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Characterization of Products Containing Lead and Cadmium in Municipal Solid Waste in the United States, 1970 to 2000

Final Report

Executive Summary and Chapter 1, Lead and Cadmium in Municipal Solid Waste: Overview and Summary

EXECUTIVE SUMMARY

As disposal of municipal solid waste (MSW) has become an issue of increasing importance in the United States, combustion of wastes has been recognized as one of several alternative management approaches. A concern associated with municipal waste combustion, however, is that heavy metals (lead and cadmium in particular) have been found in analytical tests of the ash from these facilities. This report characterizes the sources of lead and cadmium in products disposed in MSW over the time period 1970 to 1986, with projections to the year 2000.

LEAD IN MUNICIPAL SOLID WASTE

Lead is widespread in the municipal waste stream; it is in both the combustible and noncombustible portions of MSW. Discards of lead in MSW are overwhelmingly greater than discards of cadmium (Figure 1).

Lead-acid batteries (primarily batteries for automobiles) rank first, by a wide margin, of the products containing lead that enter the waste stream. Trends in quantities of lead discarded in products in MSW (ranked by tonnage discarded in 1986) are shown in Table 1. The last two columns on the table indicate whether the total tonnage of lead in a product is generally increasing or decreasing, and whether the percentage of total MSW lead contained in a product is increasing or decreasing.

Changing trends in discards of lead are illustrated in Figure 2. Lead discards in batteries are shown to be growing steadily, as are discards in consumer electronics. Discards of leaded solder in cans and lead in pigments, however, virtually "disappear" from the graphic between 1970 and 1986. Lead discards in other products are shown to be relatively small.

Findings about the individual products in MSW that contain lead are:

* Lead-acid Batteries contributed 65 percent of the lead in MSW in 1986; this percentage has ranged between 50 and 85 percent during the 1970 to 1986 period studied. The tonnages in Table 1 represent discards after recycling, but of all the products considered, only lead-acid batteries are recycled to a significant extent. Recycling rates, which have ranged from 52 to 80 percent, have a major effect on the tonnage of lead-acid batteries discarded.

* Consumer Electronics (television sets, radios, and video cassette recorders) accounted for 27 percent of lead discards in MSW in 1986. They contribute lead from soldered circuit boards, leaded glass in television sets, and plated steel chassis. Leaded glass accounts for most of the lead in these products.

* Glass and Ceramics, as reported here, include lead in products such as glass containers, tableware and cookware, and other items such as

Figure 1. Relative discards of lead and cadmium in MSW, 1986.

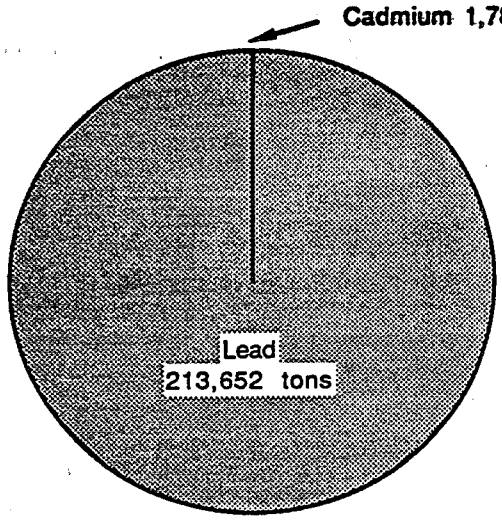
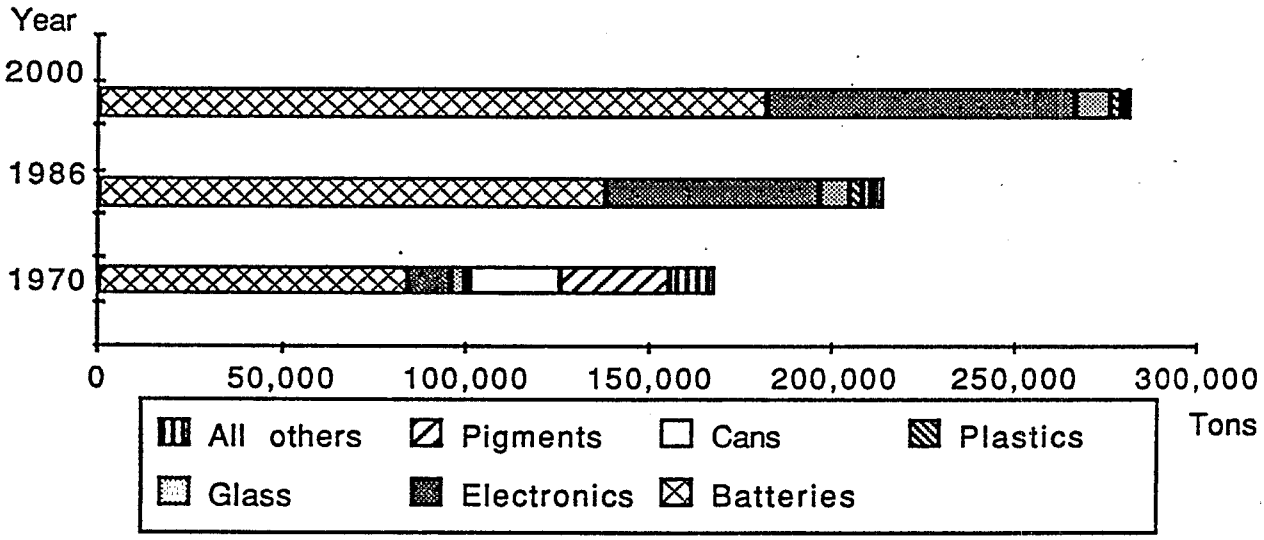


Table 1

LEAD IN PRODUCTS DISCARDED IN MSW, 1970 TO 2000
(In short tons)

Products	1970	1986	2000	Tonnage	Percentage
Lead-acid batteries	83,825	138,043	181,546	Increasing	Variable
Consumer electronics	12,233	58,536	85,032	Increasing	Increasing
Glass and ceramics	3,465	7,956	8,910	Increasing	Increasing; stable after 1986
Plastics	1,613	3,577	3,228	Increasing; decreasing after 1986	Fairly stable
Soldered cans	24,117	2,052	787	Decreasing	Decreasing
Pigments	27,020	1,131	682	Decreasing	Decreasing
All others	12,567	2,537	1,701	Decreasing	Decreasing
Totals	164,840	213,652	281,887		

Figure 2. Lead in discards of products in MSW, 1970, 1986, anc 2000.



optical glass. These contributed 4 percent of lead discards in 1986. (Leaded glass in light bulbs is included in the "All Other" category in Table 1.)

* Plastics use lead in two ways: As a heat stabilizer (primarily in polyvinyl chloride resins) and as a component of pigments in many resins. This category, which includes products such as nonfood packaging, clothing and footwear, housewares, records, furniture, appliances, and other miscellaneous products, accounted for about 2 percent of lead discards in 1986. Plastics in consumer electronics products are counted under that category.

* Soldered Cans have experienced a large decline in usage since 1970, when they contributed 14 percent of the lead in MSW. Leaded solder is currently used in steel food cans, general purpose cans (like aerosols), and shipping containers.

* Pigments containing lead compounds have declined greatly since 1970, dropping from 18 percent of total lead discards to less than one percent. This category includes pigments used in paints, printing inks, textile dyes, etc. Pigments used in plastics, glass and ceramics, and rubber products are accounted for in those categories.

* All Others include brass and bronze products, light bulbs (which contain lead in solder and in glass), rubber products, used oil, collapsible tubes, and lead foil wine bottle wrappers. Collapsible tubes contributed over 5 percent of total lead discards in 1970, but their use has declined dramatically since then. None of the other items has exceeded one percent of the total since 1970.

CADMIUM IN MUNICIPAL SOLID WASTE

Like lead, cadmium is widespread in products discarded into MSW, although it occurs in much smaller quantities overall. Since 1980, nickel-cadmium household batteries have been the Number 1 contributor of cadmium in MSW.

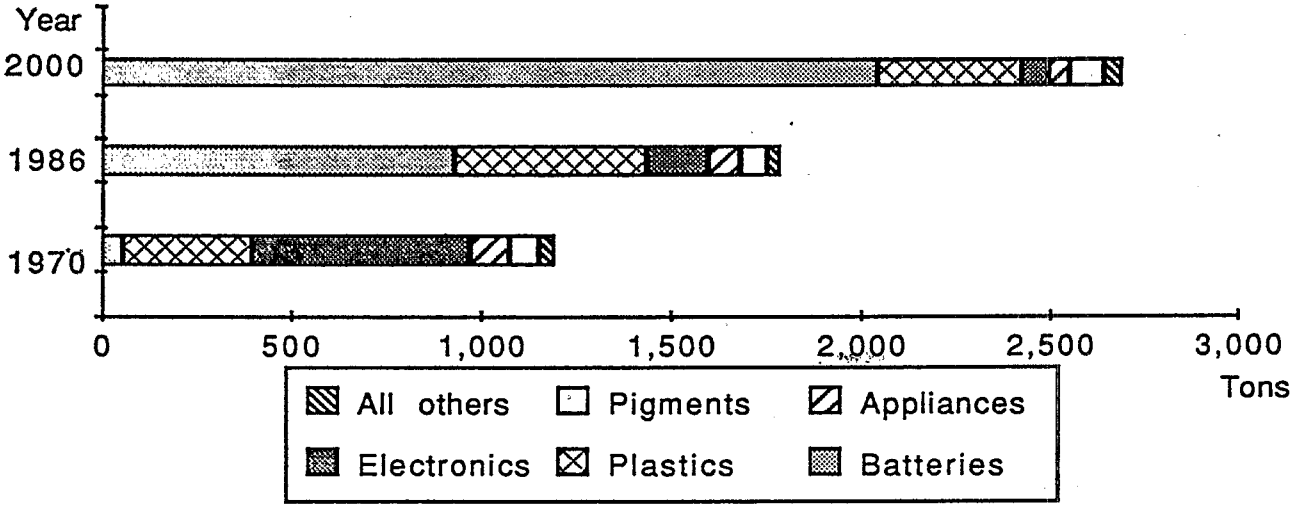
Trends in quantities of cadmium discarded in products in MSW (ranked by tonnage discarded in 1986) are shown in Table 2.

Trends in discards of cadmium in products in MSW are illustrated in Figure 3. Discards of cadmium in household batteries were small in 1970, but then increased dramatically. Cadmium discards in plastics are relatively stable. Discards of cadmium in consumer electronics are shown to decrease over time, while the other categories are relatively small.

