CADMIUM

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In 1999, production of cadmium in the United States declined by more than 4% compared with the unusually low production in 1998, while production of cadmium compounds, including cadmium sulfide, declined by more than 12% (tables 1 and 2). Apparent consumption declined by nearly 36%, but, for the fourth consecutive year, exceeded production (table 3). The difference was satisfied by imports, which were about 15 times larger than exports (table 6), and modest sales from the National Defense Stockpile (NDS). Prices continued to decrease during 1999 in response to the oversupplied world market.

In the United States, two companies, one in Illinois and another in Tennessee, produced primary cadmium as a byproduct of the smelting and refining of zinc concentrates in 1999. A third company, in Pennsylvania, recovered cadmium from scrap, mainly from spent nickel-cadmium (Ni-Cd) batteries. The value of cadmium produced in 1999 was calculated to be about $366,000. Although definitive consumption data do not exist, the International Cadmium Association (ICdA) has made the following estimates of cadmium consumption for various end uses: batteries, 74%; pigments, 13%; coatings and plating, 8%; stabilizers for plastics and similar synthetic products, 4%; and nonferrous alloys and other uses, 1% (Hugh Morrow, 1999, President, International Cadmium Association, oral commun., April 3, 2000).

In 1999, as in most years, the United States was a net importer of cadmium metal. The major source of U.S. imports was Canada, accounting for about one-third of all imports, followed by Australia and Belgium, with 26% and 21%, respectively. These three countries supplied nearly 80% of all imported cadmium metal. Cadmium compounds and pigments were subject to import duties, but unwrought and powdered metal, as well as waste and scrap, entered duty free in all but a few cases. Cadmium, in all forms, from North American Free Trade Association member states (Canada and Mexico) entered the United States duty free. As in 1998, the United States was a net exporter of cadmium sulfide, all of which was exported to two countries: Japan (90%) and Canada (10%) (table 5). Trade data for other cadmium compounds were not available.

Cadmium was refined in 31 countries in 1999. The six largest producers, in decreasing order, were Japan, China, Belgium, Canada, Mexico, and the United States. These countries accounted for more than one-half of world production; the United States accounted for slightly over 6%. Identified world cadmium resources at yearend 1999 were estimated by the U.S. Geological Survey (USGS) to be 6 million metric tons (Mt), a figure based on zinc resources typically containing about 0.3% cadmium. The world reserve base was estimated to be 1.2 Mt, and reserves were 600,000 metric tons (t).

Legislation and Government Programs

During the last decade, regulatory pressure to reduce or even eliminate the use of cadmium, a toxic metal, has gained momentum in many developed countries. In the United States, many Federal and State agencies regulate the cadmium content of air, water (including bottled water), pesticides, color and food additives, waste, etc. Most permissible exposure limits are based on the quantity of cadmium particles per unit volume, regardless of origin. To unify the different lists of environmentally dangerous elements, the U.S. Environmental Protection Agency (EPA) created a list of persistent and bioaccumulative toxic (PBT) pollutants. In the PBT list, to be used as a tool in revising the Resource Conservation and Recovery Act, EPA rated pollutants according to their human health risk potential and ecological risk potential. According to this rating, cadmium ranks as potentially more dangerous to the environment and to human health than arsenic. Since its publication, the PBT list continues to be controversial not only in the cadmium industry but also in the base metal industry.

Cadmium is one of 11 metals among 53 chemicals on the PBT list targeted by EPA for a 50% reduction by 2005. The ICdA objected to the inclusion of any metal, particularly cadmium, on the PBT list. The principal reason for its objection was that no distinction was made between various cadmium compounds and cadmium metal itself. According to ICdA, it is not possible to give a single rating for cadmium and all of its compounds because of their widely varying solubilities and bioavailabilities. Highly soluble and bioavailable cadmium chloride, for example, probably will have a different risk than cadmium metal, cadmium oxide, cadmium sulfate, and other insoluble compounds. Therefore, ICdA claims that the PBT rating for cadmium should recognize differences between the various forms of cadmium. This would lower the rating on many cadmium compounds and allow their use in products where no practical substitution exists. Rather than reducing cadmium production/consumption, ICdA advocates the recycling of cadmium products as the best way to reduce cadmium health and environmental hazards.

