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CHARACTERIZATION AND PROCESSING OF PLASTICS FROM MINNESOTA'S DEMONSTRATION PROJECT FOR THE RECOVERY OF END-OF-LIFE ELECTRONICS

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Abstract

In an innovative public/private initiative, the Minnesota Office of Environmental Assistance partnered with Sony Electronics, Panasonic Matsushita, Waste Management Asset Recovery Group, and the American Plastics Council, to collect and process end-of-life consumer electronics. Plastics characterization was done by MBA Polymers, Inc. Approximately 700 tons of electronic equipment were collected and processed during the three-month project period. This paper discusses what was learned during the project about processing plastics as well as what resins and contaminants are typically present in the residential electronics stream. In addition, because a specific goal of the project was to evaluate recovered plastics for use in high-end applications, physical properties were obtained on pelletized flame retardant HIPS material from televisions.

Introduction

In 1999, the Minnesota Office of Environmental Assistance (MOEA) launched a unique project to identify how best to capture and recycle used electronics from the residential waste stream. MOEA recognized that, to be successful, the project must involve representatives from both the public and private sectors; therefore, it enlisted support from key members of the supply chain, including Sony Electronics, Panasonic-Matsushita, Waste Management Asset Recovery Group (WM-ARG), and the American Plastics Council (APC).

Together, these partners established three goals for the project: (1) to evaluate different collection strategies and costs, (2) determine transportation and processing costs, and (3) explore market opportunities for two secondary materials—glass from cathode ray tubes (CRTs) and plastics.

For its part, APC was particularly interested in learning what plastics were present in used residential electronics, whether they could be separated into discrete streams for marketing, and what properties the recovered resins would have. While APC had conducted similar research before in partnership with such groups as the Materials for the Future Foundation, Hennepin County, Minnesota, and MBA Polymers, Inc., it wanted to expand the scope of its research and validate previous efforts with larger samples.

Collection Sites, Strategies, and Amounts

To begin the project, the partnership selected eight regional collection entities across Minnesota, which, in turn, established 65 individual collection sites. The sites were selected to ensure geographic and demographic diversity as well as involvement from profit, non-profit, public, and private organizations. Collection events varied in length from one day to more than one month and were held either as one-time special events or part of ongoing programs. Collection strategies varied from curbside collection of electronics to drop-offs at household hazardous waste collection sites, recycling centers, garbage transfer stations, neighborhood clean-up events, and retail stores.

During the project, electronic products—defined as anything with a plug or embedded battery except for large appliances or white goods—were collected over a three-month period. Approximately 9,000 of the estimated 1.3 million residents reached by the program

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availed themselves of the opportunity to return used electronics.

Surprisingly, 700 gross tons of electronics were collected during the demonstration project and transported to WM-ARG, much more than originally anticipated. Of that amount, 575 tons were actual electronic products with the remaining 125 tons consisting of packaging and shipping materials. The latter included gaylord boxes, pallets, and shrink wrap, all of which were necessary to properly handle and ship materials. The collection volume equates to about 128 pounds of electronics and 28 pounds of packaging per participating person.

Transportation and Demanufacturing

At the WM-ARG processing facility in Inver Grove Heights, Minnesota, electronics were sorted into five product types: (1) televisions; (2) monitors; (3) personal computers, including keyboards, mice, and hard drives; (4) home communication electronics, including telephones, fax machines, and scanners; and (5) household electronics, including small kitchen appliances, hairdryers, curling irons, radios, and so forth.

As Table 1 shows, televisions accounted for more than half of the 700 tons of electronics collected. Interestingly, packaging was the next largest item by weight at 125 tons, followed by home communication electronics at 70.5 tons.

As Table 1 also shows, if packaging is removed from the equation, the distribution by product type looks somewhat different. Televisions account for 67.9 percent—or more than two-thirds—of the total, followed by home communication electronics at 12.3 percent, household electronics at 7.4 percent, computer monitors at 7.1 percent, and personal computers and components at 5.3 percent.

After the electronics were separated by product type, WM-ARG disassembled them, removed hazardous materials, and created numerous categories of scrap destined for other locations. Some materials were marketed, including plastics, glass from CRTs, copper-bearing materials, precious metal-bearing materials, non-ferrous metals, and ferrous metals. Others, including the packaging and some whole parts, were reused, and still others were sent to the landfill as solid waste. Table 2 shows how much of each outbound material was generated and where it was sent.

Plastics Generation

The next step was to ship a sample of plastics to MBA Polymers, Inc., a durable plastics processor and technical research facility in Richmond, California, for characterization. To help control for quality, APC and MBA asked WM-ARG to exclude TVs with high levels of lamination and/or high levels of obvious coatings. They also excluded monitors with large amounts of metal coatings, but left metal attachments (such as screws and molded-in metal inserts) and labels intact. Next, WM-ARG separated the plastics into three basic categories: plastics from televisions (primarily housings which are mostly black in color), plastics from computers (monitor housings, CPU housings, and peripherals which are mostly light colored), and plastics from miscellaneous electronics (all other communication and household electronic goods which are typically mixed color). As Table 2 shows, 30.5 tons—or 61,000 pounds—of plastics were collected and separated in this manner. That represents 4.4 percent by weight of the total quantity of outbound materials (including discards).

