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COLLECTION OF POST-CONSUMER PLASTICS FOR RECYCLING

A REPORT

PREPARED FOR THE

IUPAC WORKING PARTY ON RECYCLING OF POLYMERS

Submitted By

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July 1995

 CCC 1022-1360/98/$ 17.50

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Introduction

Over 15,000 communities in the United States participated in residential plastic recycling programs in 1994, which led to the recycling of over 21.3% of all plastic bottles (17.2% of all rigid plastic containers) found in the residential waste stream to processors. Five years ago, plastics recycling was one fifth of what it is today. This move toward increased recycling of residential plastic containers is the result of public interest in recycling, state legislative actions, and, industry commitment to post-consumer plastics recovery.

High per ton collection costs remain one of the largest barriers to increased plastic recycling. Significant research on reducing collection costs, both for plastic containers and for other recyclables, has been conducted over the past five years. This report summarizes the results of that research.

Plastic Generators

This report concentrates on collection of residential rigid plastic containers. Residential rigid containers represents less than 1.5% by weight of plastics found in municipal solid waste in the United States in 1993 (EPA report). Table 1 illustrates typical plastic wastes generated by broad generator categories.

TABLE 1
GENERATION OF PLASTICS BY GENERATOR CATEGORY

Generator	Material Generated
Residents	Bottles and other rigid packaging Films Durables
Farms	Rigid containers Films
Commercial	Bottles and rigid packaging Specialized rigid packaging Films and shrink wrap packaging Durables
Manufacturing	Durables Business equipment Rigid containers Films and shrink wrap packaging Plastic Pallets
Institutions	Bottles and rigid packaging Foam food service containers and trays Plastic cutlery

To date, there has been little overlap in collection programs, with separate collection programs for each generator type. Agricultural collection programs have been driven over concerns about pesticide residues and have concentrated on pesticide containers. These programs typically rely on the farmer to deliver the containers to drop-off locations operated by extension services or pesticide manufacturers. More recently, with the expansion in the use of agricultural plastic films, there has been increased research into collection and processing systems for these films.

Plastics generated by industrial activities tend to be high volume, homogeneous plastics. As a result, large generators either enter into agreements with brokers to collect the plastic, or densify the plastic on-site and market it to a broker.

Until recently, there has been little recycling activity for commercial and institutional plastics. As a consequence a collection infrastructure has only recently been established. Private haulers now provide collection programs for certain high volume plastics generated by specific businesses or institutions (e.g., polypropylene bottles from hospitals). These collection programs are currently not integrated with residential collection programs.

Finally, there is a separate collection infrastructure for plastic bags recycled from supermarkets and department stores. In most cases, this material is being dropped off by shoppers at the stores, densified and shipped back to the bag manufacturer for recycling.

Reliable data are not available on quantities of plastics collected for recycling from agricultural, commercial, institutional, and manufacturing sources. Because of the potential to collect large volumes of potentially homogeneous material from some of these sources, this is an area that invites more research, and is likely to experience substantial growth over the next five years.

Data are available on the generation and recycling of plastic containers from households. Between 1991 and 1994, the American Plastics Council (APC) conducted extensive research on residential recycling known as the Model Cities Demonstration Program. These data are summarized below because of their importance to understanding collection of residential plastics. Although many of the examples come from the United States, the information is applicable to plastics collection in Europe and other parts of the world as well.

Household Generation of Plastic Bottles

Table 2 presents data from sorting of wastes and recyclables from 1000 households in 7 regions of the United States. Data are presented for plastic bottles as well as for other containers typically included in a residential recycling program.

While there are limitations to the data presented in Table 2, the data are more reliable than estimates of household generation based on national resin production statistics. This is because national statistics do not account for distribution of plastic containers by region or allocation of containers among residential, commercial, institutional and industrial generators.

TABLE 2
ESTIMATED POUNDS OF RECYCLABLE CONTAINERS POTENTIALLY AVAILABLE PER HOUSEHOLD IN 1993

	Bottle Bill State		Non-Bottle Bill State	
MATERIAL	(lbs/yr)	(%)	(lbs/yr)	(%)
All Plastic Bottles	25	10.6	35	12.3
Glass Containers	166	70.6	201	70.5
Aluminum Cans	5	2.1	17	6.0
Steel Cans	39	16.6	32	11.2
Total, Containers	235	100.0	285	100.0

As illustrated in Table 2, an average of 235 pounds of potentially recyclable containers were estimated to be generated per household per year in states with container deposit legislation. In states without container deposit legislation, total discards averaged 285 pounds per household per year. The difference of 50 pounds may reflect containers diverted through the deposit system. However, such factors as family size, income levels, and regional packaging variables may also come into play.