The U.S. Department of Transportation (DOT) proposed replacement of cadmium plated fittings and cone caps in the oxygen delivery system of certain airplanes, not because of toxicity concerns but because of a mechanical problem. The DOT airworthiness directive was prompted by reports that a field survey of the affected parts revealed a reaction process which was causing cadmium flaking. The actions specified by the proposed airworthiness directive are intended to prevent cadmium flaking from blocking valves and impairing the oxygen system for crew and passengers during an emergency (Department of Transportation, 1999, [no date], Airworthiness Directives, accessed March 20, 2000, at URL http://frwebgate3.access.gpo.gov).

Production

The most common cadmium mineral is greenockite, which is almost always associated with the zinc ore mineral, sphalerite. The average ratio between contained zinc and cadmium in sphalerite is about 400:1 or 0.25%. It is estimated that at least 80% of current cadmium output worldwide arises as a byproduct of primary zinc production. The remaining 20% is obtained from secondary sources such as baghouse dust and recycling of cadmium products. Because of depressed cadmium prices, the processing of many wastes for cadmium recovery is not economically viable. Thus, cadmium is usually extracted for other reasons, such as the recovery of other metals or because it is required by Government regulation.

In the United States, only two companies produced primary cadmium: Big River Zinc Corp., Sauget, IL, and Pasminco Ltd., Clarksville, TN. Both companies used an electrolytic process and recovered the cadmium as a byproduct during the roasting and leaching of zinc concentrate. After removing various impurities, cadmium sponge can be processed to final form by either refining or electrowinning.

The Sauget operation, owned by Korea Zinc Co. Ltd., can produce up to 85,000 t per year (t/yr) of zinc and 800 t/yr of cadmium metal and oxide. About 80% of its concentrate feed was supplied by mines in Missouri and Tennessee, and the remaining 20% was imported, mainly from Canada, Mexico, and Peru (Mining Journal, 1999). The cadmium content of zinc sulfide concentrate is usually between 0.1% and 0.8%. The concentrate is heated in fluidized bed roasters to produce an impure zinc oxide (calcine) suitable for acid leaching. Between 60% and 85% of the calcine, which contains cadmium and other impurities, is volatized with the sulfur dioxide gas generated during the roasting process. Calcine and fume are separated from the gas and collected in waste heat boilers, cyclones, and electrostatic precipitators. The collected calcine dust is combined with the unvolatilized portion of the calcine and dissolved in sulfuric acid at a leaching plant. Generally, manganese dioxide is added to the leaching tank to remove iron and significant amounts of other impurities. These insoluble residues are sold to other smelters for further processing as iron cake. The leachate is sent to a series of cold and hot purification tanks where cadmium and other remaining undesirable metals are removed from the solution. After the first stage of zinc sulfate purification, discharged impurities form copper cake, which, like the previously captured leach residues, are sold for processing. The bulk of cadmium is precipitated in the second stage of purification, and the remainder is precipitated in a third stage. The cadmium precipitate is filtered and forms a cake containing about 12% cadmium, 25% zinc, and small amounts of other impurities. The cake is then redissolved in sulfuric acid. After two additional acid treatments, a cadmium sponge is produced, which is dissolved in another sulfuric acid bath, and the solution, if sufficiently pure, is passed into electrolytic cells where the cadmium is deposited on cathodes. The more than 99.99%-pure cadmium metal that results is melted and cast into 50-millimeter-diameter ball anodes or 250-millimeter-long sticks or burned to make cadmium oxide powder. Higher purity cadmium for special purposes, such as for semiconductors, can be produced by vacuum distillation (U.S. Environmental Protection Agency, 1987).

In February 1999, Savage Zinc Inc. and its parent company, Savage Resources Ltd. of Australia in a takeover bid were acquired by another Australian zinc miner, Pasminco Ltd. The takeover, launched in October 1998, was aimed mainly at acquiring control of Savage Zinc and its zinc operations in Tennessee, consisting of a 105,000-ton-per-year refinery in Clarksville and two mines in Gordonsville and Clinch Valley. At first, the takeover was resisted by Savage management. After gaining about 60% acceptance from Savage shareholders, however, management recommended that the remaining shareholders accept the takeover bid from Pasminco. Less than a week later, Pasminco won additional shareholders, giving it a 75% acceptance, and representing more than 90% of Savage’s capital, the compulsory acquisition threshold. The acquisition extended Pasminco’s distribution network into the U.S. market. The proven and probable reserves at the Gordonsville and Clinch Valley mines amount to 22.7 Mt, grading 3.2% zinc (Pasminco Ltd., [no date], 1999 annual report, accessed May 3, 2000, at URL http://www.pasminco.com.au). According to Pasminco, plans by Savage to triple capacity at the Clarksville smelter were only postponed and not rejected. When more favorable market conditions develop, Pasminco may expand the smelter. By tripling the existing capacity, the Clarksville smelter would become one of the lowest cost zinc smelters in the world.

