicates that the largest component of MSW is, has been, and will continue to be packaging and containers (table 4-3). By 1986 packaging and containers had leveled out at 30 percent of all MSW, where it is projected to remain to 2000. The second largest category typically has been nondurable, and this is the only major category whose relative proportion is estimated to be growing. The relative proportion of food wastes is estimated to be declining.[16]

In terms of absolute weight, all major categories except food waste are expected to grow (table 4-4). The model also includes information about various subcategories of products. For example, subcategories of MSW that are expected to increase by more than 10 percent by the year 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, plastic containers, and other plastic packaging (ch. 3). Beer and soft drink aluminum cans are expected to increase 14 percent from 1990 to 1995, while all aluminum was expected to increase 18 percent in the same period.

Several caveats must be noted, however. First, because the data are in terms of weight, the

[16] Food wastes could be decreasing because of increased use of sink garbage disposals, better packaging, or increased consumption of pre-prepared meals are resulting in less spoilage.

Table 4-3-Estimated Proportion of Products and Other Materials in MSW, By Decade and Including 1986, After Materials Recovery

Category	Percentage (by weight)					
	1960	1970	1980	1986	1990	2000
Durables[a]	11.1	12.4	13.8	13.6	13.6	13.6
Nondurables[b]	18.5	19.0	22.1	25.1	25.8	28.1
Containers & packaging	29.4	34.9	32.6	30.3	30.5	30.3
Food wastes	14,9	11.4	9.2	8.9	8.4	8.9
Yard wastes	24.5	20.6	20.5	20.1	19.8	20.1
Miscellaneous inorganics	1.6	1.7	1.7	1.8	1.9	1.8

aDurables include major appliances, furniture, tires, and miscellaneous items such as sporting equipment, hobby supplies, toys, jewelry, consumer electronics, and watches.
bNondurables include paper products such as newspapers, books and magzines, officpaper and commercial printing, tissue, towels, plates and cups, plus clothing and footwear.

SOURCE: Franklin Associates, Ltd., *Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988),* report prepared for the U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response (Prairie Village, KS: Mar. 30, 1988).

proportions can be biased toward categories with materials that tend to be heavier. This may give greater emphasis to the durables and packaging categories. For instance, paper comprises the largest materials group within the nondurable category, but it is lighter than materials such as glass and metals. Also, the EPA/Franklin model has some acknowledged limitations that could affect these estimates (ch. 3).

Another problem is that national estimates cannot account for variations in the composition of products in local MSW. Local studies show wide variations in the portions of **materials** in MSW (ch. 3) because of differences in both local conditions and sampling methods. However, few studies examine **products** at a local or State level.

Factors That Affect Consumer and Producer Choices

Many factors can affect the decisions made by producers and consumers, and often they can act as constraints on MSW prevention. Several factors that appear to influence MSW per-capita generation rates—household size, degree of urbanization, socioeconomic status, and demand for convenience—were discussed in chapter 3. Some additional factors that influence MSW generation rates are discussed here. Although these factors all can influence per-capita generation to some degree, it is not clear how they interact.

Information Availability-Consumers rarely are provided with information that allows them to make product purchasing decisions based on the idea of reducing the toxicity or quantity of products discarded in MSW. Instead, and not unreasonably, they make choices based on product quality, convenience, attractiveness, and price. Consumers could be encouraged to include MSW prevention in their decisionmaking in the same way that other changes (e.g., in diet) are encouraged—primarily by education, information, and example. This is one rationale for some of the options discussed in chapter 1, such as an information clearinghouse and labeling programs. This assumes, however, that alternatives do exist and that consumers have knowledge about these alternatives.

Product Cost Factors—Several factors influence product cost and also inhibit quantity reduction. For example, products that last longer because of higher quality manufacturing often have higher purchase prices. However, these products may not always be affordable to all consumers. Thus some consumers, out of necessity, choose cheaper, less durable products. Another example involves buying food products in large containers or in bulk, which can result in less packaging per product. Some consumers cannot afford to buy larger amounts due to low cash flow, lack of storage space at home, or the need to reach shopping areas by foot or bus.

Purchase price is not always a guide to longer lifetimes, however, and consumers often lack the information needed to compare lifecycle costs with purchase costs. For instance, most battery manufacturers offer several grades of batteries, but they do not give the consumer enough information to know

Table 4-4-Estimated Percent Change In the Total Weight of Products and Other Materials in MSW, By Decade

Category	Percent change in total weight, by decade			
	1960-70	1970-80	1980-90	1990-2000
Durables	34	14		14
Nondurable	27	19	35	25
Containers & packaging	41	5	13	15
Food wastes	5	-7	5	-2
Yard wastes	2	3	11	9
Miscellaneous inorganics	21	14	22	16

SOURCE: Franklin Associates, Ltd., *Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988),* report prepared for the U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response (Prairie Village, KS: Mar. 30, 1988).

whether a $2 battery will last more than twice as long as a $1 battery.

Another factor is the cost of repair versus replacement. Replacement costs today tend to be less than repair costs. This may result from the difference between lower foreign labor costs for production and higher domestic labor costs for repairs, or the difference between automated production costs and manual repair costs. Whatever the reasons, it encourages consumers to throw items away and replace them rather than get them repaired.

Advertising-Whether consumers make decisions about products because they are influenced by advertising, or whether advertising is geared to respond to consumer demands is arguable; both occur to some extent. Some researchers studying packaging characterize consumer demand for convenience as being very *strong* **(69).** At the same time, however, consumers also demand products that are safe, functional, and aesthetically appealing. Moreover, consumer boycotts demonstrate that moral values can be attached to certain products regardless of their marketing methods.

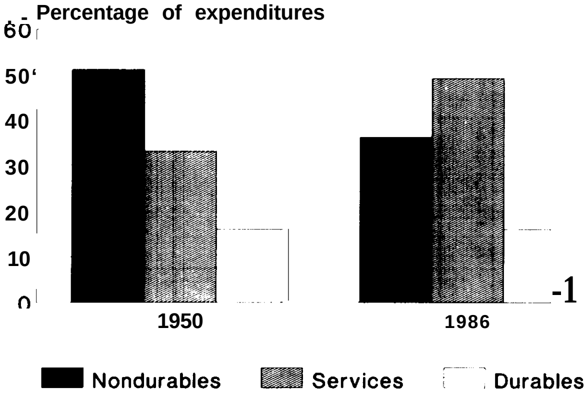
Of greater significance, however, is that advertising has rarely, if ever, used reduction of MSW toxicity or quantity as a selling point, even though over $50 billion are now spent on national advertising each year (82). Some producers told OTA that industry does not promote its good actions because the public regards such advertising as self-serving, or that consumers do not care and thus such advertising does not help to sell products (79). However, some advertising of this sort has occurred, for example, chemical manufacturers' slogans for better living based on better chemistry.

Overall Consumption Patterns-Disposable personal income in the United States grew from $716 billion in 1970 to $3.02 trillion in 1986, while personal savings as a percent of this income declined from 8 to 4 percent in 1986 (82). This means that we now are spending more of our income on goods and services.

