CADMIUM

By Jozef Plachy

In 1997, two companies produced primary cadmium in the United States. These companies, one in Illinois and one in Tennessee, recovered the cadmium as a byproduct of smelting and refining of zinc concentrates. A third company, in Pennsylvania, recovered cadmium from spent nickel-cadmium (Ni-Cd) batteries. The value of cadmium produced in 1997 was calculated at about $2.3 million. The estimated U.S. consumption pattern included batteries, 67%; pigments, 14%; coatings and plating, 8%; stabilizers for manufacture of plastics and similar synthetic products, 8%; nonferrous alloys, 2%; and other, including electro-optics, 1%.

To date, cadmium recycling has been practical only for Ni-Cd batteries, some alloys, and dust from electric arc furnaces—the latter typically containing 0.003% to 0.07% cadmium.

The United States, as in most years, was a net importer of cadmium metal in 1997. The major source of imports in 1997 was Canada, with more than one-half of imports, followed by Mexico, Germany, and Australia. Cadmium compounds and pigments are subject to import duties, but unwrought and powdered metal, as well as waste and scrap, enter duty-free in all but a few cases; cadmium, in all forms, from North American Free Trade Association (NAFTA) member states (Canada and Mexico) enters the United States duty-free. In 1997, the United States was a net exporter of cadmium sulfide, most of which was exported to Canada, followed by Colombia and Australia. Trade data for other cadmium compounds were not available.

Cadmium was refined in 31 countries in 1997. The four largest foreign producers—Belgium, Canada, China, and Japan—together accounted for 37% of world production, compared with 11% for the United States. Identified world cadmium resources at yearend 1997 were estimated by the U.S. Geological Survey at 6 million metric tons, a figure based on zinc resources containing typically about 0.3% cadmium. The world reserve base was estimated at 1 million tons and reserves at 0.5 million tons.

Legislation and Government Programs

In 1997, numerous regulatory decisions were passed by Federal and local agencies, mostly affecting individual companies. The Minnesota Legislature passed one of the most stringent laws concerning disposal of specific batteries. According to Minnesota Statutes 1997, Chapter 115A.9155, a dry cell battery containing cadmium or mercury that was purchased by a government agency, or an industrial, communications, or medical facility may not be placed in mixed municipal waste. Most of the responsibility for enabling the collection of used batteries was placed on the manufacturer. It must ensure proper collection, transportation, and processing of waste batteries; it must identify collectors and proper ways of disposal by providing in a clear and conspicuous manner a telephone number for pertinent information. In addition, the manufacturer must accept waste batteries and is allowed to include the cost of recycling in the price of the battery. A manufacturer that has complied with these requirements is no longer responsible for improper disposal, by others, of waste batteries (Minnesota Statutes, 1997, table of contents for Chapter 115A, accessed April 7, 1998, at URL http:/www.revisor.leg.state.mn.us/st97/115A).

Production

Most of the virgin cadmium currently being recovered around the world is a byproduct of zinc smelting and refining. The cadmium is associated with the zinc in concentrates of sphalerite (ZnS) and related sulfide ore minerals. It is also recovered during the beneficiation and refining of some lead ores and complex copper-zinc ores.

Only two companies produced primary cadmium in the United States in 1997: Big River Zinc Corp., Sauget, IL, and Savage Zinc Inc., Clarksville, TN. Both companies used an electrolytic process and recovered the cadmium as a byproduct during roasting and leaching of zinc concentrate. In April 1996, Korea Zinc Co. Ltd. purchased Big River Zinc and the Sauget smelting and refining operation from its owner, Dillon Read & Co., for $52.5 million. The Sauget operation can produce up to 82,000 tons of zinc and 900 tons of cadmium metal and oxide per year. About 80% of its feed is supplied by mines in Missouri and Tennessee. The remaining 20% is imported, mainly from Canada, Mexico, and Peru. Cadmium is extracted during conversion of impure zinc oxide (calcine) into pure zinc sulfate solution. In the leaching tanks, calcine reacts with sulfuric acid, producing impure zinc sulfate solution and insoluble metal residues, including cadmium, that settle on the bottom of the tank. Zinc sulfate is reagent-treated at the first-stage purification, discharging impurities in a form called copper cake, which is combined with the previously captured leach residues and sold for processing. Impure cadmium, recovered during the second-stage of purification, is purified to more than 99.9% purity, melted, and cast into 50-millimeter-diameter ball anodes or 250-millimeter-long sticks, or burned to make cadmium oxide powder.

In 1997, Savage Zinc Inc., the wholly owned subsidiary of Sydney-based Savage Resources Ltd., sold 359 tons of cadmium and 15.6 tons of germanium, produced at its Clarksville, TN, smelter and refinery. During the year, Savage spent $750,000 for rebricking of the roaster, upgrading of pipes in the acid plant, and boiler maintenance. It also conducted a feasibility study to assess an expansion from 110,000 tons to about 275,000 tons of zinc per year. The major constraint on such a sizable expansion is the availability of feed. In 1997, the total feed amounted to 150,583 tons of concentrate of which nearly 60% was sourced from

Savage's Tennessee mines. The remaining 40% was provided by ASARCO, Incorporated which operates three underground zinc mines in the Mascot-Jefferson City zinc district in east Tennessee. Additional feed could come from the planned 10% increase of output at Savage's Gordonsville Mine. Additional concentrate may ensue from the successful conclusion of an exploration effort conducted at the Columbia vein system in western Kentucky; about 80% of the holes drilled in 1997 intersected potential economic zinc grades (Savage Resources Limited, 1998).