The amount of cadmium that is recycled is difficult to estimate for a number of reasons. For example, cadmium from baghouse dust generated at lead and copper smelters enters the primary cadmium production circuit at zinc refining operations and may or may not be included in reported production statistics for primary cadmium metal. Electric furnace dust, which contains about 0.05% cadmium, is recovered in zinc recycling processes only because it is mandated by environmental regulations; cadmium prices are so depressed that the processing of furnace dust for any other reason is not economically feasible. Although the amount of cadmium produced from the recycling of Ni-Cd batteries is fairly accurate, there are no firm data on the amounts of cadmium recovered from other sources such as electric arc furnace dust, electroplating wastes, filter cakes, sludges, and other cadmium-containing materials. Even the recycling of spent Ni-Cd batteries, the easiest way to recover cadmium, is mainly carried out to avoid high disposal costs.

In 1995, International Metals Reclamation Co. Inc. (INMETCO), a subsidiary of the International Nickel Co., began reclaiming cadmium from spent batteries at its Ellwood

City plant northwest of Pittsburgh, PA. The $5 million cadmium High Temperature Metal Recovery plant addition, built by Davy International Ltd., was the first facility of its kind in the world. To date, cadmium recycling at the facility has been practical only for Ni-Cd batteries, some alloys, and dust from electric arc furnaces—which typically contained 0.003% to 0.07% cadmium. The most difficult aspect of Ni-Cd battery recycling is the collection of spent batteries. Large industrial batteries, containing 25% of the cadmium used for batteries, are easy to collect and are recycled at a rate of about 80%. About 75% of the cadmium used in batteries goes into small consumer Ni-Cd cells and batteries that are usually discarded in municipal solid waste. Therefore, various organizations and Government agencies are devising ways to improve the collection of these small batteries. Economies of scale are very important, and the larger a recycling operation, the lower its unit cost is likely to be. Several different collection programs have been developed by INMETCO to meet the needs of battery manufacturers and the numerous consumers, firms, organizations, and agencies that use many diverse products, such as power tools, cellular phones, and personal computers. The largest of these programs, the Rechargeable Battery Recycling Corp. (RBRC), is associated with the battery manufacturers and is operated by a nonprofit public service organization. The RBRC has undertaken an extensive public education campaign and has established several recycling programs, such as the Retail Recycling Plan, the Community Recycling Plan, and the Public Agency Recycling Plan. During 1998, according to the latest available data, RBRC increased household collection sites in the United States to more than 24,000 and expanded Canadian collection, which began in 1997. For certain small dry cell Ni-Cd batteries, INMETCO recruited manufacturers for the mail-back of used batteries, community-based prepaid container programs, and other similar arrangements. Most of the industrial wet Ni-Cd batteries were recycled through collection programs in which producers of industrial batteries collect and send their spent batteries to INMETCO by issuing a purchase order, then arranging their own transportation. A smaller portion of industrial batteries was collected and shipped by various environmental organizations (Bleakney, 1998).

The process of cadmium recovery from industrial and consumer sealed batteries, both of which contain about 12% to 15% cadmium by weight, differs only in the manner of battery preparation. Processing consists of draining sodium hydroxide electrolyte, cutting the tops off the batteries, and separating nickel and cadmium plates. Small batteries must be hand-sorted because only a few newer batteries are color coded and almost none carry bar codes, making optical scanning and other automated sorting very difficult.