Plastic bottles represent about 11 percent of recyclable containers by weight, or 25 pounds per household per year in bottle bill states. In non-bottle bill states, plastic bottles represent 12 percent of recyclable containers or 35 pounds per household per year.

Accurate data on quantities of non-bottle rigid containers (e.g., yogurt and cottage cheese containers) were only collected during one sampling period in one region. These limited data indicate that between 3 and 7 pounds of rigid plastic food packaging is generated per household per year. In most cases, this will be a mix of polyethylene, polypropylene and polystyrene material, with the mix dependent on regional packaging variables.

Table 3 illustrates the composition of plastic bottles by resin type found in the household waste stream.

TABLE 3
AVERAGE POUNDS OF PLASTIC BOTTLES AVAILABLE, BY TYPE, PER HOUSEHOLD, PER YEAR

	Bottle Bill State		Non-Bottle Bill State	
MATERIAL	(lbs/yr)	(%)	(lbs/yr)	(%)
PET Soda	1.1	4.5	13.1	36.6
PET Custom	2.4	9.8	3.7	10.3
Total PET (#1)	3.5	14.3	16.8	46.9
HDPE Pigmented	6.2	25.3	4.3	12.0
HDPE Natural	12.6	51.4	11.9	33.3
Total HDPE (#2)	18.8	76.7	16.2	45.3
PVC (#3)	0.6	2.4	0.6	1.7
LDPE (#4)	0.1	0.4	0.1	0.3
Polypropylene (#5)	0.4	1.6	0.5	1.4
Polystyrene (#6)	0.0	0.0	0.0	0.0
Other Plastic (#7)	0.1	0.5	0.2	0.6
Uncoded	1.0	4.1	1.4	3.9
Total, All Bottles	24.5	100.0	35.8	100.0

About 90 percent (or 22 pounds) of plastic bottles in the average bottle bill state were either PET (3.5 pounds) or HDPE (18.8 pounds). PVC bottles represented 2.4 percent of the plastic bottle stream or 0.6 pounds per year. The remaining resin types -- LDPE, PP, PS, and "other" -- accounted for only 2.3 percent or 0.6 pounds of the plastic bottles, with PP representing the majority of these bottles at 0.4 pounds per year. Uncoded bottles represented another 1.0 pounds or 4.1 percent of the plastic bottle stream.

The composition of the plastic bottle stream in bottle bill states is significantly different than that found in non-bottle bill states. In non-bottle bill states, PET soda bottles (as opposed to HDPE bottles) are the largest component of the plastic bottle stream, with an average of just over 13 pounds generated per household per year. Total PET--including both custom (non-soda) and soda bottle PET--averages 16.8 pounds per household per year, or 48.5 percent of all plastic bottles. Natural HDPE (primarily milk and juice bottles) and pigmented or copolymer HDPE (primarily detergent bottles) add another 16.2 pounds per household per year to the plastic bottle stream. Thus, together, PET and HDPE comprise more than 95 percent of the plastic bottles discarded from the average household in non-bottle bill states, as illustrated by Table 3.

Capture Rates For Residential Plastic Bottles

Table 4 presents average measured capture rates observed across seven regions of the United States. Multiplying household generation rates by potential capture rates yields the amount of material available for collection. It should be noted that capture rates for plastic containers should increase over time as more households become accustomed to recycling this material.

TABLE 4
AVERAGE MEASURED CAPTURE RATES FOR RECYCLING CONTAINERS(1)

Material	Average Capture Rate (% of Total Available)	Range Bottle Bill (%)	Range Non-Bottle Bill (%)
Glass	80	77-88	56-93
Steel Cans (2)	68	60-88	53
Aluminum Cans	71	69-84	56-85
Plastic Bottles (Total)	55	39-65	50-66
HDPE (Natural)	70	55-87	70-72
HDPE (Pigmented)	39	21-47	41-56
PET (Soda)	60	37-61	60-75
PET (Custom)	48	27-56	47-61
PVC	39	13-44	51-54
All Other Plastic Bottles	20	10-18	17-39

(1) Exclusive of containers returned for deposit.
(2) Steel cans were only collected in two of the non-bottle bill Model Cities Demonstration Programs and were not reported separately from aluminum in one of the two projects.