Findings about cadmium discards in individual products in MSW are:

* Household Batteries (rechargeable nickel-cadmium batteries) have accounted for more than half of cadmium discards in the U.S. since 1980. This growth is projected to continue unless they are replaced by another type of battery.

Figure 3. Cadmium in discards of products in MSW, 1970, 1986, and 2000.



* Plastics continue to be an important source of cadmium in MSW, contributing 28 percent of discards in 1986. Cadmium is used in stabilizers in polyvinyl chloride resins and in pigments in a wide variety of plastic resins. Cadmium is found in nonfood packaging, footwear, housewares, records, furniture, and other plastic products.

Table 2

CADMIUM IN PRODUCTS DISCARDED IN MSW, 1970 TO 2000
(In short tons)

Products	1970	1986	2000	Tonnage	Percentage
Household batteries	53	930	2,035	Increasing	Increasing
Plastics	342	502	380	Variable	Variable; decreasing after 1986
Consumer electronics	571	161	67	Decreasing	Decreasing
Appliances	107	88	57	Decreasing	Decreasing
Pigments	79	70	93	Variable	Variable
Glass and ceramics	32	29	37	Variable	Variable
All others	12	8	11	Variable	Variable
Totals	1,196	1,788	2,684		

* Consumer Electronics (television sets and radios) formerly had cadmium-plated steel chassis in many cases. These chassis have been replaced by circuit boards, so cadmium discards in consumer electronics are declining as the older units are replaced. They contributed 9 percent of the total in 1986.

* Appliances (dishwashers and washing machines) formerly had cadmium-plated parts to resist corrosion. This source of cadmium is declining as cadmium-plated parts are replaced by plastics, which are themselves another source of cadmium discards in appliances. Cadmium discards from appliances accounted for about 5 percent of total in 1986.

* Pigments used in printing inks, textile dyes, and paints may contain cadmium compounds, although this is not a large source of cadmium in MSW (about 4 percent of total).

* Glass and Ceramics may contain cadmium as a pigment, as a glaze, or as a phosphor. This is a relatively small source of cadmium in MSW.

* All other sources of cadmium include rubber products, used oil, and electric blankets and heating pads. These contribute very small amounts of cadmium to MSW.

LEAD AND CADMIUM IN COMBUSTIBLE AND NONCOMBUSTIBLE PRODUCTS

Removal of the noncombustible products containing lead and cadmium before municipal solid waste is incinerated has been suggested as a way to manage the heavy metal content of incinerator ash. Using data developed in this study, the lead and cadmium content of the combustible and noncombustible fractions of MSW was examined.

Almost 98 percent of the lead in MSW is found in noncombustible products, mostly in lead-acid batteries (Figure 4). If all the noncombustible products containing lead were removed, most of the remaining lead would be in plastics (71 percent) and other pigments (24 percent).

Noncombustible products also contribute the majority (64 percent) of cadmium in MSW, with nickel-cadmium batteries being the primary source (Figure 5). If all of the noncombustible products containing cadmium were removed, plastics would contribute most of the remainder (88 percent), with other pigments accounting for 11 percent.

POTENTIAL EFFECTS OF RECYCLING

Recycling of lead-acid batteries to recover lead has a very significant influence on the amount of lead discarded. A previous study for EPA estimated the recycling rate of these batteries to be 80 percent in 1986; if there were no recycling of batteries, up to 700,000 additional tons of lead would have been discarded. The battery recycling rate has been as low as 52 percent in the early 1980s. The rate is affected by several factors, including the price of lead and regulatory requirements.

No other recycling of lead or cadmium was identified, although small amounts of nickel-cadmium batteries may be exported for recycling. There are, however, several products that are recovered for recycling in which lead or cadmium is an incidental constituent. The lead or cadmium is thus removed from the waste stream entering an incinerator by the recycling process. The recycled products identified are: paper products that are deinked for recycling purposes, soldered cans, rubber tires, appliances, glass containers, and plastics.

LIMITATIONS OF THIS REPORT

While this report contains useful data on discards of lead and cadmium in municipal solid waste, there are some limitations in its application to the issue of lead and cadmium in municipal waste combustor ash. These limitations are:

Figure 4. Relative discards of lead in combustible and noncombustible products, 1986.

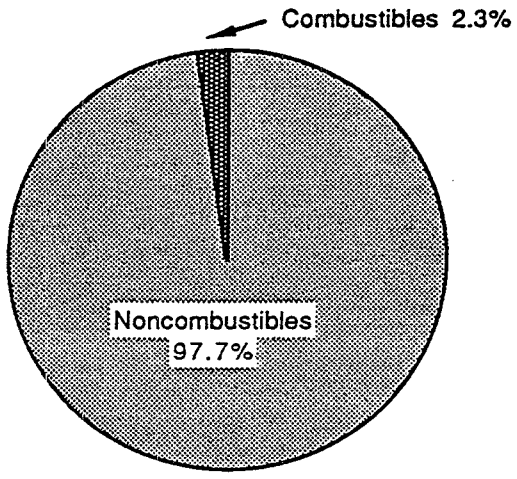
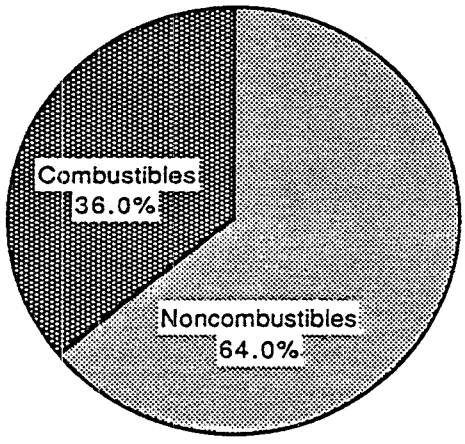


Figure 5. Relative discards of cadmium in combustible and noncombustible products, 1986.



* This characterization identifies the sources of lead and cadmium in MSW; it does not tell us whether these are the major sources of leachable lead and cadmium in MWC ash.

* The MSW characterization presented here may not correlate well with the waste input at any particular MWC facility.

* The identified compounds of lead and cadmium may recombine with other materials in the combustion chamber to form new compounds; this issue is beyond the scope of this study.

* In addition to MSW, other nonhazardous wastes contain lead and cadmium; these wastes may in some instances be incinerated along with MSW. These wastes, which were identified but not characterized in this study, include: municipal sludge, construction and demolition wastes, industrial and military wastes, and automotive and other transportation equipment wastes.

Chapter 1

LEAD AND CADMIUM IN MUNICIPAL SOLID WASTE: OVERVIEW AND SUMMARY

In the past few years, environmentally-sound disposal of municipal solid waste (MSW) has become a major issue for the United States, especially at the local and state levels. As more and more landfills are closed and new landfills become increasingly difficult to site, communities are seeking methods of disposal. Recovery and recycling of materials and combustion (incineration) of MSW are two important alternatives that are being considered and implemented.

Municipal waste combustion (MWC) is attractive to many communities because combustion reduces the volume of waste by up to 90 percent and the weight of waste by up to 80 percent. In addition, sales of recovered energy products (e.g., steam or electricity) help to offset the costs of disposal. Combustion of municipal solid waste does present some problems, however, and one of these is the disposal of the ash remaining after the combustion process is complete.

Analytical tests have detected heavy metals (lead and cadmium in particular) in the ash remaining after municipal waste combustion (1). This report addresses one of many unanswered questions about MWC ash: What are the sources of lead and cadmium in municipal solid waste?

OVERVIEW OF THIS REPORT

This report characterizes lead and cadmium in products disposed in municipal solid waste over the time period 1970 to 1986, with projections of disposal to the year 2000. A summary of the findings is included in this chapter, with more detailed discussions on lead in Chapter 2, and cadmium in Chapter 3.

Wastes Included in This Report

Municipal solid waste is defined in EPA's Subtitle D* reports (2) as wastes coming from household, institutional, and commercial sources. Examples of institutional sources include hospitals (except for infectious wastes), schools, and prisons. Examples of commercial sources include retail stores, office buildings, and warehouses. Some wastes from industrial sources are also included, for example: corrugated boxes and other packaging, cafeteria and washroom wastes, and office wastes.

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* Subtitle D of the Resource Conservation and Recovery Act (RCRA) regulates those wastes generally classified as nonhazardous, while Subtitle C deals with hazardous wastes.

Wastes Not Included in this Report

A number of wastes* regulated under Subtitle D are not characterized in this study, including:

- Municipal sludge
- Industrial nonhazardous process waste
- Small quantity generator waste
- Construction and demolition waste.

While these wastes are not characterized for lead and cadmium content in this report, they may contain those metals and if incinerated along with MSW, they could contribute to lead and cadmium in the ash.

METHODOLOGY

The general methodology for this study is called the materials flow methodology; it is based on a methodology for estimating municipal solid waste that was developed at EPA in the mid-1970s (3) and that has been used periodically for EPA reports ever since. The materials flow methodology applies to the United States as a whole; it is not tailored to any specific locality. Data series on production of the products and materials in the waste stream are used as a basis. Adjustments are then made for imports and exports of the products, for diversions away from the waste stream, for the lifetimes of the products, and for materials recovery.

Application of the methodology to discards of lead and cadmium required some additional steps. Numerous assumptions were required to determine end uses of products (like lead-containing solder) that would enter the municipal waste stream rather than others, such as demolition wastes. Also, lead and cadmium occur in many intermediate products, such as pigments, that enter the waste stream as part of another product. All assumptions were documented. The methodology is summarized in Figure 1-1, and a more detailed description is included in Appendix A of this report.

RELATIVE DISCARDS OF LEAD AND CADMIUM

Both lead and cadmium have been detected in analyses of ash from municipal waste combustors (MWC). Discards of lead in products classified as MSW are, however, very much greater than discards of cadmium.** As Figure 1-2 demonstrates, nearly 100 times more lead than cadmium was discarded in 1986; this relationship has been relatively constant since 1970.

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* See Reference 2 for definitions and discussion of these wastes.

** Later in this chapter, relative discards of lead and cadmium in the combustible and noncombustible fractions of MSW are discussed.