The cadmium plates from the industrial batteries and the small batteries, from which the plastic wrapping has been removed, are charged into a cadmium recovery furnace. In the furnace, cadmium is reduced by carbon, vaporized, and then condensed. The resulting cadmium metal, which is cast into small flattened discs, 4 to 6 millimeters in diameter, to facilitate handling and to reduce erratic rolling, has a purity of greater than 99.95% Cd, some as high as 99.999% Cd. These discs are usually shipped to Ni-Cd battery manufacturers for reuse in new batteries, but they also could be used in the manufacture of corrosion-resistant coatings or in paint pigments.

In addition to the pyrometallurgical process, in which cadmium vapor is collected and then solidified by condensation or oxidation, there is the hydrometallurgical process. In this wet process, batteries are dissolved in strong acids, then subjected to selective precipitation or ion exchange reactions to separate the cadmium from nickel and iron.

Although secondary production will likely increase in the future, primary production will probably remain basically unchanged for the next few years. Any future increases in production of virgin cadmium will likely come from the Crandon/Rhinelander zinc-copper deposit in northeastern Wisconsin. Its development will depend on the zinc market and on Nicolet Minerals Co., a wholly owned subsidiary of Rio Algom Mining Corp., acquiring some remaining permits from the Wisconsin State government. Nicolet's proposal of a future mine near the headwaters of the Wolf River, however, aroused local opposition from those who feared the pollution of underground water and altered water levels of nearby lakes caused by pumping of water to keep the shafts dry. The deposit contains an estimated 62 Mt of ore grading 5.6% zinc, 1.1% copper, and 0.01% to 0.23% cadmium (Skillings' Mining Review, 1978). Sphalerite from one particular stratigraphic sequence, the Skunk Lake unit, consistently has had the highest cadmium values, averaging 0.09% cadmium (Lambe and Rowe, 1987). Pyrite is ubiquitous throughout most of the deposit. Development of the deposit would include the building of a 2-Mt-capacity mill with an annual production of between 200,000 and 300,000 t of zinc concentrate and about 20,000 t combined copper-lead concentrate (Metal Bulletin, 1996).

Another factor in the cadmium supply in recent years has been the sale of cadmium from the NDS. In 1991, the U.S. Congress authorized the disposal of the entire cadmium stockpile of 2,872 t as excess material. To date, about 1,200 t of the stockpile has been sold, including 5 t in 1999.

Environmental Issues

Cadmium is toxic, particularly in its soluble and respirable forms. Although it is commonly associated with zinc, the two behave somewhat differently in biological systems. Zinc is an essential element in almost all biological systems and plays an important role in metalloenzyme catalysis, metabolism, and the replication of genetic material. However, prolonged exposure to high concentrations of cadmium, particularly the respirable and soluble forms of cadmium are known to have toxic health and environmental effects. Dermal contact with cadmium results in negligible absorption. Inhaled cadmium fumes or fine dust, however, are much more readily absorbed than ingested cadmium. Repeated exposure to excessive levels of dust or fumes can have irreversible effects on the kidneys or renal system and on the lungs, producing shortness of breath and emphysema. Because of these potential adverse effects, occupational exposure to cadmium in the United States is stringently regulated by the EPA. Similarly, strict air and water emission limits on cadmium as well as land disposal restrictions are in effect in the United States and other countries. Any discharge of cadmium chemicals above a specific threshold level into navigable waters is subject to reporting requirements.

The four main environmental and human health concerns involved with Ni-Cd batteries are occupational exposure, manufacturing emissions and wastes, product use, and product disposal. Because most of the environmental and health problems involved in the production of Ni-Cd batteries can easily be controlled, recent regulations have focused on disposal options. Basically, only four disposal options are available—composting, incineration, landfilling, and recycling. The first two options are not practical; landfilling was the most frequently used alternative and recycling was the one most preferred by the industry and environmentalists. An effective collection and recycling system for spent batteries may protect the environment more than would a ban on cadmium in batteries. Because most cadmium is produced as a byproduct, mainly of zinc production, restrictions on the use of cadmium in batteries could increase the amount of cadmium exposed on land by zinc producers.

Consumption

The USGS does not collect actual consumption data on either cadmium metal or cadmium compounds. Apparent consumption of cadmium metal in the United States is calculated from production, trade, and stock changes. Apparent consumption decreased by nearly 36%, compared with that of 1998.

