Waste characterization studies and the solid waste hierarchy

by Marjorie J. Clarke

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Well-designed waste characterization studies can provide the baseline data to help design solid waste management programs.

Municipal solid waste composition has been changing significantly and will continue to change due to various factors that evolve over time — technology, regulation, legislation, education, convenience and environmental conscience. A lack of attention to the changing nature of municipal solid waste (MSW) has made it seem deceptively easy to design incinerators, which have been sized too large to accommodate waste prevention policies that may affect the levels and types of incinerator emissions and ash leachate released over a plant's typical 20-year life span. If ignored, changes in the waste stream will continue to make accurate planning for environmentally sound, integrated solid waste prevention and management difficult to accomplish.

Earlier waste characterization studies did not include sufficient information to permit the development of effective recycling, reuse and reduction programs. Thus incineration/ash management has been perceived as the only reasonable solid waste strategy for most of the waste and the apparent comparative viability of alternative methods of managing and preventing generation of solid waste has been reduced.

Fortunately, waste characterization studies are evolving and should, in the future, serve as the information base for the optimal design of comprehensive source reduction, reuse and recycling programs, economic incentives, government and industry product procurement requirements, and legislation.

Early waste characterization studies

As recently as the 1980s, solid waste management studies amounted to reports on the feasibility, design and environmental impact of a proposed resource recovery plant and were often based on inadequate waste characterization analysis. When waste characterization studies were conducted, a key interest was to determine waste characteristics that would affect incineration in order to design resource recovery plants and their emission control systems. Factors that affected combustibility included Btu value, moisture content and the total quantity of waste produced in the geographic region to be served by the plant.

Since it was assumed that a plant would process all the waste generated in the local area, such information would allow engineers to size the boiler to burn efficiently and extract energy from all the waste. The result sometimes led to an oversized plant, once recycling programs began. Oversizing an incinerator discourages reduction, reuse and recycling, since diversion of materials from an incinerator reduces revenues required by the bondholders and threatens the plant's economic viability. This has occurred where recycling participation is mandatory, such as at facilities in Warren County, New Jersey and Claremont, New Hampshire and the newly opened Hudson County, New York plant.

It was always recognized that the Btu content of garbage was of great importance in designing the throughput capacity of a given incinerator. However, little attention has been paid to the Btu content or to the chlorine, sulfur, nitrogen, fluorine and heavy metals content of specific packaging or consumer products that are discarded and enter the waste stream of an incinerator; nor has much attention been paid to the impact of burning various mixtures of these items on the quality of combustion, emissions, and the quantity, toxicity and leachability of ash.

Thus, if the waste stream composition changed as a result of a new law prohibiting either the manufacture or burning of certain products or packaging types, an incinerator design based on generic waste characterization data might require a change in throughput and/or a change in operation or even a costly retrofit. In addition, it would not be possible to predict the effects on combustion, emissions and ash of any waste stream change, or to design the incinerator to handle all conceivable hanges.

Many early waste characterization studies were frequently inaccurate, since they were often adapted from studies conducted in other localities (or extrapolated from national figures), from generic figures for Btu content and other waste characteristics, and from outdated studies. New York City, for example, has until recently depended on a 1970s-vintage waste characterization study for information on which to base planning for five resource recovery plants and a recycling program for seven million residents. Also, early studies often ignored waste characteristics that might have affected the amount and toxicity of ash produced by incineration.

A few early studies that divided the waste stream by material (e.g., paper, glass, metals, plastics, wood, food, etc.) were of limited value for designing either recycling or waste prevention programs, since they did not examine the differences within each of the categories, e.g., different types of plastic, paper or metal, or the differences in chemical composition within each category.

he effect of the solid waste hierarchy

Meanwhile, as planning for resource recovery plants has continued, the increasing severity of environmental destruction in general and the rising public outrage against landfills and incinerators in particular have been forcing these assumptions and procedures to change.