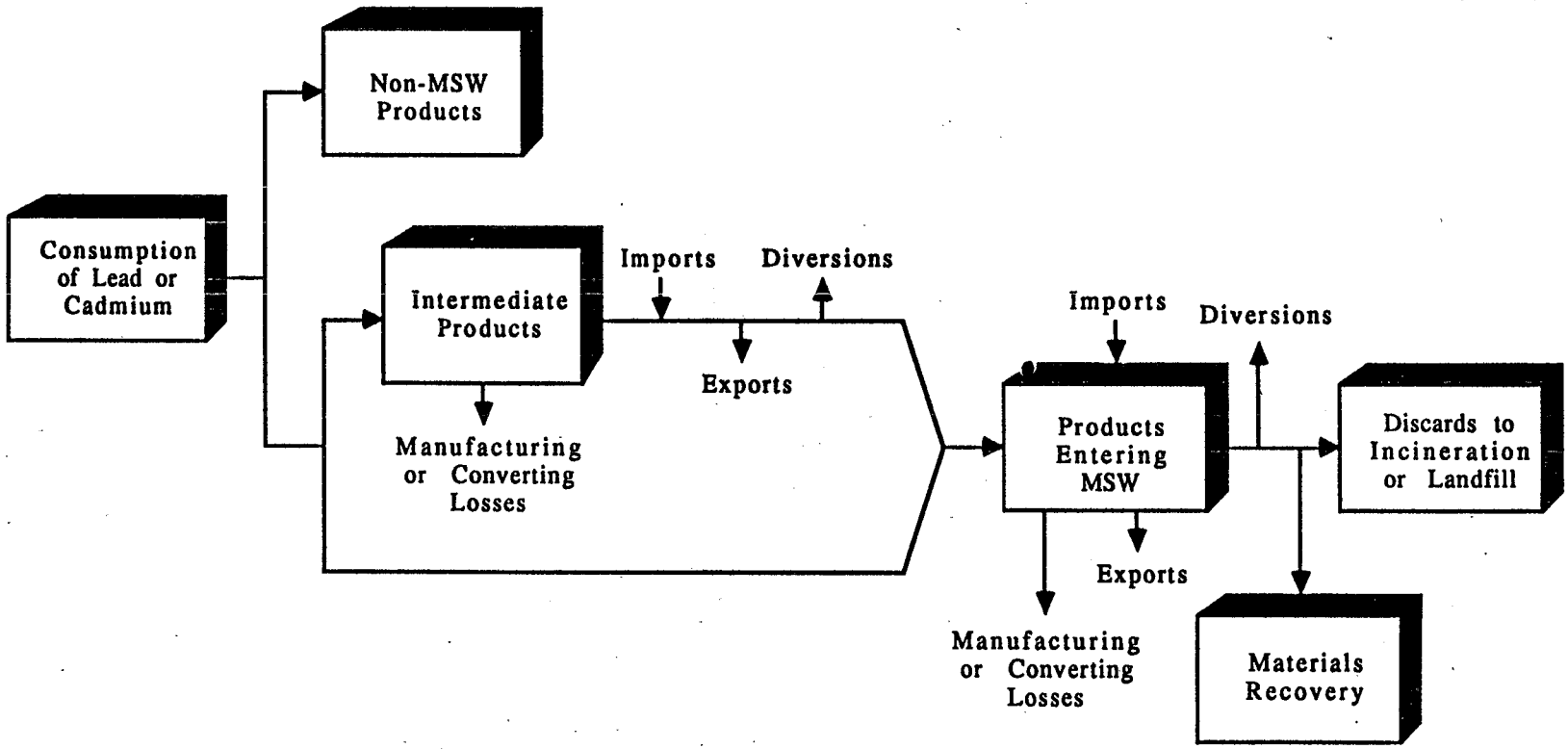
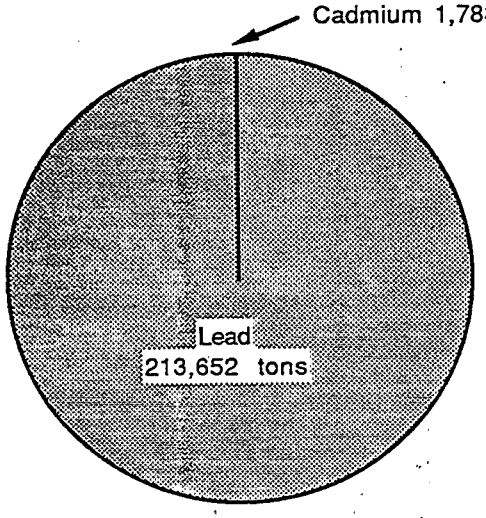


Figure 1-1. Materials flow methodology for estimating lead and cadmium in MSW discards.

Figure 1-2. Relative discards of lead and cadmium in MSW, 1986.



TRENDS IN DISCARDS* OF LEAD AND CADMIUM

Lead in MSW

Discards of lead in products in MSW from 1970 to 2000 are summarized in Tables 1-1 and 1-2. Some perspective on the discards of various products can be gained from Tables 1-3 and 1-4 and Figure 1-3. The products are discussed below in order of their relative rankings in 1986 (Table 1-3). (Each of these products is discussed in more detail in Chapter 2.)

Lead-Acid Batteries. By any measure, lead discarded in lead-acid storage batteries overwhelms all other sources. These batteries, which primarily provide starting, lighting, and ignition (SLI) for automotive products, rank Number 1 in discards for all years from 1970 to 2000 (Table 1-4 and Figure 1-3).

Table 1-2 demonstrates the high percentage of lead discarded in these batteries. They were 50 percent of the total lead discards in 1970, 76 percent in 1980, and 65 percent in 1986, a percentage that is projected to remain about constant to 2000. The figures show that discards of lead from batteries peaked in 1982 at about 409,000 tons. Several factors contributed to this: sales and imports of automotive vehicles were high in 1978 (there is a four-year lag between battery purchases and discards); the estimated pounds of lead per battery peaked at that time; and recycling of lead from batteries was declining. (Recycling is discussed in more detail later in this chapter.)

An estimated 138,000 tons of lead in batteries were discarded in 1986. These discards are projected to increase gradually to about 182,000 tons in 2000 under stable conditions (Table 1-1 and Figure 1-3).

Consumer Electronics. This category of products includes primarily television sets, radios, and more recently, video cassette recorders (VCRs). Consumer electronics were the Number 4 contributor of lead in MSW in 1970, but by 1975 they were Number 2, a position they continue to hold (Table 1-4). The sources of lead in these electronics products include soldered circuit boards, leaded glass in television sets, and plated steel chassis. Discards of lead in consumer electronics amounted to about 12,000 tons in 1970, or 7 percent of total lead discards. By 1986, this has grown to 58,500 tons, or 27 percent of total. By 2000, discards of lead in consumer electronics is projected to be 85,000 tons, or 30 percent of total. (See Figure 1-3.)

Solder containing lead is commonly used in circuit boards in consumer electronic products. This has been an increasing source of lead discards, but the amount discarded is projected to decline in the future (Table 1-1). This reflects a general decline in the use of lead in solder in

* "Discards" in this section refers to discards after recycling; in other words, the products shown in these tables and figures would be incinerated unless otherwise disposed.

Table 1-1

DISCARDS* OF LEAD IN PRODUCTS IN THE MUNICIPAL WASTE STREAM, 1970 TO 2000
(In short tons)

	1970	1975	1980	1985	1986	1990	1995	2000
BRASS AND BRONZE PRODUCTS	410	474	404	267	321	310	181	207
CANS AND OTHER SHIPPING CONTAINERS								
Solder in food cans	11,995	10,291	6,882	1,898	1,139	642	594	443
Solder in beverage cans	9,227	7,260	1,077	0	0	0	0	0
Solder general cans	2,307	1,911	1,257	911	778	439	406	303
Solder in shipping containers	588	660	459	198	135	52	46	41
Subtotal - cans and shipping containers	24,117	20,122	9,675	3,007	2,052	1,133	1,046	787
CONSUMER ELECTRONICS								
Circuit boards	1,417	1,759	3,441	5,883	6,092	3,568	2,714	990
Plastics	0	0	0	0	0	46	26	42
TV picture tubes	10,430	17,935	17,690	40,818	52,165	48,230	76,280	84,000
TV and radio chassis	386	499	683	310	279	0	0	0
Subtotal - consumer electron.	12,233	20,193	31,814	47,011	58,536	51,844	79,020	85,032
GLASS AND CERAMIC PRODUCTS**	3,465	4,122	5,396	6,911	7,956	8,415	8,663	8,910
LEAD-ACID STORAGE BATTERIES								
Starting-lighting-ignition	83,823	206,420	205,641	221,913	137,996	167,236	172,639	181,445
Portable	2	7	18	41	47	71	91	101
Subtotal - lead-acid batteries	83,825	206,427	205,659	221,954	138,043	167,307	172,730	181,546
LIGHT BULBS								
Glass	491	507	623	706	709	727	787	847
Solder	156	161	197	224	225	230	249	268
Subtotal - light bulbs	647	668	820	930	934	957	1,036	1,115
PIGMENTS+								
Printing inks	19,192	13,819	8,222	1,414	265	220	179	140
All other products	7,828	3,198	1,642	954	866	718	630	542
Subtotal - pigments	27,020	17,017	9,864	2,368	1,131	938	809	682
PLASTICS++								
Nonfood packaging	775	689	968	916	934	1,007	1,003	1,003
Clothing	116	182	67	31	29	30	30	30
Footwear	152	342	264	372	324	290	290	290
Miscellaneous nondurables	56	89	371	377	391	390	390	390
Subtotal - nondurables	1,099	1,302	1,670	1,696	1,678	1,717	1,713	1,713
Housewares	80	227	189	166	177	137	145	145
Toys	130	354	222	183	219	176	183	183
Records	97	166	304	209	242	215	95	120
Luggage	3	4	8	4	5	7	5	6
Furniture	84	155	426	368	416	362	160	177
Appliances	88	74	113	98	92	148	139	153
Miscellaneous durables	32	61	80	742	748	758	731	731
Subtotal - durables	514	1,041	1,342	1,770	1,899	1,803	1,458	1,515
Subtotal - plastics	1,613	2,343	3,012	3,466	3,577	3,520	3,171	3,228
RUBBER PRODUCTS								
Tires and rubber products	36	38	70	42	48	55	57	59
All other rubber products	16	15	33	18	21	24	24	24
Subtotal - rubber products	52	53	103	60	69	79	81	83
USED OIL	1,557	1,230	810	314	192	61	48	36
MISCELLANEOUS PRODUCTS								
Collapsible tubes	9,310	2,860	1,477	607	639	240	220	200
Foil wine wrappers	591	356	383	243	202	100	80	60
Subtotal - misc. products	9,901	3,216	1,860	850	841	340	300	260
GRAND TOTAL	164,840	275,865	269,417	287,138	213,652	234,904	267,086	281,887

* Discards after recycling.
** Except for glass in light bulbs and television sets.
\+ Except for pigments in glass, plastics, and rubber.
++ Except for plastics in consumer electronics.