Cadmium metal has a low melting temperature, good electrical conductivity, excellent corrosion resistance in alkaline and saline environments, and the ability to improve the mechanical properties of other metals. Therefore, cadmium metal is commercially used mainly as a corrosion-resistant coating on steel, aluminum, and other nonferrous metals. Cadmium metal is also added to some nonferrous alloys to improve properties such as strength, hardness, wear resistance, castability, and electrochemical behavior. All cadmium compounds are made from cadmium metal and are primarily used in batteries, pigments, ultraviolet light and weathering stabilizers, and semiconductor applications.

Although cadmium consumption for batteries has grown steadily during the past 15 years, other cadmium markets, such as pigments, stabilizers, coatings, and alloys, are regarded as mature because they are not expected to grow; in fact, some of the markets have already started to decline. Consumption of cadmium for these dispersible and dissipative applications will continue to decline because of increasingly stringent environmental regulation, concerns of manufacturers about long-term liability, and the development of less toxic substitutes. Consumption patterns varied significantly among countries because of differences in environmental regulations, industrial development, natural resources, and trading patterns. In the United States, Ni-Cd batteries provided the power for three-fourths of the most common portable products, such as cordless telephones, cellular telephones, power tools, laptop computers, and camcorders. It is estimated that there are 430 million cordless electronic products in the United States (American Metal Market, 1999).

Cadmium oxide and cadmium hydroxide are the negative electrodes in Ni-Cd , silver-cadmium, and mercury-cadmium batteries. A wide variety of cadmium sulfide-based compounds are used as yellow, orange, and red pigments for plastics, glasses, ceramics, enamels, and artists colors. Organic alternatives still cannot match many of the popular properties of cadmium pigments, especially color brightness, opacity, and processability. One of the more promising noncadmium colorants is a cerium sulfide developed in France (American Metal Market, 1997). Cadmium pigments are particularly well suited for applications requiring high temperature or high pressure processing or applications where other pigments will readily degrade. Cadmium carboxylates, such as the laurate and the stearate, are used as ultraviolet light and weathering stabilizers for polyvinylchloride (PVC). The finished PVC product usually contains no more than 0.2% cadmium. The cadmium is locked into the polymer matrix and has extremely low leachability (Donelly, 1996).

Prices

As the byproduct of other metals production, cadmium is not subject to the normal supply-demand dynamics of most metals. The inelastic supply-demand situation associated with byproduct commodities invariably leads to volatile pricing, and such has been the case for cadmium over the past 20 to 30 years. Until the late 1980's, cadmium was used mainly in pigments and alloys. After the Ni-Cd battery was developed, the battery market expanded by 20% per year, and the price of cadmium increased to $9.10 per pound by March 1988. With the exception of 1995, the 1990's were marked by a steady decline in cadmium prices due to tightening regulatory controls and thus reduced consumption in some traditional cadmium markets such as pigments, stabilizers, and coatings. In addition, recycling of cadmium batteries has also led to the availability of secondary cadmium. After reaching an average price of $1.84 per pound of metal in 1995, prices began spiraling downward in February 1996 to an average price of $0.14 per pound in 1999, based on the New York dealer price for cadmium metal. The Asian economic crisis, large exports of cadmium metal, mainly by Bulgaria and Russia, and gradual replacement of Ni-Cd batteries with lithium-ion and nickel metal hydride batteries caused prices to fall and remain low. Recovery of cadmium from spent Ni-Cd batteries, often required by local regulations, further depressed the market.

Current Research and Technology

New processing technology for depositing photovoltaic cells on glass, developed at the University of Toledo, OH, could make the use of solar energy more efficient. Two decades ago, electricity generated by solar panels cost more than $100 per watt. It has since fallen to an average of $7.50 per watt, which the recent breakthrough may lower by about 50%. The new manufacturing process allows a 2- by 4-foot solar panel to be coated with cadmium-telluride (CdTe) every 30 seconds, compared with 6 hours for the closest rival. In addition to lower manufacturing cost, the conversion solar efficiency reportedly increased to 9.1% from the prevailing 7.5%. To comply with environmental restrictions, a recycling system for spent photovoltic modules has been developed. Although the CdTe solar cell market is still very small, its growth rate in recent years shows promise (40% growth in 1997), and the world market is large and growing. It could become a significant niche market for cadmium in the near future (Welles, 1998).