In stark contrast to the priority of waste management strategies delineated in the U.S. Environmental Protection Agency hierarchy (waste reduction, recycling, incineration and then landfill), in 1988 73 percent of MSW was landfilled, 13 percent was recycled and composted, and 14 percent was incinerated, representing a 50 percent increase in incineration in the last few years (1).

Although incinerator emission standards issued in 1989 by EPA did reflect the hierarchy by requiring that 25 percent of incinerator feedstock materials be recovered for recycling and that toxics such as batteries be removed, the attempt was thwarted by the White House.

Meanwhile, waste prevention, EPA's hest priority, appeared nonexistent, ce the waste stream continues to grow by 1-2 percent each year. In just 10 years, this rise in waste generation rate can wipe out what could otherwise be considered major gains in recycling (assuming that population remains constant, which it doesn't).

The negligible amount of financial and human resources that have been committed to research, planning and implementation of waste prevention and recycling stands in stark contrast to the major investments in incineration, ash management and landfill activities.

Because effective strategies are needed to reduce and recycle large portions of the waste stream, the solid waste management hierarchy has become a driving force in prompting the compilation of detailed and increasingly differentiated waste characterization data as an essential first step to sound, long-term integrated waste management planning. In turn, integrated planning has contributed to the delay of the construction of a number of incineration plants, allowing communities to increase their emphasis on the more environmentally friendly approaches to dealing with waste.

These developments point out the need for a new generation of waste characterization studies, designed not only to provide the information needed to size and equip incinerators for optimal performance, but also to explore and demonstrate the variety of opportunities for and to optimize the design of programs and initiatives for integrated toxics and volume reduction, reuse, recycling and composting.

Recycling and waste reduction potential

Data compiled by Franklin Associates for EPA (1, 2) are useful in focusing attention on the content of preventable, reusable, recyclable and compostable items in the waste stream, and are helpful in assisting solid waste planners in designing integrated programs.

The 1990 update report indicates that paperboard and paper is currently about 40 percent of the national waste stream; glass, metals, plastics and food wastes are about 7 to 8 percent each; and yard wastes are 18 percent. This categorization of the waste stream illustrates that the earlier notion of analyzing the waste stream solely for its fuel-related characteristics was an unnecessarily narrow approach, since a large part of the waste stream (roughly 70 to 80 percent) is not only combustible, but also recyclable and compostable.

As shown by Figure 1, the tonnage of paper and plastics generated is growing (and is projected to grow) at a great rate, while the other recyclable segments of the waste stream (glass/metal, food/yard, other) have been, and are projected to remain, relatively stable.

Beyond using waste characterization studies to design incinerators or recycling programs, a third way of looking at the waste stream shows that much of the waste stream is not only combustible and recyclable, as we have just seen, but most is also potentially preventable and reusable (see Figure 2).

- The nondurables category, which includes disposables and other products which have more durable alternatives, represented 28 percent of the waste in 1988.
- Containers and packaging made up 32 percent of the 1988 waste stream, some of which are unnecessary or can be reduced.
- Durables, which represent those products that are reusable, constitute 14 percent of the 1988 waste stream. The lifespan of such products can be increased through improved design, repair and reuse.
- Food/yard waste, much of which is potentially compostable in on-site or backyard compost units, constitute the balance of 25 percent.

Thus, the four categories above, composing almost all the waste stream at the current time, demonstrate the promise of solid waste prevention techniques. Figure 3 also shows that packaging and nondurables are projected to increase to 65 percent of the waste stream by the year 2010.

This depiction of products generated in MSW demonstrates that rather than dividing the waste stream into combustible and noncombustible fractions, the solid waste hierarchy suggests the use of organic and non-organic, or more significantly for purposes of implementation of the hierarchy, preventable, reusable and compostable, with much of the remainder being recyclable.

It is important to recognize that before there can be any reduction in the waste stream, annual increases in MSW generation must be offset as well. This in itself is likely to be a challenging task.