Table 1-2

DISCARDS* OF LEAD IN PRODUCTS IN THE MUNICIPAL WASTE STREAM, 1970 TO 2000
(In percent of total lead discards)

Products	1970	1975	1980	1985	1986	1990	1995	2000
BRASS AND BRONZE PRODUCTS	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1
CANS AND OTHER SHIPPING CONTAINERS								
Solder in food cans	7.3	3.7	2.5	0.7	0.5	0.3	0.2	0.2
Solder in beverage cans	5.6	2.6	0.4	0.0	0.0	0.0	0.0	0.0
Solder in general cans	1.4	0.7	0.5	0.3	0.4	0.2	0.2	0.1
Solder in shipping containers	0.3	0.2	0.2	0.1	0.1	0.0	0.0	0.0
Subtotal - cans and shipping containers	14.6	7.3	3.6	1.1	1.0	0.5	0.4	0.3
CONSUMER ELECTRONICS								
Circuit boards	0.9	0.6	1.3	2.1	2.9	1.5	1.0	0.4
Plastics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TV picture tubes	6.3	6.5	10.3	14.2	24.4	20.5	28.6	29.8
TV and radio chassis	0.2	0.2	0.3	0.1	0.1	0.0	0.0	0.0
Subtotal - consumer electronics	7.4	7.3	11.8	16.4	27.4	22.1	29.6	30.2
GLASS AND CERAMIC PRODUCTS**	2.1	1.5	2.0	2.4	3.7	3.6	3.2	3.2
LEAD-ACID STORAGE BATTERIES								
Starting-lighting-ignition	50.8	74.8	76.3	77.3	64.6	71.2	64.6	64.4
Portable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal - lead-acid batteries	50.9	74.8	76.3	77.3	64.6	71.2	64.7	64.4
LIGHT BULBS								
Glass	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3
Solder	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Subtotal - light bulbs	0.4	0.2	0.3	0.3	0.4	0.4	0.4	0.4
PIGMENTS+								
Printing inks	11.6	5.0	3.1	0.5	0.1	0.1	0.1	0.1
All other products	4.8	1.2	0.6	0.3	0.4	0.3	0.3	0.2
Subtotal - pigments	16.4	6.2	3.7	0.8	0.5	0.4	0.3	0.3
PLASTICS++								
Nonfood packaging	0.5	0.3	0.4	0.3	0.4	0.4	0.4	0.4
Clothing	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Footwear	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Miscellaneous nondurables	0.0	0.0	0.1	0.1	0.2	0.2	0.1	0.1
Subtotal - nondurables	0.7	0.5	0.6	0.6	0.8	0.7	0.6	0.6
Housewares	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Toys	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Records	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Luggage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Furniture	0.0	0.1	0.2	0.1	0.2	0.2	0.1	0.1
Appliances	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Miscellaneous durables	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3
Subtotal - durables	0.3	0.4	0.5	0.6	0.9	0.8	0.5	0.5
Subtotal - plastics	1.0	0.9	1.1	1.2	1.7	1.5	1.2	1.1
RUBBER PRODUCTS								
Tires and tire products	0.02	0.01	0.03	0.01	0.02	0.02	0.02	0.02
All other rubber products	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Subtotal - rubber products	0.03	0.02	0.04	0.02	0.03	0.03	0.03	0.03
USED OIL	0.9	0.4	0.3	0.1	0.1	0.03	0.02	0.01
MISCELLANEOUS PRODUCTS								
Collapsible tubes	5.6	1.0	0.6	0.2	0.3	0.1	0.1	0.1
Foil wine wrappers	0.4	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Subtotal - misc. products	6.0	1.2	0.7	0.3	0.4	0.1	0.1	0.1
GRAND TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Discards after recycling.
** Except for glass in light bulbs and television sets.
\+ Except for pigments in glass, plastics, and rubber.
++ Except for plastics in consumer electronics.

Table 1-3

DISCARDS* OF LEAD IN PRODUCTS IN THE MUNICIPAL WASTE STREAM, 1986
RANKED IN ORDER OF WEIGHT OF LEAD
(In short tons and percent of total)

Products	Short Tons	Percent
LEAD-ACID STORAGE BATTERIES		
Starting-lighting-ignition	137,996	64.6
Portable	47	0.0
Subtotal - lead batteries	138,043	64.6
CONSUMER ELECTRONICS		
Circuit boards	6,092	2.9
TV picture tubes	52,165	24.4
TV and radio chassis	279	0.1
Subtotal-consumer electronics	58,536	27.4
GLASS AND CERAMIC PRODUCTS**	7,956	3.7
PLASTICS+		
Nonfood packaging	934	0.4
Clothing	29	0.0
Footwear	324	0.2
Miscellaneous nondurables	391	0.2
Subtotal-nondurables	1,678	0.8
Housewares	177	0.1
Toys	219	0.1
Records	242	0.1
Luggage	5	0.0
Furniture	416	0.2
Appliances	92	0.0
Miscellaneous durables	748	0.3
Subtotal-durables	1,899	0.9
Subtotal-plastics	3,577	1.7
CANS AND OTHER SHIPPING CONTAINERS		
Solder in food cans	1,139	0.5
Solder in general cans	778	0.4
Solder in shipping containers	135	0.1
Subtotal-cans and shipping containers	2,052	1.0
PIGMENTS++		
Printing inks	265	0.1
All other products	866	0.4
Subtotal -pigments	1,131	0.5
LIGHT BULBS		
Glass	709	0.3
Solder	225	0.1
Subtotal-light bulbs	934	0.4
COLLAPSIBLE TUBES	639	0.3
BRASS AND BRONZE PRODUCTS	321	0.2
FOIL WINE WRAPPERS	202	0.1
USED OIL	192	0.1
RUBBER PRODUCTS		
Tires and tire products	48	0.02
All other rubber products	21	0.01
Subtotal-rubber products	69	0.03
GRAND TOTAL	213,653	100.0

* Discards after recycling.
** Except for glass in light bulbs and television sets.
+ Except for plastics in consumer electronics.
++ Except for pigments in glass, plastics, and rubber

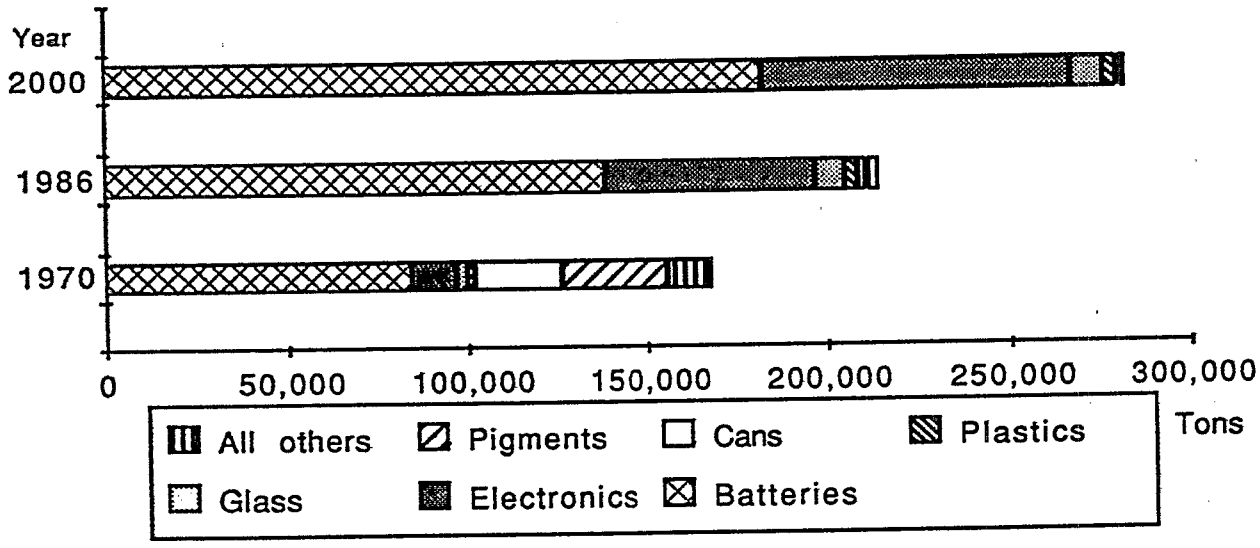
Table 1-4

SOURCES OF LEAD IN MSW, RANKED BY TONNAGE, 1970 TO 2000

RANK / YEAR	1970	1975	1980	1986	1990	1995	2000
No. 1	Lead-Acid Batteries	Lead-Acid Batteries	Lead-Acid Batteries	Lead-Acid Batteries	Lead-Acid Batteries	Lead-Acid Batteries	Lead-Acid Batteries
No. 2	Pigments	Consumer Electronics	Consumer Electronics	Consumer Electronics	Consumer Electronics	Consumer Electronics	Consumer Electronics
No. 3	Soldered Cans	Soldered Cans	Pigments	Glass Products	Glass Products	Glass Products	Glass Products
No. 4	Consumer Electronics	Pigments	Soldered Cans	Plastics	Plastics	Plastics	Plastics
No. 5	Collapsible Tubes	Glass Products	Glass Products	Soldered Cans	Soldered Cans	Soldered Cans	Light Bulbs
No. 6	Glass Products	Collapsible Tubes	Plastics	Pigments	Pigments	Light Bulbs	Soldered Cans

Lead-Acid Batteries are primarily automotive batteries.
Pigments include pigments in paints, inks and dyes, but not those in glass, plastics, and rubber.
Soldered Cans include food, beverage, and other cans.
Consumer Electronics include circuit boards, picture tubes, TV and radio chassis, and plastics.
Collapsible Tubes are tubes of the type used for artists' paints.
Glass Products include all uses except light bulbs and TV picture tubes.

Figure 1-3. Lead in discards of products in MSW, 1970, 1986, and 2000.



electronic components as reported by the Bureau of Mines, and reflects changes in the manufacturing processes. Discards of lead from solder in consumer electronics were about 1,400 tons in 1970 (less than one percent of the total), and were about 76,000 tons in 1986 (about 3 percent of total). These discards of lead are projected to decline to less than 1,000 tons and less than one percent of total discards by 2000.

Leaded glass in television picture tubes is the major source of lead in consumer electronic products. (According to the Bureau of Mines, 75 percent of lead used in glass is used in picture tubes.) Lead in the glass provides shielding from X-rays and otherwise enhances the qualities of the glass. This source of lead in MSW has increased steadily since 1970, and is projected to continue to do so (Table 1-1). Discards of lead from glass in TVs were about 10,000 tons in 1970 (6 percent of total), and were about 52,000 tons in 1986, or 24 percent of total lead. These discards are projected to be 84,000 tons, or 30 percent of total, in 2000 if present trends continue.

Finally, many steel chassis in television sets and radios were coated with terne metal (a lead and tin alloy) up until 1980. This has never been a major source of lead in MSW (less than one percent), and is projected to disappear as old television sets are phased out.