The use of vegetation to clean sites contaminated with heavy metals, called phytoremediation, may now be on the brink of commercialization. At least three new companies have formed during the past few years to employ this new technology, which utilizes plants called “hyperaccumulators” because they absorb high levels of contaminants via their roots. According to a U.S. Department of Energy report on phytoremediation research, the best hyperaccumulators should exhibit the following characteristics: a high accumulation rate, even at low environmental concentrations of the contaminant; an ability to accumulate very high levels of contaminants; an ability to accumulate several heavy metals; fast growth; high biomass production; and resistance to diseases and pests. Closest to this description is a plant from the genus *Thlaspi*, or Alpine pennycress, which can accumulate significant amounts of cadmium, zinc, and, if certain chelators are added to the soil, lead. Phytoremediation for only cadmium and zinc is more practical because they are usually co-occurring pollutants. Researchers are now working with plants that can accumulate up to 25,000 milligrams (mg) of zinc and 1,000 mg of cadmium per kilogram of dry plant matter. Phytoremediation has been estimated to cost one-third that of traditional methods of remediation (Journal of Metals, 1998).

Outlook

Historically low prices, limited growth in many cadmium markets, and pending environmental restrictions must be considered in forecasts for the cadmium industry. Zinc mining companies that produce cadmium as a byproduct, are beginning to regard the metal as a cost rather than a credit. The cost of producing cadmium, which is difficult to determine apart from zinc, may already exceed the sale price. The immediate future of the cadmium industry rests largely with the Ni-Cd battery market, which is the only market that continues to grow, especially in certain sectors such as power tool uses and in lesser developed countries. Stability has developed in the coatings and pigments markets, and they are not expected to erode any further in the future. The stabilizers and alloys markets are expected to diminish and eventually close due to substitution by cadmium-free products. However, several new applications, such as telecommunications, electric and hybrid electric vehicles, remote area storage systems, and solar cells, could become significant cadmium markets.

The future of the cadmium market will be determined by the extent to which industry is able to fully implement the collection and recycling of cadmium products. That means the establishment and the development of new recycling technologies, not only for batteries, but also for other principal end-use products. Recycling of industrial Ni-Cd batteries, which retain nearly 100% of the market for emergency lighting, alarms, and power tools, and have a production rate that is growing by about 3% per year, has been developed and is expanding. The rechargeable battery industry has been growing significantly in recent years and is expected to continue to grow well into the 21st century. State and Federal mandates now require manufacturers and battery resellers (companies that use Ni-Cd batteries in their products) to recycle rechargeable batteries and prohibit commercial users from discarding them in municipal solid waste. Further increases in the recycling rate for rechargeable batteries will depend on the cooperation of consumers, which in turn will reflect the convenience of collection systems (Rechargeable Battery Recycling Corp. (RBRC), [no date], The nonprofit company that recycles Ni-Cd rechargeable batteries, accessed April 25, 2000, at URL http://www.rbrc.org). According to a survey conducted by the RBRC, 95% of Americans own cordless electronic products, but just 16% recycle their power sources (American Metal Market, 1999). For the recycling industry, the first step will be the establishment of a global collection system for Ni-Cd spent batteries because they are 100% recyclable. This is rapidly becoming a reality. The collection and recycling rates must, however, continue to increase to reassure regulators and the general public that any human health or environmental risks associated with cadmium will be well managed. Improved recycling of Ni-Cd is also necessary to forestall any future threat of a ban on the use of cadmium in Europe. However, according to current estimates of cadmium present in the environment, only 2% is attributable to the applications in which it is used. Most of the cadmium released into the environment is attributed to the burning of fossil fuels and to iron and steel production (Metal Bulletin, 1999). Recycling of cadmium products other than batteries will be considerably more difficult. The proper disposal of discarded plastics, obsolete electronic parts, incinerator residues, and municipal sewer sludge—all of which often contain low levels of dispersed cadmium—is still a problem.

The U.S. collection and recycling program for small rechargeable batteries is in a period of rapid expansion. The RBRC generates revenue for the program by licensing its seal of approval to individual companies involved in the manufacturing, importation, and distribution of rechargeable batteries or battery-operated products. The Portable Rechargeable Battery Association (PRBA), one of the sponsors, has helped enlist the participation of county and municipal governments, hospitals, and fire departments. Spent Ni-Cd, nickel-metal hydride, lithium-ion, and small sealed lead-acid batteries are all being collected under the program. The PRBA believes that by the end of 2001, roughly 70% of the spent Ni-Cd batteries generated in the United States will be recycled. According to the RBRC, about 22% of rechargeable batteries were recycled in 1997 (latest available data) representing more than 1,700 t of batteries. Assuming an average cadmium content of 15% per battery, more than 250 t of cadmium was recycled rather than discarded in landfills (Price, 1998).