From 1960 to 1988, the total tons generated in the U.S. rose from 87.8 to 179.6 million tons, more than doubling (see Table 1). Table 2 projects that by 2010 the waste stream will total 250.6 million tons, a further increase of 40 percent. This increase in the waste stream is due to two forces: a growing population and increases in the consumption of nondurable and less durable products.

Nondurables. It is important to note that the nondurables category of products in the waste stream is increasing at the fastest rate, almost tripling in tonnage from 1960 to 1988 (Table 1). Before 2000, nondurables are projected to overtake the packaging category as the largest fraction of the waste stream (see Table 2). As such, nondurables will also contribute most to per capita increases in waste generation rates.

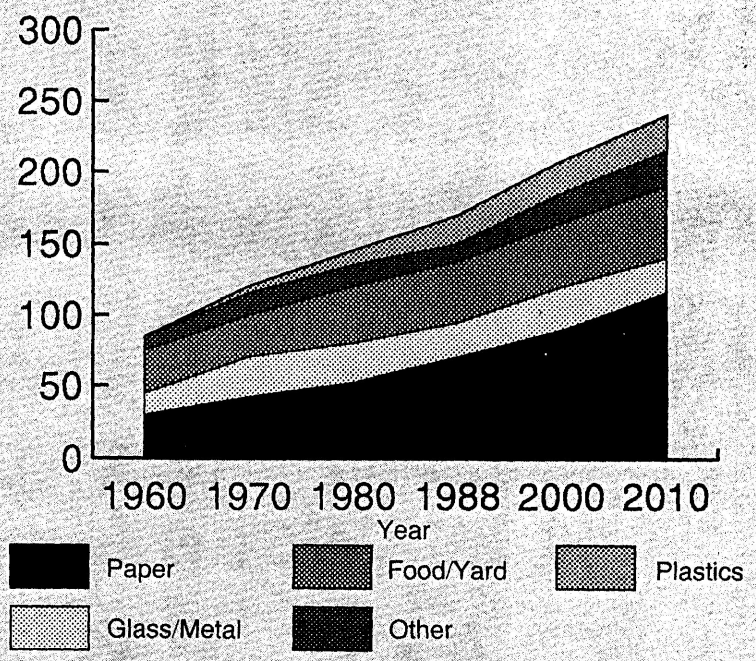
In order to reverse this trend, it is necessary to understand what constitutes the nondurables sector. Some examples of modern-day nondurables are disposables that once predominated in durable form, such as cheap furniture, appliances and electronics (disposable cameras), kitchen utensils and clothing. Nowadays, these are typically made from lesser quality materials and more poorly constructed and in such a way that repair is uneconomical or impossible. In the past, more products were made to last from metal, ceramic, wood and cloth — in some cases, lasting for tens and hundreds of years as heirlooms and antiques. Other nondurables, designed to be used once or a few times, including throwaways (e.g., diapers, pens, razors and eating utensils) that are consumed in the billions annually. Source reduction for nondurables would affect the volume of materials remaining in the waste stream for recycling and incineration, and thus the sizing of facilities both to process or incinerate the waste.

Durables. A fraction of the durables category also has potential for reduction. (According to the U.S. Department of Commerce definition, durables are considered to last at least three years.) The durables fraction contains consumer items such as automobiles, furniture, appliances, electronics and clothing, which may still last more than three years, but which, to increase the sale of new products, are now often made to lower specifications (e.g., inferior materials, flimsy designs, non-universal, or hard-to-find parts) and with shorter or no warrantee periods.