It is of interest to note that in 1986, lead-acid batteries and lead in consumer electronics together accounted for 92 percent of lead discards in MSW.

Glass and Ceramic Products. It was possible to quantify lead in glass in television picture tubes and light bulbs separately (Chapter 2). Lead discards in the remaining products in MSW were quantified in total, but it was not possible to determine separate end uses of the lead. This category of discarded products includes glass containers for food, beverages, and miscellaneous products such as cosmetics; glass and ceramic tableware and cookware; mirrors; optical glasses; electronic products; enamels for appliances and other uses; and miscellaneous decorative and other uses.

The major uses of leaded glass are in television picture tubes and light bulbs, as described elsewhere. Other uses of leaded glass include tableware and bifocal lenses in reading glasses.

Lead is a component in glazes and enamels used on glass containers, tableware, and cookware. Enamels used in silk screening designs on glass typically contain 40 to 50 percent lead monoxide. Lead is also used as a colorant in some of these designs.

These discards ranked Number 3 in 1986 at almost 8,000 tons and almost 4 percent of total lead discards. In 1970 lead use in these glass products ranked Number 6 at 3,500 tons and 2 percent of total. This use is projected to grow to 9,000 tons in 2000, or 3 percent of the total.

Plastics.* Discards of lead in plastic products did not rank in the top six sources in 1970, but in 1986 plastics ranked fourth, and this is projected to continue (Table 1-4). Lead is used in two ways in plastics: as a component in compounds designed to act as heat stabilizers, primarily in polyvinyl resins, and as a component in pigments used in a variety of plastic resins.

Discards of lead in plastic products has been growing, but this source contributes a small portion of the total (Figure 1-3). In 1970 lead in plastic discards contributed 1,600 tons, about one percent of the total. In 1986 lead in plastics comprised about 3,500 tons, less than 2 percent of total. Projections to 2000 show about 3,200 tons of lead in plastics being discarded, slightly more than one percent of total. The projected decline is attributed to regulations on lead in certain products, such as toys and furniture.

Discards of lead in products made of plastics ranked as follows in 1986: nonfood packaging (highest tonnage), miscellaneous durables, furniture, miscellaneous nondurables, footwear, records, toys, housewares, appliances, and others.

Soldered Cans. In 1970, lead in solder in cans and shipping containers represented the Number 3 discard into MSW, but by 1986 this was the Number 5 source of discards (Table 1-4). The use of leaded solder in steel food cans has declined dramatically, and soldered steel beverage cans have virtually disappeared. Use of leaded solder in general purpose cans, such as aerosols, and in shipping containers has also declined. Figure 1-3 illustrates this decline.

Discards of lead in soldered cans were 24,000 tons, or over 14 percent of total discards, in 1970. In 1986, only 2,000 tons of lead were discarded in soldered cans, representing less than one percent of total. These discards are projected to be about 800 tons, much less than one percent of total, in 2000.

Pigments. Discards of pigments in plastics, glass, and rubber are discussed in other sections. The remaining pigments--those used in paints, printing inks, textile dyes, and miscellaneous uses--are included in this section. These pigments ranked second in discards of lead into MSW in 1970, but they are ranked Number 6 in 1986 (Table 1-4). As illustrated in Figure 1-3, use of lead in pigments has been in decline, in large part due to concerns about toxicity.

Discards of lead in printing inks, once an important source of lead, have declined dramatically, from 19,000 tons in 1970 to less than 300 tons in 1986. Use of lead in many kinds of paint has been regulated, also leading to a decline in consumption.

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* Plastics in consumer electronics are counted in that category.

Total discards of lead in these pigments was 30,000 tons in 1970, or 16 percent of total lead discards. This had declined to about 1,200 tons in 1986--less than one percent of total. The decline is projected to continue, to about 700 tons in 2000, much less than one percent of the total.

Light Bulbs. Light bulbs are not a large source of lead in MSW, but are of interest because they contain two sources of lead: solder and leaded glass. While not ranked in the top six sources of lead in MSW in 1986, light bulbs are projected to be the Number 5 source in 2000 (Table 1-4).

In 1970 lead discarded into MSW from light bulbs was estimated to be about 600 tons, less than one percent of the total. By 1986 these discards were over 900 tons; by 2000, over 1,000 tons. The percentage of total is not projected to be over one percent in any case.

Collapsible Tubes. Collapsible tubes made of lead are used for products such as artists' paints. These tubes represented the Number 5 source of lead in MSW in 1970 (Table 1-4), at over 9,000 tons and over 5 percent of total discards. By 1986, however, collapsible tubes contributed only about 600 tons, less than one percent of the total. The decline is projected to continue, to only 200 tons in 2000.

Brass and Bronze Products. Lead is a component of some brass and bronze products, although most of these applications are not discarded into MSW. Brass and bronze items that may be discarded into MSW include locks, keys, and miscellaneous products such as clock and watch parts, musical instruments, etc.

Discards of lead in brass and bronze products are a very small part of total lead discards, estimated to be less than 500 tons per year since 1970 and declining.

Foil Wine Wrappers. Lead foil wine wrappers are used to cover the corks on some wine bottles, although aluminum foil is replacing lead in many instances. Discards of lead from this source are estimated to have declined from about 600 tons in 1970 to about 200 tons in 1986, with a continued decline to about 60 tons in 2000.

Used Oil. Gasoline additives were formerly an important use of lead before the phase-out due to regulatory action began. Some of the lead from the additives enters used automotive oil, as does some lead from other sources such as engine wear. It was estimated that about 1,500 tons of lead in used oil entered MSW in 1970, almost one percent of total discards. By 1986 this had decreased to less than 200 tons, and by 2000, lead in used oil is projected to be only 36 tons.

Rubber Products. Most of the lead consumed by the rubber industry is used in products like lead-sheathed hose that do not enter MSW. It was estimated that 100 tons or less of lead enters MSW in rubber products each year. About 50 tons of lead in rubber were discarded in 1970; about 70 tons in 1986; and a projected 80 tons in 2000.

Cadmium in MSW

Discards of cadmium in products in MSW from 1970 to 2000 are summarized in Tables 1-5 and 1-6. Tables 1-7 and 1-8 show how products discarded into MSW rank in their contributions of cadmium. A perspective on the changing importance of the various sources of cadmium is shown in Figure 1-4. Products containing cadmium in MSW are discussed below in order of the relative rankings in 1986 (Table 1-7). (More details on these products are contained in Chapter 3.)

Household Batteries. Household batteries (primarily rechargeable nickel-cadmium batteries) have been the Number 1 source of cadmium in MSW since 1980 (Table 1-8). Their growth has been rapid--they were the Number 5 source of cadmium in 1970. Nickel-cadmium (Ni-Cd) batteries have become very popular for uses such as portable hand tools, small appliances such as vacuum cleaners and mixers, portable television sets, cameras, etc.

In 1970 discards of cadmium in household batteries were estimated at 53 tons, or 4 percent of total cadmium discards. By 1986 this number was 930 tons, or 52 percent of the total. If this growth continues as projected, discards in 2000 will be over 2,000 tons, or 76 percent of total (Figure 1-4).

Plastics. Plastics have ranked second only to household batteries as a source of cadmium in MSW since 1980 (Table 1-8). Like lead, cadmium is used as a stabilizer in polyvinyl chloride resin and as a pigment in a variety of resins.

Discards of cadmium in plastics were 342 tons in 1970, or almost 29 percent of the total cadmium discards. Cadmium in plastics peaked at 595 tons in 1978 (38 percent of total discards), then generally declined to 502 tons in 1986 (28 percent of total discards). Projected discards are 384 tons in 2000, or 14 percent of total (Figure 1-4). The decline is generally attributed to concern over toxicity and regulations on the use of cadmium in products like toys and furniture.

In 1986, plastic products containing cadmium in discards ranked as follows: nonfood packaging (highest tonnage), miscellaneous durables, miscellaneous nondurables, furniture, toys, records, footwear, and others.

It is of interest to note that household batteries and plastics combined accounted for 80 percent of cadmium discards into MSW in 1986.

Consumer Electronics. Discards of cadmium-plated chassis in radios and television sets gave consumer electronics the Number 3 ranking in cadmium discards in 1986. This is a declining source of cadmium discards, however, ranking Number 1 in 1970 and Number 4 in 2000 (Table 1-8 and Figure 1-3). Cadmium was formerly used to plate the chassis or steel sheet that holds electronic parts of the radio or TV together. By 1980 this technology has been replaced by printed circuit boards, so this source of cadmium is declining as older equipment is replaced.

Table 1-5

DISCARDS* OF CADMIUM IN PRODUCTS IN THE MUNICIPAL WASTE STREAM, 1970 to 2000
(In short tons)

Products	1970	1975	1980	1985	1986	1990	1995	2000
APPLIANCES								
Cadmium plating	47	39	32	25	24	19	12	9
Plastics	60	52	77	54	64	38	46	48
Subtotal - appliances	107	91	109	79	88	57	58	57
CONSUMER ELECTRONICS								
Cadmium plating	571	330	176	158	161	101	67	20
Plastics	0	0	0	0	0	36	41	47
Subtotal - consumer electronics	571	330	176	158	161	137	108	67
GLASS AND CERAMIC PRODUCTS	32	27	23	25	29	32	34	37
HOUSEHOLD BATTERIES								
Nickel-cadmium batteries	51	209	996	996	927	1,305	1,709	2,032
Dry cell casings	2	2	2	3	3	3	3	3
Subtotal-household batteries	53	211	998	999	930	1,308	1,712	2,035
PIGMENTS**	79	65	56	59	70	78	85	93
PLASTICS+								
Nonfood packaging	209	133	128	139	166	150	150	150
Clothing	15	36	8	2	2	2	2	2
Footwear	19	70	31	27	21	21	21	21
Miscellaneous nondurables	11	13	37	43	51	46	46	46
Subtotal-nondurables	254	252	204	211	240	219	219	219
Housewares	19	56	33	21	31	20	22	22
Toys	34	109	53	32	44	34	33	33
Records	12	21	65	22	29	12	7	8
Luggage	5	6	9	5	9	7	6	7
Furniture	10	18	77	35	46	23	11	13
Miscellaneous durables	8	21	15	73	103	78	82	82
Subtotal-durables	88	231	252	188	262	174	161	165
Subtotal-plastics	342	483	456	399	502	393	380	384
RUBBER PRODUCTS++	10	13	8	6	6	8	9	9
USED OIL	1	1	1	1	1	1	1	1
MISCELLANEOUS PRODUCTS								
Electric blankets and heating pads	1	1	1	1	1	1	1	1
GRAND TOTAL	1,196	1,222	1,828	1,727	1,788	2,015	2,388	2,684

* Discards after recycling.
** Except for pigments in glass, plastics, and rubber.
+ Except for plastics in appliances and consumer electronics.
++ Assumed to be all nontire products.