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT CADMIUM STATISTICS 1/

(Metric tons, cadmium content, unless otherwise specified)

	1995	1996	1997	1998	1999
United States:					
Production of metal 2/	1,270	1,530	2,060	1,240 r/	1,190
Shipments of metal by producers 3/	1,280	1,310	1,370	600 r/	440
Exports of metal, alloys, and scrap	1,050	201	554	180 r/	20
Imports for consumption, metal	848	843	790	514 r/	294
Stocks of metal, Government, yearend	2,260	2,030	1,870	1,740	1,740
Apparent consumption of metal	1,160	2,250	2,510	2,030 r/	1,300
Price, average per pound, New York dealer 4/	$1.84	$1.24	$0.51	$0.28	$0.14
World: Refinery production	20,100	18,900 r/	19,500 r/	19,100 r/	19,100

r/ Revised.
1/ Data are rounded to no more than three significant digits, except prices.
2/ Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.
3/ Includes metal consumed at producer plants.
4/ Price for 1 to 5 short-ton lots of metal having a minimum purity of 99.95% (Platt's Metals Week).

TABLE 2
U.S. PRODUCTION OF CADMIUM COMPOUNDS

(Metric tons, cadmium content)

Year	Cadmium sulfide 1/	Other cadmium compounds 2/
1998	125	638
1999	64	604

1/ Includes cadmium lithopone and cadmium sulfoselenide.
2/ Includes oxide and plating salts (acetate, carbonate, nitrate, sulfate, etc.).

TABLE 3
SUPPLY AND APPARENT CONSUMPTION OF CADMIUM METAL 1/

(Metric tons)

	1998	1999
Industry stocks, January 1	1,060 r/	729
Production	1,240 r/	1,190
Imports for consumption of metal, alloy, scrap	514 r/	294
Shipments from Government stockpile excesses	128	5
Total supply	2,940 r/	2,210
Exports of metal, alloys, scrap	180 r/	20
Industry stocks, December 31	729 r/	893
Consumption, apparent 2/	2,030 r/	1,300

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Total supply minus exports and yearend stocks.

TABLE 4
INDUSTRY STOCKS, DECEMBER 31

(Metric tons)

	1998		1999	
	Cadmium Metal	Cadmium in compounds	Cadmium Metal	Cadmium in compounds
Metal producers	633	W	800	W
Compound manufacturers	96 r/	36	93	15
Distributors	W	(1/)	W	(1/)
Total	729 r/	36	893	15

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Compound manufacturers."
1/ Less than 1/2 unit.

TABLE 5

U.S. EXPORTS OF CADMIUM PRODUCTS, BY COUNTRY 1/

Country	1998 Quantity (kilograms)	1998 Value	1999 Quantity (kilograms)	1999 Value
Cadmium metal: 2/				
Belgium	-- r/	-- r/	9,420	$15,000
Canada	--	--	917	19,200
China	6,680	$10,700	--	--
Finland	18,700	771,000	--	--
France	57,000 r/	40,300 r/	2,940	136,000
Germany	-- r/	-- r/	332	110,000
India	95,100	42,600	2	4,730
Japan	1,110 r/	45,500 r/	2,330	113,000
Korea, Republic of	--	--	67	11,500
Mexico	569 r/	21,700 r/	2,490	76,900
Taiwan	--	--	1,040	17,400
United Kingdom	356 r/	34,000 r/	811	19,500
Total	180,000 r/	966,000 r/	20,400	523,000
Cadmium sulfide: (gross weight)				
Canada	--	--	11,100	4,240
Germany	10,900	5,650	--	--
Japan	--	--	96,200	24,000
Korea, Republic of	8,170	4,250	--	--
Taiwan	9,860	5,130	--	--
Total	28,900	15,000	107,000	28,200

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes exports of cadmium in alloys and scrap.