Of the 61,000 pounds of outbound plastics, more than 31,000 pounds were shipped to MBA Polymers for further study. The remaining plastics from dismantled TV housings were sold into the export market at about five-cents per pound, and the rest of the plastics were disposed of as waste along with wood from old televisions.

Plastics Separation and Identification

In total, 31,588 pounds of plastics were shipped to MBA Polymers. Plastics from televisions comprised 54 percent of the sample, computer plastics comprised 38 percent, and miscellaneous plastics comprised 8 percent. The entire sample—100 percent of each category—was accepted for further processing by MBA. It put the plastics through a dry process designed to reduce size and remove metals, and then through proprietary separation processes to produce discrete streams of plastic. During the first process, about 10 percent of the sample was removed as metal, fluff, or fines. An additional 5% of the sample was lost during the separation process, leaving a total of 27,301 pounds of plastic for characterization.

Next, MBA identified the plastics by resin type using equipment developed, in part, by APC. As Table 3 shows, MBA was able to identify eight different basic resins. In the total sample, HIPS was the predominant resin at 56 percent, followed by ABS at 20 percent and PPO at 11 percent. As the table also shows, the quantity of those resins varied within product categories. HIPS was clearly the predominant resin in television plastics whereas ABS was the predominant resin in both computer and miscellaneous plastics.

Plastic Resin Separation

Another goal of the project was to determine whether individual plastic resins could be separated into discrete streams that could be marketed into high-end applications. For this part of the test, MBA chose to focus on flame-retardant television HIPS (T-HIPS) since it was, by far, the most abundant resin in the sample.

Using a proprietary separation process, MBA took the entire television plastics sample and, from that, successfully created a nearly pure stream of flame-retardant T-HIPS. The yield from the process was 8,215 pounds of final product, which represents 48 percent of the total feed stream (i.e., all television plastics) and 67 percent of the available HIPS. MBA believes it can increase this yield as it gains familiarity with the material and fine-tunes its separation system. In addition, while similar separation tests were not performed on other resins, MBA maintains that, given sufficient quantities, it should be possible to separate television plastics to yield high quality ABS and PPO as well.

Extrusion and Material Testing

A final goal of the project was to develop a specification sheet for T-HIPS to determine if it could be used in high-end applications. To that end, MBA dried, extruded, and pelletized the recovered T-HIPS and then, injection-molded test bars and tested properties. Table 4 shows the results of those tests and compares the melt flow rate, impact strength, tensile strength, and density of post-consumer T-HIPS with three similar virgin resins currently on the market. The results of these tests show that the properties of flame retardant T-HIPS from recovered residential televisions are comparable to virgin resins; therefore, recycled T-HIPS could potentially be used in similar applications given a consistent quantity and quality of supply.

Comparisons to Previous Research

APC has done considerable research in the area of durables recovery over the past eight years. It also is responsible, in large part, for the development and testing of several types of identification and separation technology used in the present study. While numerous reports have been written on various components of APC's research, its recent report, titled "Plastics from Residential Electronics Recycling: Report 2000," is probably the most comparable to this project. It involved characterizing plastics from electronics recovered by Hennepin County, Minnesota, from its residential collection program. Therefore, it makes the most sense to compare the results of that previous work with the results of this more current study.

What do comparisons reveal?

- ✓ First, the current project tested a much larger sample—31,000 pounds compared to 3,000 pounds--and, thus, is statistically more representative of which plastics can be found in used consumer electronics.

- ✓ Second, the distribution by product type was quite different. In the current project, television plastics comprised a much smaller portion of the sample (54 percent compared to the previous 67 percent) and computer plastics comprised a much larger portion (38 percent compared to the previous 18 percent). This is not surprising given the proliferation of computers in recent years and the maturation of television saturation. It also bodes well for recycling plastics from used consumer electronics because computers tend to have higher-value engineering plastics than televisions.

- ✓ Third, MBA Polymers accepted 100 percent of the current plastics sample but only 35 percent of the previous sample. That is mostly because WM-ARG did an excellent job of sorting plastics to meet MBA's specifications, choosing to export or discard plastics that did not meet specs prior to shipment. If all demanufacturers work similarly to meet market specs, it should improve the viability of recycling plastics from recovered electronics.

- ✓ Fourth, the resin composition of the total current sample was both similar to and different from the previous sample. For example, in both samples, HIPS was the predominant resin followed by ABS and PPO. Interestingly, HIPS increased as a portion of the total current sample, ABS comprised the same portion of each sample, and PPO declined as a portion of the current sample. (See Table 5.) In addition, in the current sample there was slightly more PVC, PC/ABS, and PC, and slightly less "other."