One outcome of increased consumption is that households today tend to have multiple sets of some consumer products. Since 1975, for instance, the average number of television sets has increased by 20 percent, to almost 2 per household (82). Increased ownership of goods can increase MSW generation when this kind of consumption encourages other purchases (e.g., records and tapes) that generate packaging waste. In addition, changing fads and technological advances can increase MSW by encouraging the replacement of goods that are still usable but "out of style. " For example, the anticipated introduction of high-definition TV in the 1990s may render current TV sets obsolete or at least more likely to be discarded.

Historical data also show that since the 1950s personal consumption expenditures have shifted among durables, nondurable, and services (figure 4-4). The shift toward services may be moving some MSW generation from households to institutions and also may be increasing certain kinds of wastes. For instance, Americans spent 55 percent more for meals and beverages purchased outside the home in 1986 than in 1980, and franchise restaurants grew from 33,000 in 1970 to an estimated 86,000 in 1987 (82). This results not only in the shifting of some food waste generation from households to restaurants, but also in the perception that packaging wastes and litter have increased.

Figure 44-Shifts In Personal Consumption



SOURCE: U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States, 1978*, 99th annual edition (Washington, DC: U.S. Government Printing Office, September 1978); U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States, 1988*, 108th edition (Washington, DC: U.S. Government Printing Office, December 1987).

Product Trends

Examining trends in the production and consumption of different categories of products can help identify potential targets for efforts to reduce MSW generation. This section discusses trends in the following categories: packaging, 'single-use' products, reusable products, mail and telephone books, and miscellaneous technological changes.

Packaging

Packaging refers to materials used to prepare finished goods for shipment, distribution, storage, merchandising, and end use (41). In 1986, an estimated $55 billion was spent on packaging—about 4 percent of the value of all finished goods made in the United States (41). Slightly more than half of these expenditures are on packaging for food and beverages.

Functions of Packaging-Packaging consists of all kinds of containers (e.g., boxes, jars, cans, bottles, and bags) and packing materials made from a variety of materials (e.g., paper, plastic, glass, and metal) .*7 Packaging is used for multiple purposes (12, 69), including:

- protection during shipping and shelf-life;
- protection to prevent tampering;
- prevention of food spoilage;
- compliance with government regulations;
- provision of information;
- protection of consumers against toxic contents;
- attractiveness and merchandisability; and
- provision of convenience.

For example, one recent trend has been toward self-service shopping, accompanied by an increase in mass merchandising and a decrease in the number of sales people (e.g., modern home centers have replaced many traditional hardware stores). This has contributed to increased pilferage in retail stores and, consequently, to an increase in protective packaging for thousands of products. Shoplifting, for example, accounts for 27 percent of theft losses in supermarkets (employee theft accounts for 53 percent) (26). Even a small amount of pilferage may represent a large portion of a company's profit margin.[18] The functions of packaging are often interrelated. For example, the use of plastic wrap and bags helps decrease food spoilage, which reduces the generation of food waste from households (12), and these materials make it easier to display the products and information about the contents.

Defining Excessive Packaging-One major complaint heard about packaging today is that it is ''excessive. However, what one person views as excessive may be considered necessary by another person. Defining excessive is particularly difficult because packaging serves so many functions simultaneously.

The "blister pack" (i.e., packaging made of semi-rigid clear plastic that encases small products) illustrates this difficulty. This form of packaging offers several advantages: it allows small items to be sold in self-service displays, thereby reducing the need for employee service, and it helps avoid pilferage. The package also provides space for information about the product. Although most of the marketing and convenience value accrues to the

[17]The packaging industry characterizes packaging into three basic groups (54)—primary (i.e., a package such as a bottle, can, or box *that* is *in* direct contact with the product), secondary (i.e., packaging such as a six-pack that unites several primary packages), and tertiary (i.e., packaging that seines to transport products from manufacturers to retailers).

[18]OTA attempted to quantify total retail losses resulting from pilferage but was unable to do so.

retail store, cost savings from reduced pilferage can be passed on to consumers. However, the common perception is that this type of packaging is wasteful because once removed it is discarded.

Indeed, how quickly packaging enters the MSW stream is one criterion for evaluating packaging. For example, packaging that serves only to transport a product must be removed in order to use it. In some cases, this packaging can be recycled; for example, the recycling rate for corrugated cardboard used in packaging is relatively high (ch. 5). In other cases, as with the blister packs, the packaging ends up in landfills or incinerators.

Industries generally respond to charges of excessive packaging by stating that profit factors already drive them to design minimal packaging. It is true that the amount of materials used in packaging has been reduced in some instances. However, this argument is not valid for all products. For example, the higher profits obtained from cosmetics, fragrances, and luxury goods can justify packaging that is more than minimal. As an example of an extreme, one cosmetic product includes a cellophane wrap, a cardboard box, a corrugated sheet to protect the mirror, and a plastic container (62).

In the 1970s, EPA suggested that the communication and convenience functions of packaging could be better targets for eliminating excessive packaging than would be the protection function (87). Recent analyses by academic researchers agree, but they also note that reducing convenience could create enormous consumer outcry (69).

This suggests that prevention efforts might be served best not by having the Federal Government define excessive packaging, but instead by having it concentrate on getting MSW-related criteria incorporated into decisions about packaging design. For example, the government could provide incentives for manufacturers to consider packaging reduction in their designs; the government also could periodically evaluate packaging from an MSW prevention perspective. In addition, industry efforts to develop such criteria could be encouraged. These and other policy options are discussed in chapter 1.

Data on Packaging and Containers—Table 4-5 presents data from the EPA/Franklin model about packaging and containers. Paper packaging is the largest subcategory, comprising over one-half of all packaging and almost 20 percent of all MSW by weight. Together, corrugated boxes and glass containers make up almost 60 percent of all packaging. Packaging made of plastics, a target of many community bans, amounts to about 4 percent by weight of all MSW, although its share may be increasing.[19]

Before targeting any of these subcategories for reduction, various trade-offs need to be considered. For example, eliminating all plastic packaging apparently would reduce MSW generation by 4 percent by weight. However, in reality the replacement materials are likely to be heavier and thus could actually increase MSW, at least in terms of weight. The use of lighter-weight materials such as plastics and paper has brought cost savings to manufacturers and retailers, and it has decreased concerns about breakage of glass bottles. Other concerns (e.g., litter, recyclability), however, again illustrate the trade-offs that need to be balanced.

Eliminating plastic packaging might even increase the volume of MSW. For example, corrugated cardboard boxes, which make up 67 percent of paper packaging and 12 percent of all MSW by weight, are being replaced in part by shrink-wrap film in combination with a cardboard or rigid plastic tray, in consumer products such as baby food jars and canned food (72, 73). The newer packaging makes it easier to display products. It also takes up less volume when discarded and thus can lower disposal costs. One study estimated that the use of multimaterial flexible packages in place of metal cans and glass bottles can bring savings in the costs of transporting filled and empty containers, even though the replacement material is more expensive to produce (72). A West German study estimated that replacing plastic with other materials would increase the weight of packaging by a factor of 4, volume by a factor of 2.5, and use of energy during production by a factor of 2 (31).