Toxics. Attention is now beginning to be paid to the toxic characteristics of specific waste items, like batteries. Due to their potential environmental impacts, products and packaging containing pollutant precursors, such as heavy metals and chlorine, sulfur and nitrogen, (e.g. batteries, heavily pigmented packaging, polyvinyl chloride plastics) may complicate whichever disposal option is chosen. For example, a battery disposed of in a landfill can discharge corrosive, toxic materials into groundwater resources; when disposed in an incinerator, it is transformed into emissions and toxic content in bottom and fly ash, which can disperse in the wind and/or

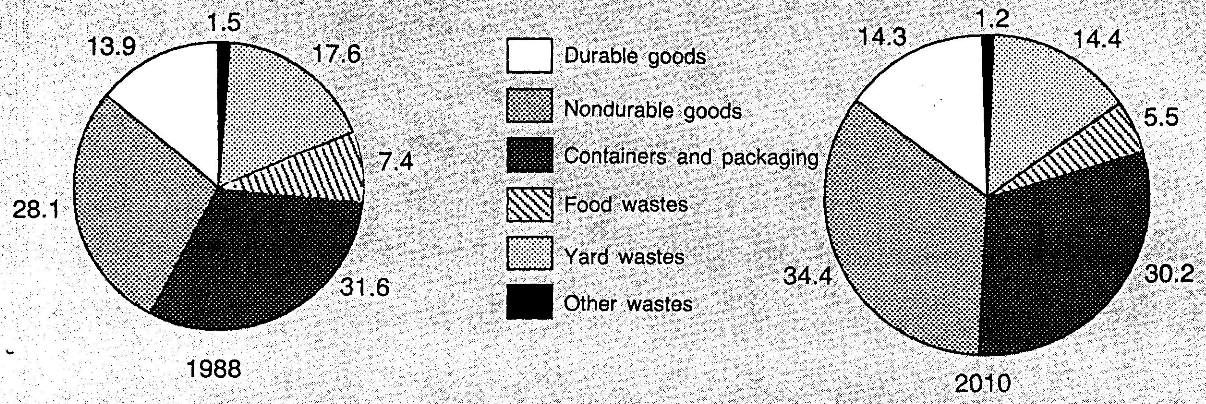
■ Figure 1 — U.S. municipal solid waste generation, 1960-2010

Millions of tons



Source: U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1990 Update,* prepared by Franklin Associates, Ltd., June 1990.

■ Figure 2 — Products generated in municipal solid waste, 1988 and 2010 (in percent)



Source: U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1990 Update,* prepared by Franklin Associates, Ltd., June 1990.

leach into groundwater; if recycled, processing can release emissions, effluents, sludges and residues. Proper environmental controls are thus necessary for ll processing and disposal technologies by the presence of toxics in consumer products and packaging.

Accurate waste characterization studies, designed to locate and quantify toxics in the waste stream, are thus necessary to target problem toxics and develop prevention-oriented programs, regulations and other initiatives to address these toxics.

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■ Table 1 — Categories of products generated in the municipal waste stream, 1960 to 1988 (in millions of tons and percent of total generation)*

	Millions of tons						
Products	1960	1965	1970	1975	1980	1985	1988
Durable goods	9.4	11.1	15.1	17.5	19.7	21.5	24.9
Nondurable goods	17.6	22.2	25.5	25.6	36.5	42.6	50.4
Containers and packaging	27.3	34.2	43.5	44.4	50.5	51.8	56.8
Total nonfood product wastes	54.3	67.5	84.1	87.5	106.7	115.9	132.1
Other wastes							
Food wastes	12.2	12.7	12.8	13.4	13.2	13.2	13.2
Yard wastes	20.0	21.6	23.2	25.2	27.5	30.0	31.6
Miscellaneous inorganic wastes	1.3	1.6	1.8	2.0	2.2	2.5	2.7
Total other wastes	33.5	35.9	37.8	40.6	42.9	45.7	47.5
Total municipal solid waste generated (weight)	87.8	103.4	121.9	128.1	149.6	161.6	179.6