Types of Residential Collection Programs

Collection programs for residential plastics and beverage containers from restaurants and bars can be divided into three broad categories:

- Beverage containers collected in states with deposit legislation
- Drop-off recycling programs
- Curbside collection programs

Deposit Containers

Deposit containers are dropped off by consumers at grocery and beverage stores, and at special redemption centers established to handle this material. The material is then generally collected by the beverage distributor, often as a backhaul after delivery of beverages. In some cases, the distributor or beverage producer will contract with a third party to collect the deposit containers from the stores or redemption centers for delivery to a processor. The cost of the collection program is borne by the distributor or bottler, and is wholly or partially off-set by a handling fee paid to the distributor by the retailer and, in some cases, unredeemed deposits. Container return rates have been reported to be as high as 90 percent (State of Massachusetts), and legislation has been proposed in various states and the Federal level to expand deposits to additional beverages and to enact Federal deposit legislation. These efforts have been unsuccessful to date because of disagreement over whether operating a separate collection system for deposit containers is cost effective.

Drop-off Programs

Many rural communities have implemented drop-off recycling programs which include plastics. Collection costs incurred by the municipality are reduced because individual residents are responsible for bringing their recyclables to the drop-of facility. However, in one study conducted in rural Orwell and Cornwall, Vermont[1] it was shown that when the cost of each resident driving to the drop-off was included, curbside collection was less costly than drop-off programs, even in rural areas. This is because most residents do not combine a trip to the drop-off facility with other errands. For example, in the Orwell and Cornwall study, individuals were estimated to have driven 7,000 and 8,800 miles per year respectively, to the drop-off facilities. This compares to every other week curbside collection routes in the two towns totaling 1,250 and 1,390 miles annually.

Drop-off facilities conveniently located at destinations where people are already driving to (e.g., shopping center, supermarket, school) may be one way to reduce individual trips and improve the economics of drop-off programs. There are a number of "igloo" collection containers located in shopping malls which incorporate plastics. However, the high volume associated with plastic containers significantly increases the number of times these igloo storage containers (average capacity 4.25 yd^3) must be emptied.

At more conventional drop-off recycling centers, plastics are typically stored loose or compacted in 40-50 cubic yard roll-off containers and trucked to processors, or stored in bins and baled on-site using small vertical balers.

Curbside Collection

There were estimated to be in excess of 9,000 curbside collection programs in the United States in 1994. These programs can be divided into the following general types:

- **Curbside collection of source separated material** in which recyclables are set out at the curb in different containers and loaded in separate bins on the collection vehicle;

- **Curbside sorting of commingled materials** in which recyclables are set out commingled at the curb and sorted at the curb into separate truck compartments;

- **Commingled programs** in which recyclables are set out commingled at the curb and separated into *fiber* and *containers*, at the truck;

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[1]DSM Environmental Services, A Comparison Of Drop-Off And Curbside Collection In Orwell And Cornwall, Vermont, prepared for the American Plastics Council, 1992.

- **Commingled programs** in which recyclables are set out commingled at the curb and sorted on the truck between stops;

- **Co-collection programs** where containers and fiber are collected in separate compartments on the truck and mixed solid waste is compacted in a third compartment on the truck; and

- **Co-collection programs** in which recyclables are set out at the curbside in plastic bags, collected, and compacted with garbage.

Plastics can be added to any of the collection programs listed above. However, because rigid plastic containers are a light weight, high volume material, unless compacted, they occupy a significant amount of space in the curbside collection vehicle. Table 5 compares the average uncompacted densities of various recyclable containers measured throughout the United States.

TABLE 5
AVERAGE UNCOMPACTED DENSITY OF RECYCLABLE CONTAINERS

Material	Average Density (lbs./yd^3)	Range (lbs./yd^3)
All Plastic Bottles	30	28-37
HDPE Natural	20	17-22
HDPE Pigmented	42	NA
PET	32	31-33
Glass	396	369-419
Steel Cans	127	107-155
Aluminum Cans	57	30-84
Aseptic Containers	32	30-35

Traditionally, recyclables have not been compacted at drop-off collection facilities or on curbside collection vehicles. This has negatively affected plastics collection because the low density plastic containers occupy a disproportionate amount of space on the collection vehicle compared to heavier recyclable containers. Space requirements vary, but on average, uncompacted plastic bottles will require between 48 and 50 percent of the space devoted to all recyclable bottles and cans.

The amount of space occupied by plastic bottles on the collection vehicle or drop-off storage container can be substantially reduced through compaction, either of just plastic bottles, or of all recyclable containers.

For example, compaction ratios ranging between 3:1 and 4:1 can be achieved using conventional stationary compactors and enclosed roll-off containers. In addition, a number of companies now manufacture one and two cubic yard capacity on-board compactors. These can either be mounted between the cab and body of the collection vehicle or in the collection body. Compaction ratios of 10:1 can be achieved with these on-board compactors.

Key issues associated with the decision to utilize on-board compaction include:

- The outside dimensions of the plastic compactor determine the *effective* compaction ratio. That is, a one cubic yard compactor specified as having a 10 to 1 compaction ratio, has an effective compaction ratio of 3.4:1 because the typical one cubic yard compactor takes up 2.9 cubic yards of space on the truck based on its outside dimensions.

