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Project Summary

Resource Recovery from Plastic and Glass Wastes

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As one objective of the Resource Conservation and Recovery Act, a research program was initiated to assess and evaluate the state-of-the art for recovery of glass and plastics from solid wastes. Currently, labor-intensive source separation of glass and plastics predominates, but mechanical and thermal recovery will achieve greater importance in the years ahead. Where data were available, these technologies were discussed in terms of technical, economic, and environmental aspects, and obstacles to recycling. Past and present research efforts were identified, and research needs to enhance recovery of resources were addressed.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Plastic Manufacturing and the Plastic Industry

Plastics is a generic term describing strong, durable, light, easy to fabricate, fairly inexpensive materials derived from petrochemical feedstock. Plastics are available in more than 40 families of material types with a broad range of performance characteristics (1). Plastics are a rapidly increasing segment of the economy, and new and variable uses and markets make industry characterization difficult.

All plastics are either thermosetting or thermoplastic. Thermosetting plastics are set into permanent shape by the application of heat and pressure, and on reheating, they cannot be reshaped. Thermosets account for more than 20 percent of the total U.S. polymer production, and they are often used for durable goods such as counter tops, pot handles, knobs, and highly engineered applications. They do not significantly add to the municipal solid waste stream (1).

Thermoplastics soften upon reheating and harden upon cooling. Ease of use of thermoplastics, plus specific resin characteristics enhance their use. Thermoplastics are often found in the municipal solid waste stream (1), and they account for approximately 80 percent of polymer production (2).

Plastic manufacturing is a diversified and complex operation. From the raw material input to the final consumer product, the various operations within the plastic industry are integrated into various segments. Integration of operations within the plastic industry is extensive. Thus one company can be a resin producer, compounder, and fabricator, and a manufacturer/packager can sometimes operate as fabricator and converter. As a plastic product is made, starting from the resin, it normally passes through manufacturing facilities that progressively become smaller in size and more dispersed geographically.

Glass Manufacturing and Glass Industry

Glass is chemically inert, impermeable to all liquids and gases, sanitary and odorless, capable of transparency, and versatile and adaptable in that it can be molded to almost any shape and size (3). The manufacturing process is usually a fully integrated, one-step process that begins with raw material feedstock and yields a finished product at the same location. Basic raw materials include soda ash, limestone, and sand. Limestone and sand are cheap and abundant. Cullet, or waste glass, can be used in lieu of soda ash, which is in demand.

State of the Art for Resource Recovery of Plastic Wastes

Plastic Waste Generation

Plastic waste is generated from industrial-manufacturer, commercial, and municipal sources. The amount of plactic wastes generated in 1977 and projected for the years 1980-1990 is presented in Table 1.

Plastics production in 1977 totaled 33,948 million lb (1). Of that amount, approximately 80 percent was thermoplastic, and thus amenable to remelting and refabrication, to a certain extent. The largest single end use for plastics is in packaging, although most plastics are put to long-term uses. As a result, the source of plastics found in the municipal waste stream is normally plastics packaging. No hard data exist to indicate exact quantities of plastics recovered from waste streams. Estimates indicated that 4,850 million lb were recovered, primarily through industrial recycling (1). Solid wastes are produced at essentially every step in the manufacture of plastics, with the post-consumer segment accounting for most of it.

Resource Recovery from Plastic Wastes

Because of the tremendous growth in the use of polymers or plastics, especially for short-term packaging, increasing attention has been focused on its recovery. But the recovery of plastics from municipal refuse within the United States is basically embryonic. Currently, only specific plastics that are uncontaminated and segregated from other polymers and wastes have potential for recovery. Polyester-polyethylene terephthalate (PET) bottles, polyvinyl chloride (PVC) scrap, polyethylene containers, and high-density polyethylene (HDPE) film are currently sporadically recovered for recycling. As a result, energy derived from combustion in waste-to-energy plants most likely represents the future prevalent made of plastics recycling.

Table 1. *Estimates and Forecasts by Year of Plastic Wastes Generated and Recovered*[a,b]

Category of Waste	*1977*	*1980*	*1985*	*1990*
Total solid waste (MT)[c]	*148*	*160*	*180*	*200*
Municipal generation (MT)	*6.9*	*8.4*	*11.2*	*13.4*
Commercial generation (MT)	*0.8*	*0.9*	*1.2*	*1.4*
Industrial generation (MT)	*0.6*	*0.7*	*1.0*	*1.2*
Recovery (MT)[d]	*1.4*	*1.6*	*2.4*[e]	*2.8*[e]
Total waste as generated (MT)	*6.9*	*8.4*	*11.0*	*13.2*
Total waste as disposed (MT)	*6.9*	*8.0*	*9.6*	*10.0*
Plastic in mixed wastes, %	*4.9*	*5.3*	*6.2*	*6.6*
Plastics recovery as a % of plastic wastes (municipal) for energy recovery	*0*	*4.2*	*13.4*	*24.3*