	Percent of total generation						
Products	1960	1965	1970	1975	1980	1985	1988
Durable goods	10.7	10.7	12.4	13.7	13.2	13.3	13.9
Nondurable goods	20.0	21.5	20.9	20.0	24.4	26.4	28.1
Containers and packaging	31.1	33.1	35.7	34.7	33.8	32.1	31.6
Total nonfood product wastes	61.8	65.3	69.0	68.3	71.3	71.7	73.5
Other wastes							
Food wastes	13.9	12.3	10.5	10.5	8.8	8.2	7.4
Yard wastes	22.8	20.9	19.0	19.7	18.4	18.6	17.6
Miscellaneous inorganic wastes	1.5	1.5	1.5	1.6	1.5	1.5	1.5
Total other wastes	38.2	34.7	31.0	31.7	28.7	28.3	26.5
Total municipal solid waste generated (percent)	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Generation before materials recovery or combustion. Details may not add to totals due to rounding.

Source: U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1990 Update*, prepared by Franklin Associates, Ltd., June 1990.

■ Table 2 — Projections of categories of products generated in the municipal waste stream, 1995 to 2010 (in millions of tons and percent of total generation)*

	Millions of tons			Percent of total generation		
Products	1995	2000	2010	1995	2000	2010
Durable goods	28.6	31.3	35.7	14.3	14.5	14.3
Nondurable goods	60.5	68.3	86.3	30.3	31.6	34.4
Containers and packaging	61.9	65.7	75.8	31.0	30.4	30.2
Total nonfood product wastes	150.9	165.4	197.8	75.5	76.6	78.9
Other wastes						
Food wastes	13.2	13.3	13.7	6.6	6.2	5.5
Yard wastes	33.0	34.4	36.0	16.5	15.9	14.4
Miscellaneous inorganic wastes	2.7	2.9	3.1	1.4	1.3	1.2
Total other wastes	48.9	50.6	52.8	24.5	23.4	21.1
Total municipal solid waste generated	199.8	216.0	250.6	100.0	100.0	100.0

*Generation before materials recovery or combustion. Details may not add to totals due to rounding.

urce: U.S. Environmental Protection Agency, *Characterization of Municipal Solid Waste in the United States: 1990 Update*, prepared by Franklin Associates, Ltd., June 1990.

New York City case study

As emphasized above, national waste characterization figures, while useful indicators of general trends, are not likely to be very accurate if simply extrapolated to local conditions. For this reason, the New York City Department of Sanitation recently undertook an ambitious materials-oriented type of waste characterization study (3).

In this study, 46 materials subcategories of the residential and nonresidential waste streams were sampled in each of the five boroughs. Table 3 shows the city's residential recyclables breakdown, particularly for such categories as yard waste and food waste. The data were collected by both weight and volume, so the impact of diverting various recyclables from the city's diminishing landfill can be more accurately estimated.