One packaging change that can negatively affect both MSW generation and recycling, however, is the

[19] For example, discards from households in Tucson, Arizona, exhibited an increase in the weight of plastic from about 5 percent in 1978 to 10 percent in 1988 (95). The increase was attributed to the replacement of glass and metals in packaging by plastics.

Table 4-5 Estimated Weights and Percentages of Different Containers and Packaging in Gross Discards of MSW, by Material, in 1986

	Amount in thousands of tons	Percent of material category	Percent of containers and packaging	Percent of gross discards
Glass:				
Beer & soft drink bottles	5,543	47.0		3.5
Wine & liquor bottles	2,135	18.1		1.4
Food & other bottles/jars	4,128	35.0		2.6
Subtotal	11,806		22.1	7.5
Steel:				
Beer & soft drink cans	118			0.1
Food cans	1,777	62.7		1.1
Other nonfood cans	747	26.4		0.5
Barrels, drums, pails	91	3.2		0.1
Other steel packaging	101	3.6		0.1
Subtotal	2,834		5.3	1.8
Aluminium:				
Beer & soft drink cans	1,317	78.8		0.8
Other cans	50	3.0		0.0
Aluminum foil..	302	18.1		0.2
Closures	3	0.2		0.0
Subtotal	1,672		3.1	1.1
Paper & paperboard:				
Corrugated boxes	19,444	66.9		12.3
Other paperboard	5,440	18.7		3.4
Paper packaging	4,163	14.3		2.6
Subtotal	29,047		54.5	18.4
Plastics:				
Containers	2,871	50.0		1.8
Other packaging	2,798	48.7		1.8
Other miscellaneous	73	1.3		0.0
Subtotal	5,742		10.8	3.6
Miscellaneous other:				
wood	2,101			1.3
Rubber/leather	13			0.0
Textiles	103			0.1
Subtotal	2,217		4.2	1.4
Total	53,318			33.8

SOURCE: Franklin Associates, *Ltd., Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update* 1968), report prepared for the U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response (Prairie Village, KS: Mar. 30,1988)

trend toward wrapping products (by both manufacturers and retailers) in multiple layers of packaging or making containers with multiple materials. When this causes the size of the package or the complexity of the design to increase, subsequent MSW generation can increase (although by how much is unknown) or, in the case of multi-material products, recycling can become more difficult.

Beverage Containers.—The use of materials in beverage containers has changed dramatically during the past 20 years. In particular, the use of plastic in containers is increasing. This trend is difficult to quantify on a national basis; the EPA/Franklin model does not estimate the amounts of paper or plastics used specifically for beverage containers, although it does do so for glass, steel, and aluminum.

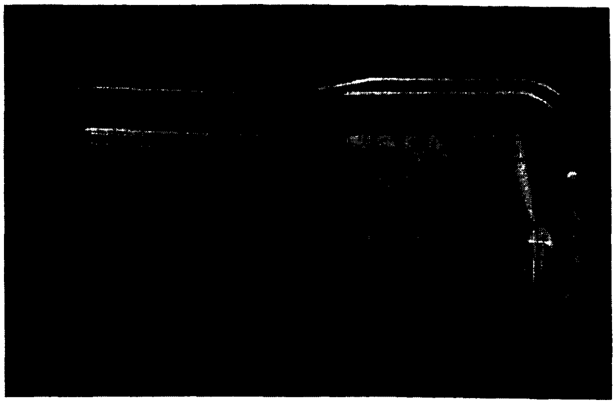
Based on data from the model (table 4-5),the total weight of beverage containers is estimated to be between 5.8 and 1l.0 percennt with an amount nearer the lower figure more likely. Glass bottles for beer, wine, and soft drinks account for 3.5 percent; steel cans for beer and soft drinks account for 0. 1 percent; and aluminum cans for beer and soft drinks account for 0.8 percent. The amount of paper (e.g., for milk cartons) could be as high as 3.4 percent but probably is lower (because the category "other paperboard" contains nonbeverage containers), while the amount of plastic could be as high as 1.8 percent.

In some cases, lighter-weight materials may not be used because they do not impart the proper image. For example, plastic is sometimes viewed as a low value material, while glass is considered by some customers to impart a quality or premium image (83). Glass and ceramic jars dominate in the imported and gourmet foods markets and for some cosmetic products.

Food Packaging—It is difficult to estimate how food packaging is changing overtime. Data from the EPA/Franklin model suggest that food packaging comprises 10 percent or more of MSW by weight. According to the model, steel food cans and glass food jars for nonliquid products make up another 3.7 percent (table 4-5). In addition, about 12 percent of all MSW is corrugated cardboard, and one representative of the packaging industry estimated that up to one-half of this-or 6 percent of MSW—might be used for food packaging (1). The amount of other paperboard and plastic used in food packaging cannot be estimated.

Some visible changes in food packaging have occurred. Consumers are buying more "ready to eat" foods and "fast-food" meals.[20] Changes in packaging have made such foods convenient to purchase, prepare, and eat, as well as last longer. The use of plastic packaging is increasing, and many consumers prefer plastic containers for a variety of foods (20). These changes have increased the amount of packaging entering the MSW stream, but at the same time packaging manufacturers have reduced the amount of material used in other packages.

The phenomenal growth in the use of microwave ovens is having a striking effect on food preparation and packaging design. In 1986, almost 21 million microwave ovens were imported or produced in the United States, twice the amount than in 1983 (82). One survey indicated that 83 percent of all respondents had microwave ovens (20). Microwaveable products often tend to use "container cooking" packaging: they include a cooking/serving dish and several layers of plastic and paper wrapping to preserve the contents, improve the effectiveness of the microwave as a heat source, make the product table-ready, and eliminate the need for dishwashing.



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Reducing this type of packaging is a challenge, but it would be possible. For example, MSW would be reduced if a dish was not included with every purchase or if the functions of the wrappers were restricted to protection. Durable cooking ware also could be designed so that microwaveable food could be packaged in simple pouches, ready to be placed in reusable ware for cooking.

Shipping Packaging-Packaging used in shipping is undergoing changes that reduce the weight of the materials used. This reduction is related to the development and use of new materials and designs that decrease transportation and waste management costs to manufacturers, wholesalers, and retailers (72). For example:

- General Motors introduced reusable, collapsible or stackable boxes to replace expendable corrugated boxes for parts delivery from its suppliers;
- Nordyne ships mobile home air-conditioner and furnace units that are shrink-wrapped with plastic onto pallets, with comers, tops, and bottoms protected by corrugated cardboard; and

[20] This also could be shifting some generation of food waste from residences to the industrial and commercial facilities that prepare such foods.

Photo credit: Office of Technology Assessment

Infants wearing single-use, disposable diapers are a common sight. Consumers like these diapers because of their convenience and buy more than 18 billion every year. The total cost of using a diaper service for the cotton equivalent of disposable diapers appears to be less than the cost of buying and disposing of the disposable diapers.

- Gerber has adopted a distribution package for glass jars that includes shrink wrap and a corrugated tray but does not require corrugated partitions between the bottles.