[a]*Assume no variation in industrial-municipal, commercial ratios of generation.*
[b]*Composite of Midwest Research Institute and PES estimates.*
[c]*Million tons.*
[d]*Recovery is composite of source separation and energy recovery.*
[e]*Incorporates PET recycling at 25% efficiency.*

A less familiar but equally important area is that of pre-consumer wastes, or those generated by producers, processors, and fabricators of products. Though recovery of plastics from municipal refuse is not extensive, industrial (and to a certain extent commercial) recovery is quite extensive. Essentially, scrap recovery has long ceased to be an afterthought in most plastic processing operations. Scrap handling has the potential for being as important a plastic processing operation in its own right as processing virgin polymers, since the rising costs of feedstocks make even small losses significant.

Reuse strategies have shown that clean and single material plastic waste streams derived from municipal waste (PET, for example) can be collected and recycled. Such activities are limited, however, and are useful only for beverage packaging.

Except on such limited bases, recovery of plastic materials from the mixed municipal waste stream appears to be technically or economically unfeasible at present. The greatest potential for successful plastic waste recovery seems to be (a) the derivation or recovery of energy from combustion of a mixed plastic/organic waste fraction in the municipal waste stream, (b) the enhancement of volume reduction through various forms of thermal treatment by utilizing the high energy value of plastics, and (c) selected source separation.

State of the Art for Recovery of Glass Wastes

Glass Waste Generation

Waste glass generation in the United States stems primarily from industrial, commercial, and municipal sources. The total glass production in 1978 was estimated to be about 20 million tons. About 70 percent of this glass was container glass, but the amount of container glass found in municipal waste is reported to be about 90 percent (4). Such a figure is expected, since in the absence of reuse systems, the useful life for container glass is relatively short when compared with other glass types such as flat glass and fiberglass. According to the latest available statistics, glass is reported to make up to 10 percent of the total municipal wasteload (5) of 148 x 10^6 tons. Table 2 presents a projection of glass waste and the amounts recovered from mixed municipal waste for the period 1980-

Table 2. *Projection of Glass Waste Generation, Processing, and Recovery for Municipal Waste*[a]

Category	1972	1975	1980	1985	1990
Total solid waste (MT)[b]	130	140	160	180	—
Glass available (MT)	13	14	16	16	16
Glass as % of total waste	10.1	10.5	10.3	9.3	—
Glass processed for recovery[c] (MT)	0	0.020	0.170	0.540	0.860
Glass recovery (MT) source separation collection	0.175	0.180	0.225	0.225	0.225
Cullet dealers	0.100	0.085	0.050	0.050	0.050
Waste recovery plants	0	0.010	0.100	0.350	0.600
Total resource recovery of glass (MT)	0.275	0.275	0.375	0.600	0.850
Amount recovered as % of total glass waste	2.8	1.8	2.3	3.6	5.0

[a]Estimates by Midwest Research Institute.
[b]Million tons.
[c]Processed in central facility with glass subsystem.

1990, incorporating such factors and beginning with the base year of 1972.

Resource Recovery from Glass Wastes

The recovery of glass from municipal waste within the United States today is more representative of any emerging technology rather than an age-old practice. Nonetheless, a secondary materials industry does exist, and methods for recovering materials from municipal waste are achieving new levels of sophistication and success.

Within the recycling "closed system," three defined segments exist: (a) glass manufacturing and secondary materials users; (b) cullet dealers; and (c) municipal and private collection programs. Glass manufacturers are the principal actors. Raw material users have traditionally used glass cullet derived from off-specification glass, etc. Most recycled glass from post-consumer sources has been used by glass container manufacturers to produce new containers. Recently there has been a shift to composites of glass, plastic, and fibers. These new secondary uses promise glass recycling an expanded cullet capacity with reduced specification levels. In addition, economic problems exacerbated by inflation and energy shortages have improved the economics of smaller-scale enterprises. The theory is that small scale, local industries will be more apt to utilize locally derived cullet, thereby eliminating high transfer costs (6).

Cullet dealers represent a second segment. As intermediate processors, they provide the important function of aggregation and quality control. Cullet dealers are, however, a diminishing segment of the industry. Fewer than 20 dealers exist today.

Finally, the delivery or collection system, represented by grass roots recyclers, municipalities, and small businesses, form the third segment. They often deal through intermediate processors, although larger programs may sell directly to a manufacturer.

Environmental and Economic Evaluation

In the commercial and manufacturing segments, resource recovery activities have been straightforward. The economics are based on materials of known composition and quality that are free of contamination. In particular, the economics of the plastics industry is very much dependent on the recycling of scrap (waste) internally or by sale. Scrap is usually reintroduced into the production stream either directly or downstream of the resin manufacturers. Through the recovery of plastic and glass wastes, adverse environmental and economic impacts are mitigated and beneficial impacts are realized.