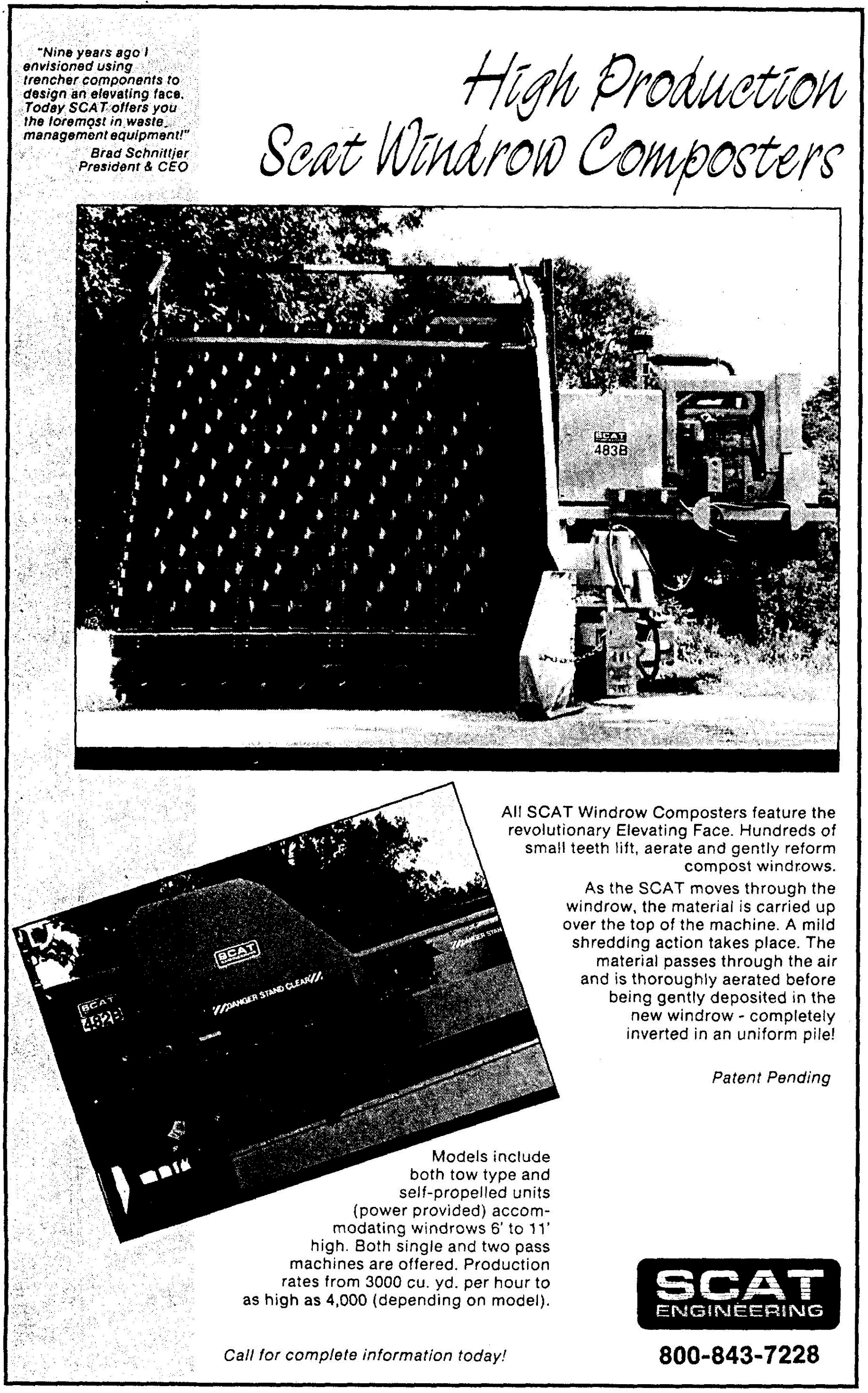
The startling conclusion of the study was that over 75 percent of New York City's residential waste stream consists of recyclable and compostable materials. About 40 percent of this figure is represented by materials currently being collected by the department in its curbside recycling program, and about 35 percent are materials identified for future collections as part of the department's intensive recycling programs, now in the early stages of pilot testing in Brooklyn.

The study provides a clear snapshot of the city's potential for recycling and composting, and can be used to target precious financial resources towards capturing those materials in the waste stream present in greatest quantity and for which markets exist.

This waste characterization study was well designed and gathered a remarkable amount of detailed information; however, it is of limited value in planning for reduction and reuse. This is because items in garbage that originate as consumer products, packaging or organic waste are frequently not only capable of being landfilled, burned, composted or recycled, but many are excellent candidates for source reduction strategies.

This can be illustrated by observing disposable plastic shopping bags: They can be reduced (by carrying purchases in a string or canvas bag), reused (by using the plastic bags themselves again and again), recycled into new plastic products, incinerated or landfilled. If a lower priority waste management method is used for a given waste item, such as this plastic bag, then it precludes a higher priority method from being used. Thus, basing integrated solid waste management planning solely on a materials-oriented waste characterization study implies that recycling is the most-favored planning strategy.