Changes in the design of containers can eliminate the need for some shipping packaging. For example, interlocking plastic bottles have been introduced to reduce packaging costs for the beverage industry. This eliminates the need for cartons, overwraps, and plastic straps, although trays may still be needed to support the weight of multiple containers (25).

"Single-Use" Products

Products that are used once and discarded have become ingrained in our society, replacing similar products with longer lifetimes. They are often called "disposable" or "throwaway'" products, but because all products and packages are ultimately disposable, OTA generally calls these "single-use' products. They include some diapers, plastic and paper plates and cups, single-use razors, plastic utensils, and many other products, even some cameras and flashlights. One product that has received particular attention is polystyrene foam cups (ch. 8). (See box 4-E.)

One appeal of single-use products is convenience—they help people save personal time and help retailers save labor costs. For example, a paper or plastic plate, cup, or utensil does not have to be washed and stored; a single-use camera does not require time to replace film. Another appeal is purchase price. Often they can be purchased for a fraction of the initial cost of the alternative reusable product. For example, a new single-use baby bib designed for newborn babies to 18-month-old babies sells in packages of one dozen for less than $2 (52).

Single-use products make a substantial contribution to the U.S. economy. For example, sales of single-use razors are around $100 million per year (3), and sales of single-use diapers are around $4 billion (43).

The one single-use product that makes the largest identifiable contribution to MSW generation is the single-use (disposable) diaper. Consumers buy more than 18 billion disposable diapers every year, and these make up about 2 percent of all MSW and perhaps 4 percent of all residential MSW (43) (ch. 3). The annual lifecycle cost of all single-use diapers, including landfilling costs, have been estimated to be about $3.9 billion (43).

In contrast, a diaper service can reuse a cotton diaper about 150 times, resulting in fewer diapers being sent to landfills and in fecal material being sent for treatment at municipal sewage treatment plants. The costs of washing (including electricity, labor, profit, and waste water processing) the cotton

Box 4-E—Foam Polystyrene Packaging

Public concern about foam polystyrene (PS) packaging (e.g., fast-food containers and meat trays) originated over the use of chlorofluorocarbons (CFCs) as blowing agents and the impacts of CFCs on ozone depletion and global warming. New concerns about the volume of PS packaging in landfills have increased the visibility of this issue. As a result, PS packaging has been the target of legislative bans in several States and localities (ch. 8).

The actual use of CFCs in foam products is relatively small and foam PS accounts for only 2 to 3 percent of the use of CFCs. The use of CFC- 11 and CFC-12 ended voluntarily in 1988 for most foam PS packaging associated with food products. Some foam PS products, such as most molded foam cups, do not use CFCs as the blowing agent; these typically use other hydrocarbons such as pentane. More significant uses of CFCs are in refrigeration, air-conditioning, and polyurethane production.

Similarly, PS comprises a small percentage of all plastics produced and those that are discarded in MSW. By weight, plastics contribute a relatively small portion of MSW, around 7 percent. About 2 million tons of PS (both rigid and foam) were consumed in the United States in 1987 (68)-about 10 percent of all plastics used and about 15 percent of the plastics used in packaging and in consumer and institutional markets (ch. 5). Half of this was used in durable products including appliances, building and construction, toys, and housewares. Packaging and single-use disposable products comprised the other half.

The foam PS portion in packaging and single-use products has attracted considerable recent attention. About 230,000 tons of foam PS are used in single-use products such as cups, plates, and clamshells. Almost 30 billion hot drink foam cups are used and discarded each year, but their overall weight amounts to less than 100,000 tons (l). About 220,000 tons of foam are used for packaging such as trays (for meats, poultry, and fish), molded cups, and loose packaging fill. Given these low numbers, it is not surprising that data from landfill excavations show the total amount of fast-food packaging (both paper and plastics) in landfills to be very small, about 0.25 percent by both weight and volume (59).

Nevertheless, the actual and proposed bans on foam PS have demonstrated how industry can respond relatively quickly to change to alternative production materials and begin establishing pilot recycling programs. For example, industry has responded to the CFC concern by substituting other blowing agents. By the end of 1988, CFC- 12 was no longer used in most foam PS food packaging, including foam cups, sandwich cartons, trays, and carry-out containers; it was replaced with hydrochlorofluorocarbon-22, which has 5 percent of the ozone-depletion potential of CFC- 12. Manufacturers of egg cartons and meat trays are working to phase out the use of CFC- 12 by the end of 1989. However, some substitutes for CFC blowing agents create their own problems for recycling. At least one company had to eliminate the recycling of foam PS industrial scrap because the new hydrocarbon blowing agents (pentane, butane, and propane) were flammable and the recycler could not afford to modify its equipment with appropriate safety features.

equivalent of 18 billion disposable diapers might be about $2.3 billion.[21]

These estimates, however, do not account for differences in external costs (i.e., pollution) from the initial extraction, transportation, or manufacturing of raw materials into either disposable or cotton diapers. They also do not account for differences in how a baby's skin responds (e.g., fewer rashes occur with the single-use diapers) or for the appeal of convenience. In addition, newer highly absorbent single-use diapers require fewer changes than older versions; if this reduced the number of changes by one-half, then the overall costs of single-use and cotton diapers would be about the same. Even then, however, more single-use diapers would end up in landfills, while washable diapers could still be reused (and their fecal content sent into the sewer system for appropriate treatment).

Longer-Lived and Repairable Products— Changes in product durability or lifetime usually are caused by intentional decisions about product design. For example, single-use products usually are less durable and have shorter lifetimes. In addition, many single-use products are designed with no intention of repair because the cost of purchasing a replacement is less than the cost of repair. Examples include

21 Lehrburger (43) calculated a cost of $227.8 million, but OTA'S calculations indicate an error by a factor of 10.

small consumer electronic products (e.g., hand calculators), home and beauty care appliances, and disposable cameras. Many of these products cost less than $20. Another example is plastic throwaway telephones; one company was reported to be selling this item at the rate of 8,000 units per month in 1987 (35).

Manufacturers in the United States are attempting to improve their competitiveness in international markets. Two associated concepts have the potential to reduce MSW generation, although waste prevention is not an intentional consequence. First, quality manufacturing can result in products that last longer. One U.S. company that promotes a strategy based on increased product lifetimes and, consequently, less MSW generation is the Maytag Corp., whose image is based on making long-lived appliances. Second, improved design can also bring less waste and increased industrial competitiveness (6). For example, steel-belted tires last longer than their predecessors, so the generation of waste tires might be lowered.

Increases in durability, however, do not always reduce MSW generation. For example, longer-lived tires are subject to more stress over their lifetime simply because they are longer-lived. Tire manufacturers addressed this partly by increasing their use of new synthetic and natural rubbers, which in turn led to a decline in the recycling of rubber from old tires (57). In addition, steel-belted tires are more difficult to recycle than are rubber tires.

One way to encourage manufacturers to consider MSW issues when they design products would be to offer awards to stimulate higher quality manufacturing. This is done already in some areas. For example, the Department of Commerce awarded the first Malcolm Baldridge National Quality Awards in 1988.[22] Although reducing waste is not one of the seven criteria for the award, increased quality can bring increased product durability and reduced waste. Motorola, Inc., a 1988 award winner, has a quality goal of 'zero defects in everything we do," including product performance.