Table 1-6

DISCARDS* OF CADMIUM IN PRODUCTS IN THE MUNICIPAL WASTE STREAM, 1970 TO 2000
(In percent of total cadmium discards)

	1970	1975	1980	1985	1986	1990	1995	2000
APPLIANCES								
Cadmium plating	3.9	3.2	1.8	1.4	1.3	0.9	0.3	0.3
Plastics	5.0	4.3	4.2	3.1	3.6	1.9	1.8	1.8
Subtotal-appliances	8.9	7.4	6.0	4.6	4.9	2.8	2.1	2.1
CONSUMER ELECTRONICS								
Cadmium plating	47.7	27.0	9.6	9.1	9.0	5.0	0.7	0.7
Plastics	0.0	0.0	0.0	0.0	0.0	1.8	1.8	1.8
Subtotal-consumer electronics	47.7	27.0	9.6	9.1	9.0	6.8	2.5	2.5
GLASS AND CERAMIC PRODUCTS	2.7	2.2	1.3	1.4	1.6	1.6	1.4	1.4
HOUSEHOLD BATTERIES								
Nickel-cadmium batteries	4.3	17.1	54.5	57.7	51.8	64.8	75.7	75.7
Dry cell casings	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1
Subtotal-household batteries	4.4	17.3	54.6	57.8	52.0	64.9	75.8	75.8
PIGMENTS**	6.6	5.3	3.1	3.4	3.9	3.9	3.5	3.5
PLASTICS+								
Nonfood packaging	17.5	10.9	7.0	8.0	9.3	7.4	5.6	5.6
Clothing	1.3	2.9	0.4	0.1	0.1	0.1	0.1	0.1
Footwear	1.6	5.7	1.7	1.6	1.2	1.0	0.8	0.8
Miscellaneous nondurables	0.9	1.1	2.0	2.5	2.9	2.3	1.7	1.7
Subtotal-nondurables	21.2	20.6	11.2	12.2	13.4	10.9	8.2	8.2
Housewares	1.6	4.6	1.8	1.2	1.7	1.0	0.8	0.8
Toys	2.8	8.9	2.9	1.9	2.5	1.7	1.2	1.2
Records	1.0	1.7	3.6	1.3	1.6	0.6	0.3	0.3
Luggage	0.4	0.5	0.5	0.3	0.5	0.3	0.3	0.3
Furniture	0.8	1.5	4.2	2.0	2.6	1.1	0.5	0.5
Miscellaneous durables	0.7	1.7	0.8	4.2	5.8	3.9	3.1	3.1
Subtotal-durables	7.4	18.9	13.8	10.9	14.7	8.6	6.1	6.1
Subtotal-plastics	28.6	39.5	24.9	23.1	28.1	19.5	14.3	14.3
RUBBER PRODUCTS++	0.8	1.1	0.4	0.3	0.3	0.4	0.3	0.3
USED OIL	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
MISCELLANEOUS PRODUCTS								
Electric blankets and heating pads	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
GRAND TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Discards after recycling.
** Except for pigments in glass, plastics and rubber.
+ Except for plastics in appliances and consumer electronics.
++ Assumed to be all non-tire products.

Table 1-7

DISCARDS* OF CADMIUM IN PRODUCTS IN THE MUNICIPAL WASTE STREAM, 1986
RANKED IN ORDER OF WEIGHT OF CADMIUM
(in short tons and percent of total)

Products	Short Tons	Percent
HOUSEHOLD BATTERIES		
Nickel-cadmium batteries	927	51.8
Drycell casings	3	0.2
Subtotal-household batteries	930	52.0
PLASTICS**		
Nonfood packaging	166	9.3
Clothing	2	0.1
Footwear	21	1.2
Miscellaneous nondurables	51	2.9
Subtotal-nondurables	240	13.4
Housewares	31	1.7
Toys	44	2.5
Records	29	1.6
Luggage	9	0.5
Furniture	46	2.6
Miscellaneous durables	103	5.8
Subtotal-durables	262	14.7
Subtotal-plastics	502	28.1
CONSUMER ELECTRONICS		
Cadmium plating	161	9.0
APPLIANCES		
Cadmium plating	24	1.3
Plastics	64	3.6
Subtotal-appliances	88	4.9
PIGMENTS+	70	3.9
GLASS AND CERAMIC PRODUCTS	29	1.6
RUBBER PRODUCTS++	6	0.3
USED OIL	1	0.1
MISCELLANEOUS PRODUCTS		
Electric blankets and heating pads	1	0.1
GRAND TOTAL	1,788	100.0

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* Discards after recycling.
** Except for plastics in appliances.
\+ Except for pigments in glass, plastics, and rubber.
++ Assumed to be all non-tire products.

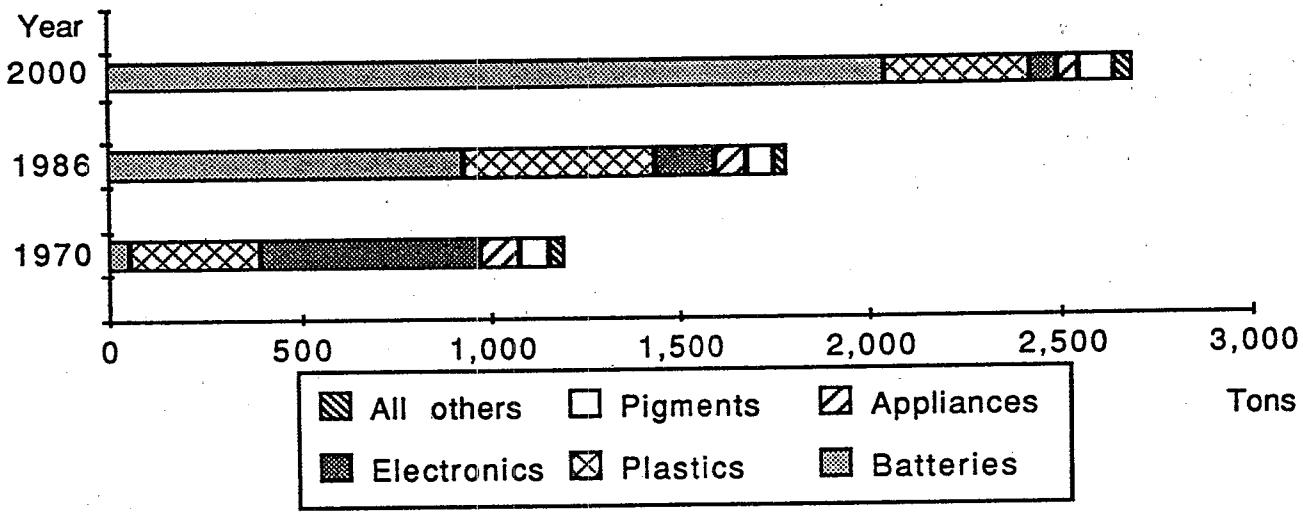
Table 1-8

SOURCES OF CADMIUM IN MSW, RANKED BY TONNAGE, 1970 TO 2000

RANK / YEAR	1970	1975	1980	1986	1990	1995	2000
No. 1	Consumer Electronics	Plastics	Household Batteries	Household Batteries	Household Batteries	Household Batteries	Household Batteries
No. 2	Plastics	Consumer Electronics	Plastics	Plastics	Plastics	Plastics	Plastics
No. 3	Appliances	Household Batteries	Consumer Electronics	Consumer Electronics	Consumer Electronics	Consumer Electronics	Pigments
No. 4	Pigments	Appliances	Appliances	Appliances	Pigments	Pigments	Consumer Electronics
No. 5	Household Batteries	Pigments	Pigments	Pigments	Appliances	Appliances	Appliances

Consumer Electronics primarily includes cadmium plating on televisions and radios, plus some plastics in later years.
Plastics include all plastic uses except for appliances and consumer electronics.
Appliances primarily include cadmium plating in dishwashers and washing machines and plastics.
Pigments includes pigments in paints, inks, and dyes, but not those in glass, plastics and rubber.
Household Batteries are primarily rechargeable nickel-cadmium household batteries.

Figure 1-4. Cadmium in discards of products in MSW, 1970, 1986 and 2000.



In 1970, cadmium discards in consumer electronics were estimated at 571 tons, or 48 percent of total discards. By 1986, these discards were 161 tons, or 9 percent of total; projected 2000 discards are 67 tons, or 2.5 percent of total.

Appliances. There are two potential sources of cadmium in discarded appliances: cadmium plating and plastics. Appliances ranked Number 4 in cadmium discards in 1986, but are projected to drop to Number 5 by 1990 (Table 1-8).

Cadmium was formerly used to plate nuts, bolts, and screws in dishwashers and washing machines because of cadmium's corrosion-resistant properties. As more appliance parts are made of plastic, however, the use of cadmium plating has been phased out.

Appliances contributed an estimated 107 tons of cadmium to MSW in 1970, or 9 percent of the total. By 1986, these discards had declined to 88 tons, 5 percent of total. A continued decline is projected, to 57 tons, or 2 percent, in 2000.

Pigments. Cadmium in pigments in glass, plastics, and rubber is discussed in other sections. It was not possible to quantify the amounts of cadmium in other individual uses such as printing inks, textile dyes, and paints; these categories are discussed collectively in this section. These pigments ranked Number 5 in discards in 1986 (Table 1-8).

Discards of cadmium in pigments have been relatively constant over the study period (Figure 1-4). In 1970, discards were an estimated 79 tons, or about 7 percent of total discards of cadmium. In 1986, discards were 70 tons, or 4 percent of total. By 2000, projected discards will be 93 tons, or just over 3 percent of total.

Glass and Ceramic Products. There are three uses for cadmium in glass and ceramic products: as a pigment in the glass, as a glaze for glass or ceramic products, and as a phosphor, e.g., in fluorescent tubes.

Glass and ceramic products account for a relatively minor portion of cadmium discards in MSW. In 1970, 32 tons, or less than 3 percent of total, were discarded. In 1986, 29 tons, or less than 2 percent of total, were discarded. In 2000, it is estimated that 37 tons, or less than 2 percent of total, will be discarded.

Rubber Products. Small amounts of cadmium are used in non-tire rubber products such as hose and hot water bottles. This is a very minor source of cadmium in MSW. An estimated 10 tons of cadmium were discarded in rubber products in 1970, less than one percent of the total. In 1986, an estimated 6 tons were discarded, again less than one percent. In 2000, discards of 9 tons of cadmium in rubber products are projected, less than one percent of the total.