Relying solely on waste characterization studies that focus on combustion characteristics of the entire waste stream and/or on the recyclables content of the waste stream may also hinder development of specific programs within the context of integrated solid waste planning. For example, if such study indicates that 10 percent of the commercial waste stream is office paper, an office paper recycling program (with capital investments and long-term contracts) might then be designed based on the full tonnage represented in the study. Any large-scale implementation of waste prevention measures, therefore, such as requiring photocopies to be double-sided and once-used paper to be reused for drafts in copying machines and computer printers or for scratch pads, would interfere with the efficiency



and economic viability of the recycling program. Similarly, if bulky MSW (furniture, white goods) is initially considered by a materials-sort to be recyclable, and not reusable, then any subsequent reuse program would disrupt a bulky goods recycling program.

Thus, there is danger in relying on a materials/recyclables characterization study that assumes as its target waste stream 100 percent of that which is generated. The result could be overcapacity problems in recycling infrastructure similar to those now being experienced at the New Jersey and New Hampshire incinerators mentioned above, which had been designed to handle 100 percent of the area's waste stream. Capital outlays for recyclables processing capacity and special collection trucks, for example, could be unwise if, after the investment

■ Table 3 — New York waste composition study: residential waste recyclables

Category	Tons	Percent	Curbside percent	Intensive percent (1)
Corrugated kraft	142,077	4.70	4.70	
Newspaper	295,137	9.76	9.76	
Office/computer	28,355	0.94		0.94
Magazines/glossy	86,810	2.87	2.87	
Books/phone books	53,267	1.76		
Non-corrugated cardboard	81,340	2.69		2.69
Mixed paper	337,460	11.16		11.16
Clear HDPE containers (2)	21,619	0.72	0.72	
Color HDPE containers (2)	23,102	0.76	0.76	
LDPE (3)	5,444	0.18	0.18	
Films and bags	146,269	4.84		4.84
Green PET containers (4)	4,628	0.15	0.15	
Clear PET containers (4)	17,952	0.59	0.59	
Polyvinyl chloride	9,146	0.30	0.30	
Polypropylene	6,624	0.22	0.22	
Polystyrene	19,004	0.63	0.63	
Miscellaneous plastics	38,350	1.27		1.27
Grass/leaves	118,948	3.93	3.93	
Brush/stumps	20,805	0.69	0.69	
Diapers	106,619	3.53		
Food waste	384,323	12.71		12.71
Miscellaneous organics	243,895	8.07		
Glass clear containers	92,193	3.05	3.05	
Glass green containers	31,821	1.05	1.05	
Glass brown containers	26,346	0.87	0.87	
Miscellaneous glass	7,450	0.25	0.25	
Food containers/foil	17,024	0.56	0.56	
Beverage cans	9,293	0.31	0.31	
Miscellaneous aluminum	4,025	0.13	0.13	
Food containers (ferrous)	61,924	2.05	2.05	
Other	59,056	1.96	0.98	0.98
Bi-metal cans	605	0.02	0.02	
Non-bulk ceramics	4,568	0.15	0.15	
Miscellaneous inorganics	59,056	1.95		
Pesticides	377	0.01		
Non-pesticide poisons	549	0.02		
Paints/solvents/fuels	5,353	0.18		0.18
Dry cell batteries	605	0.02		0.02
Car batteries	1,043	0.03		
Medical waste	605	0.02		
Miscellaneous household hazardous wastes	2,718	0.09		
Textiles	149,114	4.93		
Rubber	62,457	2.07		
Fines	72,365	2.39		
Lumber	63,896	2.11	2.11	
Bulk	99,412	3.29	3.29	
Totals	3,023,216	100.00	40.32	34.79

(1) Materials targeted for inclusion in New York City's intensive recycling program.
(2) HDPE = high density polyethylene.
(3) LDPE = low density polyethylene.
(4) PET = polyethylene terephthalate.

Source: New York City Department of Sanitation, *Wasteplan Generation Report for New York City Wastestreams*, prepared by Tellus Institute, Inc., January 1991.