Reusable Products

Systematic reuse of products such as refillable beverage bottles could effect MSW generation, but it is a practice that is disappearing as single-use products gain in popularity. It is instructive to consider the benefits and costs of returning to reuse systems.

Beverage Bottles-Many people recall the days when it was common practice to have residential delivery of milk and when most soda and beer bottles were refillable. Both systems required that empty bottles be returned for washing and refilling, which helped avoid replacement costs for discarded bottles and also helped (even if unintentionally) internalize the costs of waste management.

In the late 1940s, almost all beer and soft drinks were sold in refillable bottles, but during the 1950s the share of nonrefillable bottles and metal cans increased (57). Data from the soft drink industry show that by 1986 only 14 percent of the volume of soft drinks was packaged in refillable glass bottles, with the balance packaged in one-way glass, plastic, and cans (49). On a volume basis, refillable glass packaging declined by 8 percent between 1985 and 1986; on a unit basis, it declined by 6 percent.

These changes affect the overall weight of bottles that enter the MSW stream because while refillable bottles tend to be heavier than single-use bottles, they also last much longer. By 1966, for example, even though the total weights of shipments of refillable and single-use soft drink bottles were about the same, the number of shorter-lived, nonrefillable bottles was greater than refillables.

Most refillable beverage systems in the United States have disappeared, including those in States with beverage container deposits, which are designed to stimulate recycling.[23] The remaining systems are concentrated in the Midwest, where about 25 percent of the volume of soft drinks sold is packaged in refillable bottles, and in the South, where refillables are almost 12 percent of the market (49). This compares with 2 to 6 percent in other areas of the United States. Refillable bottling systems have declined primarily because of changes in the beverage industry infrastructure and the cost of

[22] The awards are the result of an 1987 amendment to the Stevenson-Wydler Technology Innovation Act of 1980.

[23] See ch. 8 for discussion of mandatory beverage deposit and recycling systems.

refillable systems. Returned bottles have to be cleaned and the resulting wastewater has to be disposed of properly. In addition, glass bottles are heavy and costly to transport back to the bottling facilities.

Whether a return to refillable systems is economically feasible is unclear. The cost factors mentioned above suggest that switching to refillables might increase the cost of beverages. A return to such a system also would be difficult because the infrastructure for it no longer exists, and the capital investments required for refillable systems are greater than those required for new one-way systems (l). In addition, curbside collection, which is being used in many communities to collect recyclable containers, probably would not work as a return mechanism for refillable glass or plastic bottles given the rough handling they are likely to receive; refillable glass cannot be chipped and plastic cannot be punctured.

On the other hand, the use of refillable bottles could lower the costs that the public sector must pay to manage increasing numbers of soft drink and beer containers, particularly if energy savings are realized by such systems or if refillable bottles decrease MSW generation. For example, some reduction by weight in MSW generation would occur if bottles were reused instead of discarded. However, current refillable bottles are usually glare, which weighs more than single-use containers made of aluminum or plastic. Thus, the refillable bottles would have to be refilled several times to obtain an equivalent savings of weight. With respect to the total energy requirements associated with using different bottles, the breakeven point between aluminum cans and refillable glass bottles has been estimated to range from 4 to 26 trips (1,46).

The importance of transportation costs in MSW management (ch. 2) suggests that one way to reduce costs would be to develop a lightweight refillable plastic beverage bottle. Refillable plastic bottles are being tested by Coca-Cola in West Germany. Preliminary testing shows many technical obstacles that must be overcome, including the fact that the bottles become brittle and shrink slightly after repeated washing. Coca-Cola expects to overcome these problems, however (16). In addition, sophisticated chemical detection equipment is used to test the bottles after they are washed to avoid the threat of contamination.

Rebillable Bottle Systems in Europe—Refillable bottle beverage systems are still common in some European countries. In Denmark, for example, one directive requires that beer and carbonated soft drinks be sold in refillable bottles (4, 37). A deposit is collected on the sale of beverages to encourage returns, and the number of different bottles has been limited to simplify the return systems. An estimated 99 percent of the bottles are returned (4). This law has been viewed as an anti-free trade action within the European Community. In September 1988, however, the European Community court ruled that the law was justified because it was based on environmental concerns.

In West Germany, the government has been trying for years to reverse the decline of refillable beverage bottles. The government enacted the Waste Avoidance and Waste Management Act of 1986, which requires the environment minister to negotiate with industries to set voluntary measures regarding products (ch. 8). Negotiations between the government and the beverage industry led to the development of a deposit system, and the market for single-use bottles is expected to decline as a result.

Conditions favoring refillable bottle systems in Denmark and West Germany, however, are not necessarily present in United States. For example, transportation of refillable bottles probably is less costly in Europe. Denmark has only 2 breweries, but it is small and has a dense population. West Germany has hundreds of local breweries and extensive local distribution. In the United States, in contrast, the largest brewer has only 11 breweries for the entire country.

Other Reuse Systems—In the United States, vestiges of reuse systems remain for products other than beverage bottles. Diaper services and nonprofit organizations that recycle used goods and clothes (e.g., Goodwill and shops that sell worn garments on consignment) are examples. Another example is bottled water delivery services that use refillable bottles. In the past bottled water services were associated mainly with offices, but residential use in the United States has doubled since 1980 (1 S). Growth in bottled water use in homes is mainly because of public concerns about the quality of

Photo credit: Office of Technology Assessment

Over 10 billion mail-order catalogs were mailed to consumers in 1987, most of which are discarded in MSW, Products purchased through the mail tend to arrive with more packaging than products purchased at retail stores.

public, piped water supplies. In contrast to buying small single-use bottles of water at retail stores, a home delivery system does not generate MSW because the bottles are refillable, can save money, and can be more convenient, although it does require storage space.

Mail and Telephone Books

Direct mail advertising includes items such as solicitations for contributions, mail order catalogs, and offerings of sweepstake contests. This is a category of paper products that tend to have short lifetimes. Commonly referred to as "junk mail," much of it is third class mail. The total weight of third class mail in 1986 was 3.3 million tons; it is the fastest growing segment of mail, having doubled on a pounds-per-capita basis between 1980 and 1986 (82). Assuming that most third class mail is discarded, it would represent about 1.5 percent of MSW.

Increased use of catalogs is one factor contributing to the growth in third class mail. The number of catalogs mailed doubled between 1980 and 1987; over 10 billion catalogs were mailed in 1987 (17). This can affect MSW in two ways: 1) unwanted and out-of-date catalogs are discarded, and 2) merchandise ordered through catalogs tends to arrive with more packaging than does merchandise purchased from retail stores, although some packaging is reused by consumers. The 10 billion catalogs could weigh between 1 and 2.5 million tons, which would make up about 1 percent of MSW.[24]

Mailing lists are at the heart of direct mail advertising and marketing. These lists are generated by postal zip codes and are based on assumptions about numbers of residences per building. Thus single households often receive multiple versions of the same mailing. In many cases, lists are rented to other companies, although one survey reported that 55 percent of all adults disapproved of this practice (70).