Used Oil. Studies have shown that small amounts of cadmium are detected in used automotive oil. It was therefore estimated that one ton of cadmium per year is discarded into MSW with used oil. This may overstate these discards.

Miscellaneous Uses. Cadmium is used in very minor amounts in the controls of electric blankets and heating pads. It was estimated that one ton of cadmium is discarded in these products each year. This may overstate these discards.

PRODUCTS CONTAINING BOTH LEAD AND CADMIUM

Throughout this report, estimates of lead and cadmium discards in products have been made separately. There are a number of products, however, that may often contain both metals in varying amounts. Table 1-9 presents a listing of these products in 1986. Those quantified include consumer electronics, glass and ceramic products, plastics, pigments, rubber products, and used oil.

In addition, there are other products not quantified in Table 1-9 that may contain both lead and cadmium. It is projected, for example, that some consumer electronics discarded after 1986 will include plastics that may contain lead or cadmium. Appliances are not listed here, but they may contain pigments formulated with cadmium or lead. Many products, especially packaging, are made of composite materials, e.g., paper, plastic, and foil, that could contain lead or cadmium in pigments. It is very difficult, therefore, to predict whether some products do or do not contain lead and/or cadmium.

LEAD AND CADMIUM IN COMBUSTIBLE AND NONCOMBUSTIBLE PRODUCTS

There has been considerable speculation as to whether the heavy metals in municipal waste combustor ash come from combustible or noncombustible materials (or both) in the incoming waste. While this study was not designed to address this issue directly, some interesting observations can be derived from the data series developed.

Lead in Combustible and Noncombustible Products

The relative tonnages of lead in combustible and noncombustible products in MSW are shown in Figure 1-5. The noncombustible products overwhelmingly predominate at almost 98 percent of the total weight of lead. The reasons for this are illustrated in Figure 1-6: lead-acid batteries and consumer electronics, two relatively heavy products, contribute most of the lead in MSW. Glass products and all other sources, e.g., light bulbs and soldered cans, account for the rest of the lead.

Sources of lead in combustible products in MSW are illustrated in Figure 1-7. If all of the noncombustible products were removed from the incoming waste at an incinerator (by deposits, preprocessing, or other management methods), most of the remaining lead (71 percent) would be

Table 1-9

PRODUCTS CONTAINING BOTH LEAD AND CADMIUM, 1986
(In short tons)

Products	Lead	Cadmium
CONSUMER ELECTRONICS		
Circuit boards	6,092	-
TV picture tubes	52,165	-
TV and radio chassis	279	-
Cadmium plating	-	24
Subtotal - consumer electronics	58,536	24
GLASS AND CERAMIC PRODUCTS	7,956	29
PLASTICS		
Nondurables	1,678	240
Durables	1,899	262
Subtotal - plastics	3,577	502
PIGMENTS	1,131	70
RUBBER PRODUCTS		
Tires	48	-
Non-tire products	21	6
Subtotal - rubber products	69	6
USED OIL	192	1

Figure 1-5. Relative discards of lead in combustible and noncombustible products, 1986.

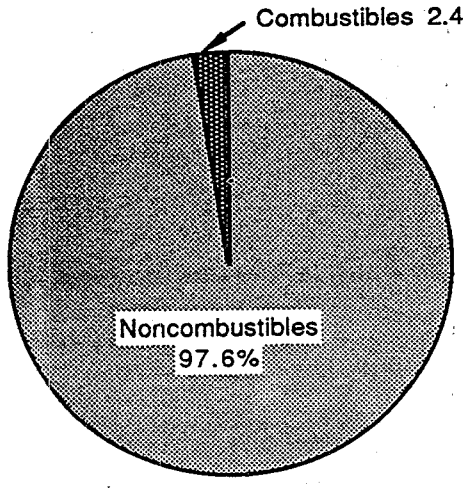


Figure 1-6. Sources of lead in noncombustible products, 1986

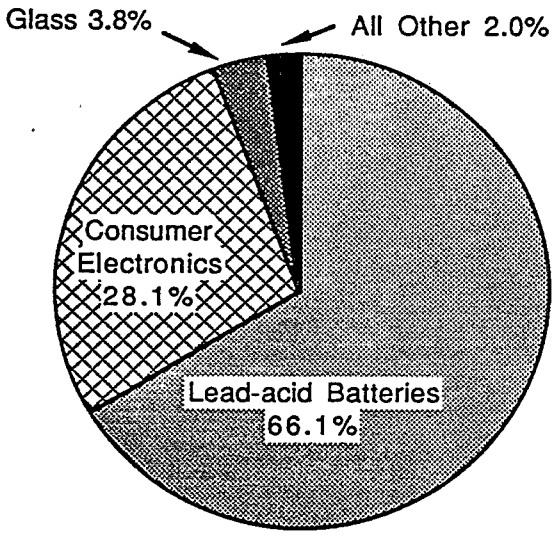
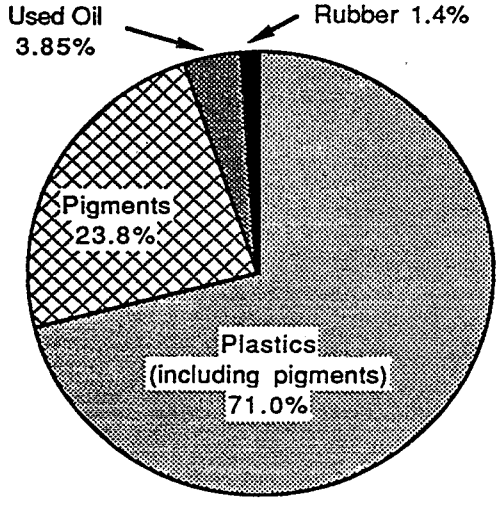


Figure 1-7. Sources of lead in combustible products, 1986.



contained in plastic products. Other pigments in painted products or products such as printed paper and dyed textiles would account for most of the rest (24 percent). Other small contributors of lead include used oil and rubber products.

Cadmium in Combustible and Noncombustible Products

Noncombustible products also contribute the majority of cadmium in MSW (64 percent), but not in such overwhelming amounts as is the case for lead (Figure 1-8). The primary source of cadmium in noncombustible products is household (nickel-cadmium) batteries (81 percent). Figure 1-9 also illustrates that consumer electronics contribute the second highest amount of cadmium in noncombustible products (14 percent). The remainder is contributed by appliances and other products (e.g., electric blankets and heating pads).

If all the cadmium in noncombustible sources were removed from MSW entering an incinerator, the cadmium in plastics would provide most of the remainder (88 percent). This is illustrated in Figure 1-10. Pigments in painted products, printed paper, and dyed textiles would contribute most of the remainder of the cadmium (11 percent). Very small amounts would come from rubber products and used oil in MSW.

Lead and Cadmium in Combustible and Noncombustible Products

The data reported above can be combined in another way to show the relative discards of lead and cadmium in combustible and noncombustible products.

Combined discards of lead and cadmium in noncombustible products come overwhelmingly from the lead in products (Figure 1-11). For both metals the primary source in this instance is batteries.

For combined discards of lead and cadmium in combustible products, lead still predominates, but not by such an overwhelming margin (Figure 1-12). Lead contributes almost 89 percent of these discards; cadmium, 11 percent. For both lead and cadmium, plastic products contribute the highest tonnage in combustible products, while pigments in other products are the second largest contributor.

THE POTENTIAL EFFECTS OF RECYCLING

Lead-acid Batteries

Recycling has been suggested as a way to reduce the amounts of lead and cadmium entering municipal waste combustors. Only one of the lead or cadmium-containing products currently identified is recycled in significant amounts: lead-acid SLI batteries. This one product is extremely significant. As noted earlier, lead-acid batteries contributed 65 percent of the lead discards in MSW in 1986--138,000 tons. If these batteries were not recovered for recycling at significant rates (80 percent in 1986), up to 700,000

Figure 1-8. Relative discards of cadmium in combustible and noncombustible products, 1986.

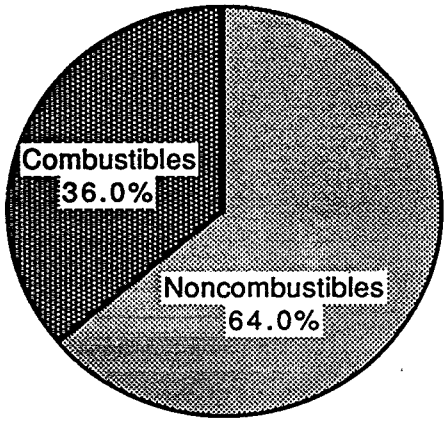


Figure 1-9. Sources of cadmium in noncombustible products, 1986.

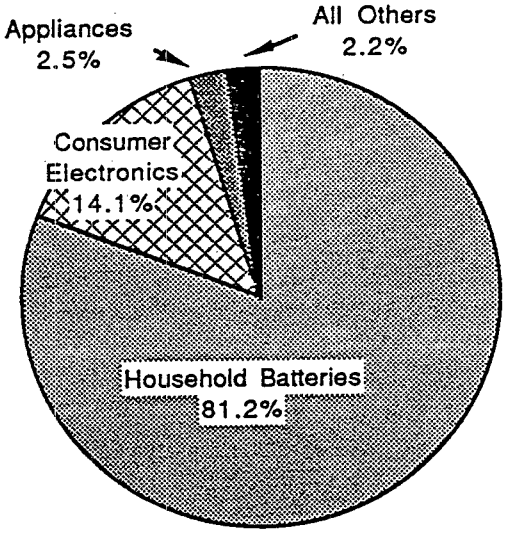


Figure 1-10. Sources of cadmium in combustible products, 1986.

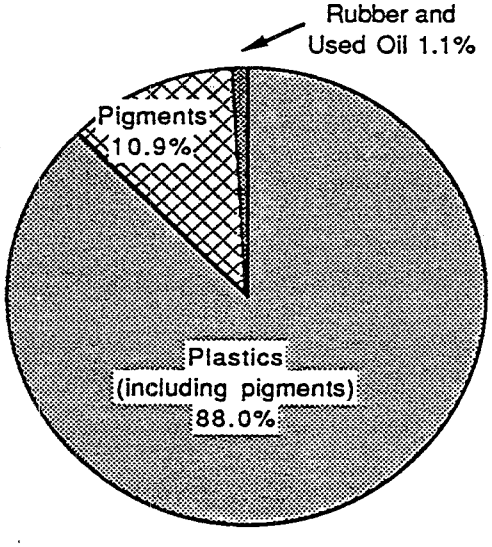


Figure 1-11. Relative discards of lead and cadmium in noncombustible products in MSW, 1986.