By contrast, plastic and glass wastes from municipal sources are mixed with other wastes and are contaminated. They must then be separated from other solid wastes or at least concentrated into suitable fractions, homogenized, and decontaminated before any successful utilization. Recycling from municipal sources is presently limited. For both plastic and glass cases, there exists a paucity of environmental and economic information. As a result, environmental and economic impacts are difficult to assess. Moreover, no existing commercial recovery system (other than certain pilot mechanical and source separation systems) recovers plastics or glass from MSW as a sole product. Consequently, identification of specific impacts and costs is, at best, a most difficult proposition.

Obstacles to Recycling

Current obstacles exist that inhibit increased glass and plastic recycling. One obstacle is the general price differential between virgin and recycled materials. Virgin materials have been cheaper in the United States because natural resources have been plentiful, because public policies favor virgin materials, and because environmental and other social costs (externalities) have been omitted from the price (7). For example, public policy on Federal land use gives competitive advantage to virgin material extractors (8), and tax structures also favor extractive industries. Railroad freight rate discrimination is another advantage enjoyed by industries dealing with virgin materials (9).

Research on Plastic and Glass Waste Recovery/Reuse

Basic plastic waste recovery research programs generally focus on the site-specific needs of manufacturers. These include: (a) processes for the chemical or mechanical separation of various blends of plastic waste, (b) processes or additives that improve the bonding characteristics of mixed plastic types, (c) development of specifications to aid consumers in identifying plastic and to enhance recyclability, and (d) processes and systems to upgrade segregated plastic scrap types normally uniformly contaminated (e.g., PVC molded around copper wire).

Research efforts focusing on municipal refuse as a source of plastic for recovery are combustion-energy recovery operations, which favor the high BTU content (10,000 BTU/lb) of plastics, selected solvent separation, cryogenics, source separation, air separation, electrodynamics, sink flotation, and research related to PET bottles.

Research efforts for glass recovery/reuse have been concerned with *mechanical separation, source separation,* new secondary products, and reuse programs. Foremost, a market for the recovered glass must exist, and presently there are only limited markets. One area of research that has been promising for glass waste recovery is its use in secondary products such as glasphalt and glass foam insulation.

Conclusions

The following conclusions were developed based on the state of the art:

Plastics

1. Industrial and commercial sources can efficiently recycle using simple, proven technology. The main reasons are that waste materials are concentrated, relatively uncontaminated, and usually of known quality and composition.
2. No proven commercial-scale recovery system singularly effects recovery of waste. Rather, such materials are recovered as one component of an overall recovery/collection approach.
3. Secondary products, on the whole, have not had specifications developed on product reuse. This situation has acted as a barrier to increased use, since reuse processes have not necessarily been standardized.
4. Combustion and energy recovery hold the greatest promise for recovery of the bulk of the plastics fraction of the solid waste stream because of the number of different types of plastics and the differing degrees of degradation of components.
5. Source separation from the industrial to the residential levels constitutes the only significant recovery of waste from municipal waste sources.
6. For the immediate future, industrial and commercial sources will constitute the majority of recycling activity. Recovery from post-consumer wastes must overcome significant market, institutional, technical, transportation, and specification barriers to compete successfully with virgin products.

Glass

1. Glass manufacturers claim that 25 percent of the post-consumer waste stream could presently be recycled. Transportation and collection/delivery problems and contaminant levels mitigate against such recovery.
2. Industrial and commercial sources can efficiently recycle using simple, proven technology. The main reasons are that waste materials are concentrated, relatively uncontaminated, and usually of known quality and composition.
3. Municipal wastes are most often mixed with other refuse components; hence recovery is difficult and not economical. Also, the ease of obtaining raw materials prevents a significant recovery incentive.
4. No proven commercial-scale recovery system singularly effects recovery of glass. Rather, such materials are recovered as one component of an overall recovery/collection approach.
5. Source separation often lacks in collection equipment and efficient processing; hence recovery is inhibited.
6. Secondary products, on the whole, have not had specifications developed on product reuse. This situation has acted as a barrier to increased utilizations, as reuse processes have not necessarily been standardized.
7. Mechanical recovery systems for glass wastes have primarily originated from other industries such as mining. They lack proven usage in waste separation, where moisture, composition, physical properties, and economics vary widely.
8. A national market for mixing color glass cullet could significantly enhance recovery of glass wastes from municipal sources by simplifying collection and processing.
9. Source separation from the industrial to the residential levels constitutes the only significant recovery of waste from municipal waste sources.
10. For the immediate future, industrial and commercial sources will constitute the majority of recycling activity. Recovery from post-consumer wastes must overcome significant market, institutional, technical, transportation, and specification barriers to compete successfully with virgin products.

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The complete report, entitled "Resource Recovery from Plastic and Glass Wastes," (Order No. PB 81-223 471; Cost: $14.00, subject to change) will be available only from:
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