Another change in the mail is that some magazines now arrive wrapped in polyethylene film, or polybags.[25] In some instances, the film has replaced heavier paper wrappers, and this results in less MSW generation by weight. However, when it replaces only a mailing label adhered to the magazine itself, then MSW generation will increase, although the increase may only be on the order of 0.01 percent.[26] Polybags also could affect MSW generation because they allow loose sheets of advertising to be enclosed. The increased use of polybags has been enhanced by changes in costs. Cost savings include faster stuffing of magazines and loose advertising sheets by machine and lower costs for materials, as well as savings in postage costs for periodicals that switch from paper to plastic wrap.

Telephone books are another growing source of MSW. Many residences now get several telephone books from different companies competing for customers. Out-of-date books tend to be discarded when a new book arrives, and most probably end up in landfills (59). About 83 million households have telephone service (82). If each household discards one 3-pound telephone book per year, then 120,000 tons, or 0.1 percent of MSW, would be generated annually. This is a conservative estimate because

[24] The weight calculation is based on an assumption that catalogs weigh 4 to 8 ounces each, which is conservative for some catalogs. The 1 percent figure would be included in the 1.5 percent figure for third-class mail cited above.

[25] Polybags also are used t. protect and extend the shelf life of other products, such as bread and toilet paper.

[26] One manufacturer of plastic sheeting for polybags estimates that 6,000 to 24,000 tons of plastic per year are used in manufacturing polybags (61). This is about 0.004 to 0.015 percent of MSW, but not all is used for magazines.

some households discard more than one book and because it does not include telephone books from commercial establishments.

Miscellaneous Technological Changes

Technological changes can influence MSW generation rates, sometimes inadvertently. In addition to the microwave oven (see “Food Packaging”), one recent example is the computer, which has increased the use of paper. It originally was thought that the widespread adoption of computers would create a ‘‘paperless’ society. However, OTA reported in 1983 that office copiers and computers have provided high-volume markets for paper use (74), and at least one other report has attributed increases in MSW generation to increased use of paper for computers and similar products (95).

Some technological changes that appear to reduce MSW generation in fact simply divert wastes to a different waste stream. For example, the use of household garbage disposals has increased during the past few decades, so less food waste may be entering MSW. However, this does not change food waste generation; it instead diverts food wastes into the sewer system.

Examples of MSW Quantity Reduction

Some firms have made product and packaging changes that happen to result in MSW quantity reduction. In general, these changes have not occurred because of MSW disposal problems, but rather in response to traditional economic forces such as improving product quality, reducing production costs, reducing costs of compliance with environmental and safety regulations, and appealing to consumer preferences. Industries have responded to public concern over MSW issues by funding recycling projects and research (ch. 5), but not by directing funding toward MSW prevention efforts.

MSW quantity reduction should be an opportunity for innovative thinking by industries, however. For example, it could lead to the development of new materials, new products, and new concepts in packaging. This, in turn, could bring millions of dollars of savings to industry (72, 73).

Changes that can decrease MSW generation can take many guises—reducing the size of products (i.e., “downsizing”), increasing product lifetimes, putting more product into the same kind of package, putting the same amount of product into less packaging (i.e., “lightweighting”), and using both less product and less packaging. Various examples show that quantity reduction is technically and economically possible, regardless of the motivation behind the change:

- Some manufacturers offer concentrated versions of products (e.g., frozen juices, concentrated pesticides, and concentrated soaps). Box 4-F describes one such product successfully marketed by Procter & Gamble in West Germany but not in the United States (figure 4-5).
- Packaging changes initiated by Procter & Gamble (27) include:
  —Pampers and Luvs diapers and diaper packages changed so that net total amount of materials in product and package was 50 percent less than preceding design;
  —Jif peanut butter and Scope mouthwash packages changed from glass to PET, reducing weight of packaging by 80 and 90 percent, respectively;
  —Tide with Bleach eliminates need for separate purchase of bleach.
- Half-gallon ice cream cartons hold the same quantity, but their weight has been reduced by about 30 percent by changing the materials used (l).
- Shrink and stretch wrap plastic materials are replacing higher volume corrugated paper in many applications.
- General Electric changed the tub of a dishwasher from enameled steel to engineered plastic, which enable the warranty on the dishwater to be increased because the tub was more durable.
- A new blow-molding tool for plastic (HDPE) milk bottles reduces their weight 10 percent while increasing strength (58).
- A heat-set technology makes it possible to use PET containers for liquids that must be hot-filled. The new technology allowed a juice company to switch from glass to plastic bottles, resulting in a **25** percent reduction in weight. The change was made to appeal to consumers’ desire for lighter weight and safer bottles and to affect long-term cost savings in bottling and shipping.

Box 4-F—Procter & Gamble Concentrated Laundry Product

In the Federal Republic of Germany, Procter & Gamble introduced a concentrated form of a fabric softener. This was marketed in addition to its existing, ready-to-use product, which was packaged in a 4-liter reusable plastic bottle, The concentrated product, sold in a flexible pouch, is used by cutting open the pouch, pouring the contents into the empty 4-liter bottle, and filling the bottle with water. The concentrated form requires about 85 percent less packaging.

The company promoted the product by emphasizing it as an initiative to reduce packaging material and waste. In addition, promotional materials pointed out that lower storage and transport costs meant that retail stores would benefit from the lower cost of the concentrate (about 60 percent less). The information also pointed out that stores could display more product in the same amount of shelf space (10 pouches in the same space as three bottles).

The company targeted its products to consumers by promoting the trouble-saving aspects of the concentrate, whose package takes up much less space and is therefore more easily discarded than the ready-to-use product. TV commercials dramatically illustrated the differences in volume of waste between the bulky plastic bottle and a rolled-up flexible pouch. The consumer campaign also had a logo-a person pouring the concentrate into the bottle-and an accompanying slogan encouraging the consumer to ''take part, to refill instead of throw away. ''

The reductions in waste generation associated with the flexible pouches might, however, be offset by increases in the amount of packaging needed to protect the product during shipping. In fact, however, the pouches have not required any additional protection and they are shipped in corrugated boxes just as the plastic bottles.

Procter & Gamble tested and marketed a similar product in the United States. Unlike the German product, this product was a concentrate sold in a plastic bottle; it was formulated to be used in smaller quantities than the undiluted product rather than being poured into another container and diluted.

This concentrated product was not as successful as was hoped, although is still being sold in the United States today. The product was called a ''triple concentrate, ' and some people in the company speculate that consumers did not understand the term. Some also speculate that the failure of one concentrate in the United States and the success of another in West Germany may be in part attributed to a greater awareness of waste disposal problems among German consumers.

SOURCE: E. Fox, Procter& Gamble, personal communication, February 1989.

- A West German technology for making narrowneck beer and soft drink bottles is reported to reduce their weight by 12 to 17 percent, which would reduce materials costs; however, use of the technology would require major capital expenditures for new machinery (67).
- Neutrogena has made a single-bar shampoo soap since about 1960; while this product requires some packaging, it avoids the use of larger containers. It differs from liquid shampoos in that it is made from soaps rather than detergents, leaves a residue when used in hard water, and is marketed primarily for men (50).
- Plastic bags bought by McDonald's to ship products to its stores are designed to be reused as garbage bags.
- Erol's, a large video rental and sales chain, trains its sales people to reuse the distinctive plastic bags that tapes are carried in and to ask customers to return tapes in the bags, in the process saving about $1 million and over 25 million bags annually (21).