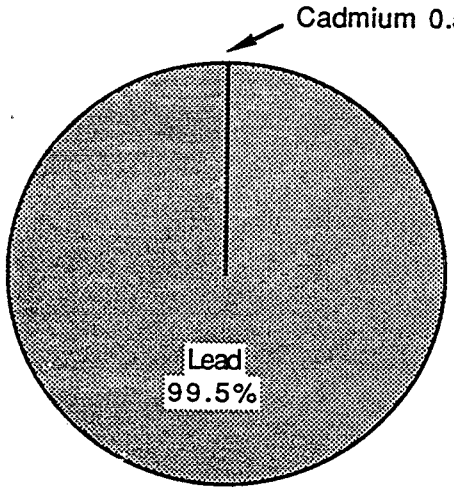
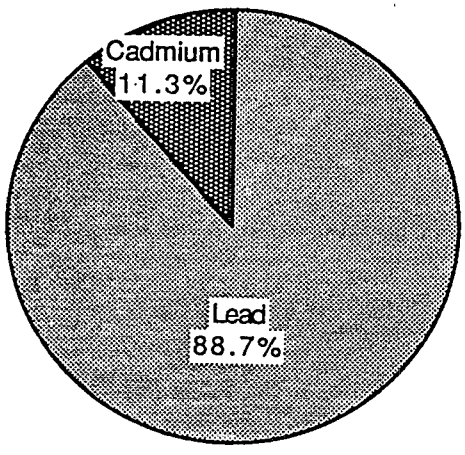


Figure 1-12. Relative discards of lead and cadmium in combustible products in MSW, 1986.



additional tons of lead from lead-acid batteries would have been discarded in 1986.

Historic discards and recycling of lead-acid batteries are illustrated in Figure 1-13. Recycling rates dropped as low as 52 percent in the early 1980s (apparently due to low prices for lead and increased regulations), and the figure illustrates that net quantities of batteries to be disposed increased at that time. Recycling obviously plays an important role in management of these batteries.

Other Products

No other recycling of lead or cadmium in products in MSW was identified, although there may be some small exports of nickel-cadmium batteries for recycling abroad. Some recycling of products in MSW that removes lead and cadmium from disposal in a landfill or incinerator as a by-product rather than as a goal of the recycling activity was identified.* These activities are discussed briefly in this section. (More information can be found in Chapters 2 and 3.)

Paper Products. A number of paper products are recovered for recycling, including some that are printed with inks that could contain lead or cadmium in the pigments. In many cases, such as newspapers made into boxboard or magazines made into roofing felt, the inks tend to remain in the recycled product. Some paper products are, however, deinked before being recycled into new products. These include recovered newspapers that are deinked before being made into new newsprint, and high grade recovered papers like computer printout that are deinked before being made into a product like paper towels.

It was estimated that up to 49 tons of lead in printing inks could have been removed by recycling of deinked papers in 1986. Since use of lead in printing inks was shown to be declining, removal of lead would also be declining. Data were not available to make similar estimates for cadmium in printing inks.

Solder in Cans. The lead in soldered steel cans is removed from the municipal waste stream when the cans are recovered for recycling, though the lead itself is not recycled, but would become an industrial waste. It was estimated that 85 tons of lead were removed through recovery and recycling of steel cans in 1986. Since the use of leaded solder in steel cans is declining, removal of lead in this manner is also declining.

Rubber Products. Although rubber is not recovered for recycling in large quantities, some recycling of rubber tires does occur. This has the potential to remove from the waste stream any lead pigments or other chemicals present in the rubber. It was estimated that 3 tons of lead were removed from

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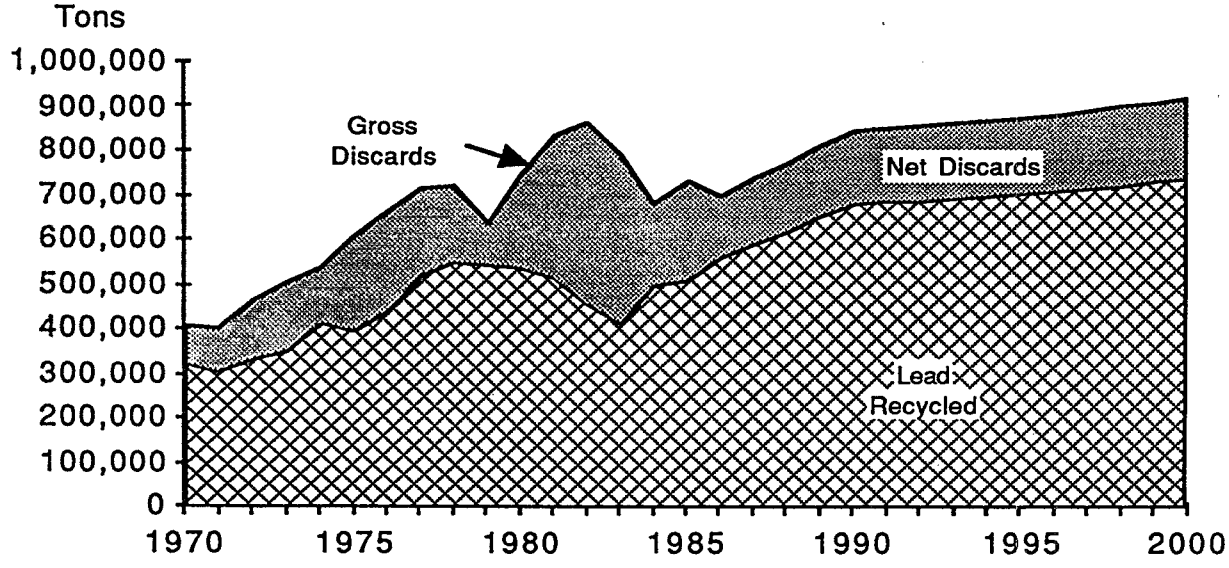
* Lead or cadmium in these recycled products would either be incorporated into the new products or would become industrial waste, e.g., sludges from deinking papers.

Figure 1-13. Discards of lead in SLI lead-acid batteries, 1970 to 2000.



the waste stream in this manner in 1986. Since all cadmium in rubber was assumed to be in non-tire products, no recovery of cadmium was estimated.

Appliances. There is cadmium plating in older model dishwashers and washing machines. If the ferrous metal in these appliances is recovered for recycling, the cadmium is removed from the waste stream as well. It was estimated that 2 tons of cadmium were removed in this way in 1986. This is a declining source of cadmium in the waste stream.

Glass Products. Although it was not possible to quantify, there are silk-screened designs that may contain lead and/or cadmium on many glass containers. Many glass containers are recycled, so some lead and cadmium is removed from the waste stream in this manner.

Plastics. Recycling of plastics in the United States has been minimal; it was estimated to be one percent in 1986. Further, most of the plastic products recycled under existing programs have been polyethylene terephthalate (PET) beverage bottles or high-density polyethylene (HDPE) milk jugs. Since lead and cadmium are not approved for use in food-contact packaging, the metals would not be affected by this recycling. There is an increasing amount of recycling of other plastic products, however, so some lead and cadmium may be removed from the waste stream in this manner, now or in the future.

Summary. Although precise estimates are not possible, probably not more than one to 2 percent of lead in MSW (exclusive of lead in batteries) is currently removed by recycling activities. The amount of cadmium affected by recycling is even smaller.

LIMITATIONS OF THIS REPORT

While this report contains useful data on discards of lead and cadmium in municipal solid waste, there are a number of limitations in its application to the issue of lead and cadmium in municipal waste combustor ash. Some of these limitations are discussed in this section.

Correlation of Characterization Data with Leachable Metals in Ash

The purpose of this report was to characterize the sources of lead and cadmium in municipal solid waste. It is beyond the scope of this study to identify the sources of leachable lead and cadmium in municipal waste combustor ash.

Correlation of Characterization Data with Individual Samples of Ash

This report contains data characterizing the lead and cadmium content of products defined as constituents of municipal solid waste. This characterization may not correlate well with the input into any particular combustion facility at the time ash samples were taken.

Management practices vary widely at municipal waste combustor (MWC) facilities depending on many factors. If the waste was pre-processed

before combustion, then many of the noncombustible materials that may contain lead or cadmium were probably removed. Facility management also varies as to whether large items such as appliances and furniture are excluded, and these items are likely sources of heavy metals. If a facility has a small capacity and small quantities of waste are handled at any given time, then the opportunity to remove large noncombustible products is more frequent.

There are also differences among facilities as to the mixtures of residential and commercial wastes handled, with some facilities processing almost exclusively one or the other.

Effects of the Combustion Process on Ash Characteristics

This report characterized lead and cadmium in products that may enter an incinerator. Whether the metals leave the incinerator in the same form that they enter is unknown. For example, lead monoxide (PbO) is a very common compound used in many products--glass, batteries, pigments, etc. The melting point of lead monoxide is 1,630 degrees Fahrenheit, well within the range of most municipal waste combustors. It is not known whether the PbO would recombine with other elements in the MWC to form new lead compounds, but it seems highly likely.

Lead and Cadmium in Other Wastes

This study was specifically designed to characterize lead and cadmium in municipal solid waste. There are instances, however, when incinerators that burn primarily MSW may receive and burn other wastes that may contain these metals. While it was not possible in this report to quantify the amounts of those wastes, nor to characterize them in terms of lead and cadmium content, some data were gathered in the course of this study that indicate where lead and cadmium may occur in some other wastes (Table 1-10). This partial listing illustrates the problems involved in identifying the sources of lead and cadmium in the ash from municipal waste combustors.

Table 1-10

WASTES OTHER THAN MSW THAT MAY CONTAIN LEAD AND CADMIUM

Nonhazardous Wastes	Possible Sources of Lead and Cadmium
Municipal sludge	Lead pipes, lead solder
Construction and demolition wastes	Siding Wall and ceiling tile Structural steel Polyvinyl chloride (PVC) pipe Wire and cable coverings Gutters and downspouts Conduit Wallcoverings Plumbing fittings and hardware Pipes and solder Light fixtures Neon tubing Some window glass Enameled building panels Flooring materials Paint (especially older houses) Caulking
Industrial and military wastes	Conveyor belts Industrial and military batteries Industrial and military electronics Communications equipment Electrical machinery Storage tanks
Automotive and other transportation wastes	Hosing Automotive finishes Upholstery and trim Auto tops Mufflers

Chapter 1

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3. Smith, F. L., Jr. A Solid Waste Estimation Procedure: Material Flows Approach. U.S. EPA, Office of Solid Waste. (SW-147). May 1975.

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