- The trend is toward commingled collection of recyclables with sorting at centralized processing facilities. The additional time per stop associated with separating plastic bottles from other commingled containers, throwing them into a compactor, and operating the compactor is of marginal value in a bottle bill state, where the majority of PET bottles are removed by the deposit system. However, the significantly greater quantities of plastic bottles in a non-bottle bill state appears to make on-board plastic compaction cost effective, even if collection is commingled.

In the past, it was commonly assumed that plastic bottles were the only recyclable material requiring compaction. In reality, all recyclables, except glass, can be effectively compacted, increasing truck capacity and reducing the number of trips off-route to unload. Given the increasing variety and quantity of recyclables being collected in communities throughout the United States, it is likely that compaction of mixed recyclables will become more popular, increasing the viability of collecting plastic containers.

Collection Economics

The costs of adding plastics to a collection program can be calculated using marginal or full cost allocation. Marginal, or incremental, costs account for only those costs that will change when a new material, such as plastics, is added to an existing program. Full cost allocation compares the total costs associated with collecting a new material in a recycling system with the total cost of collecting each of the other materials.

The problem with using incremental costs to estimate the impact of adding plastic to a collection system is that incremental costs vary greatly depending on the current capacity of the collecting system. For example, the impact of adding plastic to a truck that can barely finish a route is significantly greater then for a truck that has extra capacity and finishes a route early every day. This variation makes incremental cost accounting unreliable, particularly given the continued pressures to add new materials to recycling collection programs.

Full cost accounting, on the other hand, requires that the costs of each component of the collection system be estimated and then allocated fairly among each material collected. Capital costs for vehicles can be allocated to materials based on the percent of space they require. Capital costs for specialized equipment can be allocated to the material requiring such equipment. Operating costs require the collection day be broken down into activity categories that can be assigned, by percentage of time, to individual materials.

Table 6 presents average fully allocated collection costs, by material based on APC studies in six regions of the United States.

TABLE 6
AVERAGE COLLECTION COST PER TON BY MATERIAL (1993)

Material	Average Cost ($/ton)	Range ($/ton)
Plastic	970	560-2120
Aluminum	1670	470-4050
Steel	330	130-520
Glass	90	70-120

In most cases, the high end of the range for the lightweight aluminum and plastic represented costs in bottle-bill states where a significant amount of material was diverted via the deposit system, leaving smaller quantities over which to allocate costs.

As Table 6 illustrates, high volume, lightweight plastic, exhibits high per ton fully allocated collection costs. These costs have discouraged many municipalities from adding plastic to their recycling programs. However, factors other than cost per ton should be considered when deciding which materials to collect in a recycling program. For example, costs to consumers to purchase products in heavy packaging, and their environmental costs, are often ignored in collection cost analysis. Heavy packaging generates high recycling tonnages, and therefore, low per ton collection costs, but also generates more packaging and may result in greater total environmental impacts associated with the life cycle costs of the packaging material.

According to a 1992 CSG/Tellus Institute Packaging study prepared for the Council of State Governments and the United States Environmental Protection Agency, "the lightest weight package, per unit of product delivered, is generally the lowest [environmental] impact product."

Table 7 illustrates that on average, a pound of plastic, the lightest weight packaging material, delivers 17.5 times as much product to the household as a pound of glass, the heaviest weight packaging material.

TABLE 7
PER HOUSEHOLD AND PER CONTAINER RECYCLING COLLECTION COSTS, COMPARED TO AVERAGE PER TON COSTS

Material	Ounces Of Product Delivered Per Pound Of Packaging (oz.)	Average Per Ton Recycling Collection Costs ($)	Recycling Collection Cost Per 12 Oz. of Product Delivered (cents)	Collection Cost Per Household Per Month (cents)
Aluminum	275	1,670	1.1	24
Glass	30	90	1.8	32
Plastic	527	970	1.7	39
Steel	99	330	2.1	21

Because fewer *pounds* of plastic are generated per household than for heavier materials, *per household* recycling costs for each material are similar despite much higher "per ton" recycling costs. That is, per ton recycling costs for glass or steel are significantly less than for plastic or aluminum, but significantly greater quantities of glass and steel must be collected from each household. Thus, if a municipality is willing to collect comparatively heavy weight packaging, such as glass and steel for recycling, then from the standpoint of the household served by the program, it makes economic sense to also collect plastic packaging because although *per ton* recycling costs are higher for plastic, *total* recycling costs to the household are about the same for all materials, because the light weight materials deliver the most material to the household per pound of packaging.