Source: Bureau of the Census.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF CADMIUM PRODUCTS, BY COUNTRY 1/

Country	1998 Quantity (kilograms)	1998 Value	1999 Quantity (kilograms)	1999 Value
Cadmium metal:				
Algeria	--	--	3,000	6,940
Australia	114,000	55,300	76,000	26,800
Belgium	83,800 r/	289,000 r/	60,800	244,000
Canada	304,000 r/	438,000 r/	98,200	461,000
Finland	2,000	1,760	--	--
France	--	--	3,990	4,590
Germany	24	3,650	--	--
Japan	205	43,500	170	28,100
Mexico	10,500 r/	5,240 r/	9,300	10,700
Peru	--	--	17,700	41,300
Russia	--	--	5,000	15,100
Spain	--	--	20,000	9,700
Total	514,000 r/	837,000 r/	294,000	848,000
Cadmium sulfide: (gross weight)				
Australia	92	3,500	--	--
Japan	1,340	93,900	13,800	37,900
Russia	88	8,010	26	2,630
United Kingdom	7,940	81,800	4,640	54,300
Total	9,460	187,000	18,400	94,800

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 7

CADMIUM: WORLD REFINERY PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1995	1996	1997	1998	1999 e/
Algeria	75 r/	75 r/	75 r/	75 r/	75
Argentina	43	40	45	34 r/	30
Australia	838	639	632	600 e/	600
Belgium	1,710	1,579	1,420	1,318	1,400
Brazil e/	300	300	300	300	300
Bulgaria e/	250	250	250	200	200
Canada	2,349	2,537	1,272	1,361 r/	1,390 p/
China e/	1,450	1,570	1,980	2,130 r/	2,200
Finland 3/	539	648	540 e/	520 r/	500
France	-- e/	92 r/	309	223 r/	230
Germany	1,150 e/	1,150 e/	1,145	1,020 r/	1,100
India	254	271	298	300 e/	300
Italy	308	296	287	328	350
Japan	2,652	2,344	2,473	2,337 r/	2,600
Kazakhstan	794	800 e/	1,000 r/ e/	1,450 r/ e/	1,061 4/
Korea, North e/	100	100	100	100	100
Korea, Republic of	1,665	501	570	884 r/	900
Macedonia e/	(5/)	(5/)	(5/)	(5/)	(5/)
Mexico 6/	689	784	1,223	1,275 r/	1,300
Namibia 7/	15	14	2	--	--
Netherlands	704	603	718	739	750
Norway	317	274	290	270 e/	250
Peru	560	405	474	474	480
Poland	--	--	22 r/	25 r/	25
Romania e/	5 4/	5	4	4	4
Russia	725	730	790 e/	800 e/	900
Serbia and Montenegro	11	79	80 e/	80 e/	15
Spain	397	307	301	196 r/	--
Thailand	365	385	238	240 e/	300
Turkey	23	42	89 r/	69 r/	60
Ukraine e/	15	25	25	25	25
United Kingdom 8/	549	541 e/	455	440 e/	500
United States 8/	1,270	1,530	2,060	1,240 r/	1,190 4/
Total	20,100	18,900 r/	19,500 r/	19,100 r/	19,100

e/ Estimated. p/ Preliminary. r/ Revised. -- Zero.

1/ This is the unrounded version of the table.

2/ This table gives unwrought production from ores, concentrates, flue dusts, and other materials of both domestic and imported origin. Sources generally do not indicate if secondary metal (recovered from scrap) is included or not; where known, this has been indicated by a footnote. Data derived in part from World Metal Statistics (published by World Bureau of Metal Statistics, Ware, the United Kingdom) and from Metal Statistics (published jointly by Metallgesellschaft AG, of Frankfurt am Main, Germany, and World Bureau of Metal Statistics). Cadmium is found in ores, concentrates, and/or flue dusts in several other countries, but these materials are exported for treatment elsewhere to recover cadmium metal; therefore, such output is not reported in this table to avoid double counting. This table includes data available through May 11, 2000.

3/ Excludes secondary production from recycled nickel-cadmium batteries.

4/ Reported figure.

5/ Less than 1/2 unit.

6/ Excludes significant production of both cadmium oxide and cadmium contained in exported concentrates.

7/ Tsumeb Smelter closed in April 1998.

8/ Includes secondary.