PREVENTION OPPORTUNITIES FOR CONSUMERS

Consumers can play a powerful role in MSW prevention through their purchasing decisions, which can ultimately shape demand for products and influence product design. However, little information exists to guide consumers or offer incentives to exercise that power—even motivated consumers are limited in such circumstances. Even so, consumers have some opportunities to reduce waste by making different purchasing choices and by reusing products and packaging in their homes and places of business.

Figure 4-5-Advertising Used in West Germany for Procter & Gamble's Concentrated Fabric Softener

This ad emphasizes the product's value in reducing packaging waste and as the fact that it takes up less storage space in households.

SOURCE: E. Fox, Corporate Packaging Development, Procter & Gamble, personal communication, February 1989

Individual Consumers

Some States and public interest groups issue bulletins or brochures listing possible actions that individual consumers can take to be more responsible in their MSW generation (e.g., 56, 65). Household hazardous waste programs also provide such information.

Some of the ways in which individual consumers can influence MSW generation include:

- buying items that are reusable instead of disposable,
- selecting product brands that are durable or repairable,
- buying in bulk or large sizes,
- buying lighter versions of products,
- avoiding containers made of mixed materials,
- comporting yard and food wastes in residential backyards,
- buying fresh rather than pre-packaged fruits and vegetables,
- donating usable but unwanted materials to fiends or charities,
- buying products that contain fewer potentially toxic substances,
- reusing product containers and purchasing beverages in refillable bottles, and
- using home delivery of water instead of purchasing bottled water.

Some of these topics have been discussed in this chapter. This section discusses one idea for providing information to consumers (the ratio of product content to packaging) and several activities that consumers can undertake to reduce MS W generation (buying in bulk, reusing product containers, comporting in backyards, and reducing waste from telephone books and mail).

Ratio of Product Content to Packaging

One type of information that can help guide consumers is the ratio of product content to packaging. OTA has calculated, for illustrative purposes, the ratio of product content to packaging for a number of consumer products (table 4-6). Because products usually have information about net weight (i.e., weight of the contents), the contribution of packaging can only be obtained by weighing the total item and subtracting the net weight.[27] As the numerical value of the Content/Packaging (C/P) ratio increases, more content is purchased. As the C/P ratio approaches 1, the consumer is buying as much content as package. A C/P ratio of less than one means that more packaging than product content is bought.

However, this evaluation method does not always work. A package of 10 Twinnings teabags, for instance, is less wasteful than a box of 25 bags. The small set of bags has only a polypropylene wrapper, while the larger version also has a box. In addition, the functions of the contents also need to be considered; with laundry detergents, for example, the number of washing loads that can be accomplished with a given ratio may be more important than actual weight.

One way to extend this idea is to include the unit price (cost per ounce) in the calculations. Based on the data in table 4-6, the unit cost of many items decreases as less packaging is used. Thus, stores that make unit costs available may also be providing a guide for less wasteful buying. However, there is a critical limitation to this pricing concept. Unit prices are often related to product quality and brand name (e.g., over-the-counter medicines), so that products with the same C/P ratio could have very different unit prices.

The trend toward single-serving packages offers two important benefits, reduced food spoilage for individuals who do not consume multiple servings, and convenience. However, food packaged in single servings not only has less product per package, but the packages often are wrapped twice or are combined into packs of three or four (similar to beer six-packs) to encourage multiple purchases. For example, one package of three single cartons of orange juice with straws is wrapped in polypropylene or plastic wrap. It has 18 ounces of product per ounce of packaging (table 4-6); in contrast, frozen concentrate has a ratio of 53 to 1, and a single multiple-serving carton has a ratio of 28 to 1. Buying concentrated products thus can result in less packaging per unit of product.

[27] This simple calculation is only possible for solid weights. For fluid ounces, the total item must be weighed and the empty packaging weighed because the conversion from fluid ounces to ounces can vary depending on the density of the liquid.

Table 4-6—Relationships Between Contents and Packaging of Selected Products

Product	Weight (ounces) Contents	Weight (ounces) Total	Weight (ounces) Package	Content/ package ratio	Percent packaging of contents	Percent packaging of total	Total cost per ounce
Minute Maid Orange Juice							
Pack of 3	28.1	29.75	1.61	17.5	5.7	5.4	0.04
Frozen concentrate	53.3	54.3	1	53.3	1.9	1.8	
Carton	70.75	73.25	2.5	28.3	3.5	3.4	0.03
Fresh juice				0.7			
Chicken-of-the-Sea Tuna							
Pack of 3	9.75	13.5	3.75	2.6	38.5	27.8	0.26
Bumble Bee can.	6.5	8	1.5	4.3	23.1	18.8	
Safeway can.	6.5	8.25	1.75	3.7	26.9	21.2	
Del Monte green beans							
Microwave Ready Vegetable Classic	1.5	13.75	2.25	5.'	19.6	16.4	0.11
Can	16	18.5	2.5	6.4	15.6	13.5	0.04
Can	8	10	2	4.0	25.0	20.0	0.06
Fresh	16	16.1	0.1	160.0	0.6	0.6	
Del Monte yogurt cup							
Pack of 4	19	21.75	2.75	6.9	14.5	12.6	0.10
Del Monte pudding cup							
Pack of 4	20	22.5	2.5	8.0	12.5	11.1	0.08
Jello Instant Pudding & Pie Filling	4	4.5	0.25	16.0	6.3	5.6	
with 2 cups milk	20.2	21.05	0.85	23.8	4.2	4.0	
Mueller's Old Fashioned Egg Noodles							
Box	12	14	2	6.0	16.7	4.3	0.09
Cello bag	16	16.5	0.5	32.0	3.1	3.0	0.09
Lipton Tea							
Loose in box	8	9.25	1.25	6.4	15.6	13.5	
Bags in box (12)	3	4.25	1.25	2.4	41.7	29.4	
Twinnings Tea Bags (English breakfast)							
Bags/box (25)	1.8	3.25	1.45	1.2	80.6	44.6	
Bags/cello (10)	0.66	1	0.34	1.9	51.5	34.0	
Tide Laundry Detergent							
Box	42	44	4	10.5	9.5	9.1	
Box	17	19.75	2.75	6.2	6.2	13.9	0.09
Mennen Deodorant							
Speed Stick	2.25	4	1.75	1.3	77.8	43.8	1.33
Lady Speed Dry	1.5	3.75	2.25	0.7	50.0	60.0	1.73
Milk 2%							
Carton - 1/2 gal.	69	71.5	2.5	27.6	3.6	3.5	

NOTE: Limitations include few data on liquid-containing packages or shipping packages.

SOURCE: Office of Technology Assessment, 1989.