- ✓ Fifth, within product categories, the resin distribution varied compared to the previous sample. For example, in television plastics, there was considerably more HIPS in the current sample, and less ABS and PPO. With computer plastics, there was considerably more HIPS in the current sample, considerably less ABS and PPO, and more resins represented in general. With miscellaneous plastics, there was much less HIPS and PPO and much more ABS, PVC, and PC/ABS.

✓ Sixth, when trying to produce a pure stream of flame-retardant T-HIPS, the yield was much better in the current effort (48 percent of television plastics compared to 15 percent in the previous MFF study). This is attributable to MBA's growing familiarity with the resin and better separation equipment and techniques.

✓ Seventh, while a specification sheet was not developed for T-HIPS from the previous sample, the question was asked: In what markets might plastics from recovered electronics be used? The tests that were performed in this project show that T-HIPS could potentially be used in similar applications as virgin resins in addition to applications—such as plastic lumber, outdoor furniture, flooring applications, and road patch–in which it is currently being used.

✓

Conclusions

Clearly, this recent study is an important step forward in understanding plastics from end-of-life electronics. Not only do we know, with more precision, what resins are present in what quantities, we also know what properties the dominant resin—FR HIPS from televisions—has. This information is critical in understanding the end markets in which plastics from recovered electronics might be used.

From the overall project findings, we also have a better understanding of the economics associated with collecting, recycling, and disposing electrical and electronic products. Preliminary analysis shows that collection, transportation, and handling costs were relatively high, but that is to be expected in a first-of-its kind demonstration project. Perhaps more important, the study provides information about how those costs could be reduced in the future. The economics of recovering electronics from the residential sector will be discussed in greater detail in the project's final report, which is scheduled for release later this year.

Table 1: Incoming Products

Product	Tons (with packaging)	Percent of Total (with packaging)	Tons (w/o packaging)	Percent of Total (w/o packaging)
Televisions	390	55.7	390	67.9
Packaging	125	17.9	-0-	-0-
Communication electronics	70.5	10.1	70.5	12.3
Household electronics	43	6.1	43	7.4
Monitors	41	5.9	41	7.1
Personal computers	30.5	4.3	30.5	5.3
Total	***700 tons***	***100%***	***575 tons***	***100%***

Table 2: Outbound Materials

Material	Tons	Percent of Total	Destination
Steel breakage (ferrous)	180	25.7	steel mill
Packaging	125	17.9	Reused
CRT glass to lead	113	16.1	Lead smelter
Solid waste	92	13.1	Landfill
Printed circuit boards	41.5	5.9	Copper smelter
Export scrap	41	5.9	Export scrap processor
Export reusable	31.5	4.5	Component recovery
Plastics	30.5	4.4	MBA Polymers or export
Copper-bearing materials	23	3.3	Copper smelter
CRT glass to glass	22.5	3.2	CRT manufacturer
Total	***700 tons***	***100%***	

Table 3: Resins Found in MOEA Plastics Sample (in total and by product category)				
Plastic Resin	**Television Plastics**	**Computer Plastics**	**Miscellaneous Plastics**	**Percent of Total Sample**
HIPS	82%	25%	22%	56%
ABS	5%	39%	41%	20%
PPO	7%	17%	4%	11%
PVC	<1%	5%	15%	3%
PC/ABS	0%	6%	7%	3%
PP or PE	0%	3%	8%	2%
PC	1%	4%	1%	2%
Other	<1%	<1%	2%	<1%
Unidentified	5%	0%	0%	3%

Table 4: Test Results for Recovered Flame Retardant T-HIPS (including comparisons with select virgin resins)				
Resin	**Melt Flow Rate[1] (200/5.0) (g/10 min)**	**Notched Izod Impact Strength[2] (ftlb/in)**	**Tensile Strength[3] (psi)**	**Density (g/cm^3)**
T-HIPS	7.5	1.5	3100	1.15
Dow Styron 6515	7.5	2.8	2800	1.16
BASF ES 8120	6	2	3500	1.15
Huntsman PS 351	6.5	1.7	4000	1.16

[1]This is a measure of how easy it is for the molten plastic to flow at a given temperature (200 degrees Celsius in this case) under a given load (5.0 kg in this case).

[2]This is a measure of how much energy is required to break the material. The plastic is notched to ensure that breaking energy is concentrated on one location on the specimen.

[3] Tensile strength is the greater of tensile strength at yield, which refers to the stress beyond which a material will irrevocably deform or the tensile strength at break, which refers to the stress on a material just prior to breaking.

Table 5: Comparison of MOEA Plastics Sample to Hennepin County Sample		
Plastic Resin	**Percent of MOEA Total Sample**	**Percent of Hennepin County Total Sample**
HIPS	56%	59%
ABS	20%	20%
PPO	11%	16%
PVC	3%	<1%
PC/ABS	3%	<1%
PP or PE	2%	3%
PC	2%	<1%
Other	<1%	2%
Unidentified	3%	0%

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