However, this example points out another limitation of the C/P ratio. In particular, it does not account for shifting the production of waste to elsewhere. For example, rinds and pulp are discarded during production of orange juice. More oranges are used in making one ounce of frozen concentrate than one ounce of normal-strength juice. Thus, the amount of food waste discarded during production of the concentrate might be greater than the amount of packaging associated with the normal-strength juice.

Buying in Bulk

Buying dry, unwrapped products in bulk instead of buying prepackaged items is another way to reduce packaging, especially if consumers use their own reusable containers. This approach has been popular at food cooperatives, which represent a very small percentage of total food purchases, but the availability of bulk products in regular supermarkets has increased in recent years. For wet foods, however, buying in bulk is less practical because of concerns about spoilage.

Reusing Product Containers

Consumers can control packaging that is added at the cashier or check-out stand. For example, consumers can request that their groceries not be double-bagged and that frozen foods not be placed in individual plastic bags. They can consolidate purchases in department stores into one large bag rather than several smaller ones. Consumers also can find second uses for bags (e.g., using grocery bags as garbage liner bags, or carrying empty bags with them when they go shopping).

Backyard Comporting

In some areas of the country, the largest fraction of MSW is yard wastes (chs. 3 and 5). Reduction of yard wastes only can occur by household action—i.e., backyard comporting and mulching—as opposed to **recycling** in municipal and private comporting operations. Industry has no operational role in backyard comporting, but it does market compost products that facilitate home yard waste reduction, such as small shredders and chippers, lawnmower attachments, materials for compost bins, and pitchforks.

Backyard comporting does not necessarily add major chores to standard yard and garden upkeep because the materials have to be dealt with in some way; however, it does require space and proper maintenance. Many brochures and periodicals from State and local organizations provide details on how backyard comporting can be done cheaply and effectively (e.g., 45, 66). In the State of Washington, a nonprofit organization trains ''master composters" and promotes home comporting, and Seattle has a grant to distribute home comporting bins and educate citizens about how to compost in their backyards (8). Given the amount of yard wastes in MSW, backyard comporting maybe one of the most effective ways for consumers to change their MSW generation rates.

Mail and Telephone Books

One way to reduce the growth in mail order catalogs is for individual consumers to remove their names from mailing lists (e.g., by contacting the Direct Marketing Association). In West Germany, it is illegal to deliver anonymous (i.e., not individually addressed) advertising mail if a household places a sticker on its mailbox or door saying that such mail is not wanted (34). Another way is to replace catalogs with electronic systems, such as TV shopping (24) and computerized telephone solicitors that are already in place but have not yet captured a large share of direct mail markets.

Electronic systems offer a way to reduce the use of telephone books. The French telephone company offers subscribers free use of a mini-computer terminal, the "Minitel," as an alternative to a printed telephone book, as well as to provide other electronic services. Use of the Minitel for the latter purposes incurs a charge, while the telephone listings do not. The decrease in telephone books, however, might be offset initially by packaging waste from computers and from cable hook-ups.

Offices, Institutions, and Retailers

Changes in technology and in office practices have changed the nature of MSW generated at offices, institutions, and retail stores.[28] Photocopying machines largely have replaced carbon paper and

[28] OTA's separate background paper on medical wastes concluded that the amount of hospital waste generated per bed may have increased significantly within the last decade (80). Part of this suspected increase is caused by an observed-but unquantified-increase in the single-use items used in hospitals and other medical facilities.

their use of paper represents a growth area for paper manufacturers. Inked fabric typewriter ribbons have been replaced by plastic ribbons that only cycle once. Computer and typewriter printer ribbons, however, are being replaced by chemical toners, which may help reduce office waste, especially because some can be recharged. Some toners, however, may contain toxic substances.

Waste prevention efforts undertaken by offices, commercial establishments, and other institutions have a potentially wider effect than simply reducing their own waste generation (and, in some cases, the costs of waste disposal). In particular, prevention efforts in these establishments can help to educate employees so they practice waste prevention in their own homes. State and public interest groups are beginning to seek ways to help offices and institutions practice MSW prevention (42, 62). For example, offices and institutions could evaluate actions such as:

- more precise inventorying and ordering of materials;
- reusing materials (e.g., file folders, paper clips) within an office or business;
- adopting new technologies that use raw materials more efficiently;
- negotiating with suppliers to provide goods in more practical packaging;
- evaluating waste generation to determine where changes might be made;
- using more durable and repairable equipment;
- negotiating good service contracts;
- dual-sided copying;
- converting the blank side of paper to scratch paper;
- using electronic mail instead of paper memos;
- reduced mailing and distribution lists; and
- using reusable items for food service.

The use of electronic mail, for example, is now extending beyond internal office use. The Electronic Data Interchange Association has estimated that about 3,500 companies use electronic interchanges for external communication to some extent and that 10,500 will do so by 1991 (5). The driving force is to cut costs, but paper reduction and the loss of clerical jobs may be additional results.

Many possibilities also are applicable to retailers. The Rhode Island Solid Waste Management Corp. **(62)** cites several MSW reduction actions that have already been taken, for example, by some restaurants. In one, a pub converted some of its beer sales from single-use bottles to draft or to returnable bottles. Waste disposal savings were estimated to pay for the system in *4* years.

Public restaurants also could evaluate the possibility of converting paper and plastic single-service items to reusable ones. Restaurants benefit from single-service ware when they save on labor costs, water use, detergents, space, and investments in dishwashing equipment. However, at least part of the internal saving is converted into a cost for society, which must pay the burden of mounting waste problems. Fast-food restaurants, especially ones with take-out foods, might suffer some loss of consumer satisfaction, however, as well as an increase in operating costs. Thus, the benefits of a change to reduced MSW generation will depend not only on cost trade-offs but also on the willingness of consumers to change their eating habits.

Retail shops also generate waste in the form of the paper and plastics used to protect goods in transport. Once the products are received, this material becomes waste unless it offers some potential for reuse onsite. Reuse and recycling is common for corrugated cardboard. That opportunity, however, may not be available for other materials unless the shipping material has been designed with reuse in mind, and small retailers do not have the ability to affect that design. Large retailers, however, can pressure design changes in some cases.

Retail shops can control some of the packaging materials (e.g., wrapping papers, boxes, and shopping bags) that are added to consumer purchases. Often two or three layers of packaging are added, sometimes only so that an advertising logo can be displayed, even when the product is already well-protected and easily carried.

U.S. grocery stores typically include the cost of bags with the cost of groceries. According to Safeway, its 166 stores in the Baltimore-to-Richmond corridor use almost 4 million bags per week (three times as many plastic as paper), for a cost of about $110,000 (11). The use of plastic bags results in waste prevention (because they occupy about 1/6 the space, especially during storage, that paper bags occupy) and cost savings to the corporation (because paper bags cost about 4 cents each, compared with 2 cents each for plastic bags). However, plastic bags may bring other MSW problems related to their durability (chs. 3 and 5). One way to encourage a reduction in the number of bags used would be to charge customers for the bags. Some European stores charge customers extra for shopping bags; in Denmark, the cost varies depending on whether the bag is plastic (about 10 cents) or paper (about 20 cents). One store in Massachusetts charges its customers 3 cents per bag and encourages customers to bring their own bags. This has resulted in a 40-percent reduction in bag consumption (64).

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