In 1995, International Metals Reclamation Co. Inc. (INMETCO), a subsidiary of the International Nickel Co., began reclaiming cadmium from spent batteries at its Ellwood plant, 56 kilometers northwest of Pittsburgh, PA. The $5 million cadmium High Temperature Metal Recovery (HTMR) addition, built by Davy International, was the first facility of its kind in the world. In the cadmium recovery furnaces, cadmium is reduced using carbon, vaporized, and then condensed. The resulting cadmium metal, which has a purity greater than 99.95% Cd, some as high as 99.999% Cd, is usually shipped to Ni-Cd battery manufacturers for reuse in new batteries, but it also could be used in the manufacture of corrosion-resistant coatings or in paint pigments. The cadmium is cast into small flattened discs, 4 millimeters to 6 millimeters in diameter, to facilitate handling and reduce erratic rolling.

INMETCO processes between 3,500 tons and 3,600 tons of spent Ni-Cd batteries per year received from municipal authorities and industry; the batteries have an average cadmium content of about 12% to 15% by weight. In addition to Ni-Cd batteries, it also accepts nickel-metal hydride (Ni-MH) and nickel-iron (Ni-Fe) batteries, but these must be segregated from other batteries. Shipments from the battery manufacturing industry—Motorola Inc., Black & Decker Inc., etc.—tend to be relatively free of lead and other undesirable metals. However, batteries collected by municipal authorities from the general public must be hand-sorted. Only a few newer batteries are color coded and almost none carry bar codes, making optical scanning and other automated sorting very difficult. According to industry experts, the current recycling rate of between 10% and 15% will probably increase to about 50% by 2002.

The Crandon/Rhinelander zinc-copper deposit in northeastern Wisconsin is expected to be a significant source of primary cadmium. Its development depends on Nicolet Minerals Co., a wholly owned subsidiary of Rio Algom Mining Corp., acquiring some remaining permits from the Wisconsin State government. However, location of a future mine near the headwaters of the Wolf River, aroused local opposition fearing 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 million tons of ore grading 5.6% zinc, 1.1% copper, and 0.01% to 0.23% cadmium. Sphalerite from one particular stratigraphic sequence—the Skunk Lake unit—consistently has 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-million-ton-capacity mill producing between 200,000 tons and 300,000 tons of zinc concentrate and about 20,000 tons combined copper-lead concentrate per year.

Environment

Cadmium is toxic, particularly in soluble and respirable forms. Although cadmium 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. Cadmium, on the other hand, can adversely affect the renal and respiratory systems, depending upon exposure time and concentration, and is not readily extricated. Inhaled cadmium fumes or fine dust are much more readily absorbed than ingested cadmium. Repeated exposure to excessive levels of dust or fume can irreversibly injure the lungs, producing shortness of breath and emphysema. Dermal contact with cadmium results in negligible absorption. Because of its toxicity, the use of cadmium is affected by enactments by the U.S. Environmental Protection Agency (EPA) and other American and European regulatory control agencies. The International Agency for Research on Cancer lists cadmium metal and several of its compounds as carcinogens.

Because of higher density of population, European countries are especially concerned about the levels of carcinogenic elements in the environment. In September 1997, the Organisation for Economic Co-operation and Development (OECD) held a workshop on the Effective Collection and Recycling of Nickel-Cadmium Batteries in Lyon, France. This workshop, which was part of a chemical risk management program which began in 1990, focused on five chemicals: cadmium, lead, mercury, brominated flame retardants, and methylene chloride. It was also an effort to unify proposed varied environmental legislation in individual countries. For example, the Netherlands' proposed revision of the cadmium decree of the Chemical Substance Act of 1998 would ban the use of more than 100 milligrams of cadmium per kilogram of pigments and stabilizers, 2 milligrams of cadmium per kilogram of gypsum, and would impose a total ban of cadmium-containing surface coatings and of all other cadmium-containing products such as Ni-Cd batteries. The prohibition would not apply if cadmium is used for safety reasons or if there is no equivalent alternative to cadmium. Sweden's proposed chemical legislation would ban all products containing lead and cadmium by 2007—including lead-acid batteries essential to the automotive, electronics, and telecommunications industries, lead solder used in electronic circuit boards, and Ni-Cd batteries used in numerous applications. Because cadmium was included in most of the individual proposals, considerable time of the workshop was focused on Ni-Cd batteries as they constitute approximately 70% of the total cadmium market in the Western World. 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. As environmental and health problems connected with the production of Ni-Cd batteries can easily be controlled, most of the recent regulations are about disposal. There are basically only four disposal options available: composting, incineration, landfilling, and recycling. The first two options are not practical; landfilling is the option most frequently used; and recycling is the most preferred by both the industry and environmentalists. Establishing an environmentally responsible collection and recycling system for spent batteries may be better than banning them. Because cadmium is generated as a waste product, mainly of zinc production, restriction on use of cadmium in batteries will likely increase the amount of cadmium deposited in landfills.

The main and most difficult aspect of recycling is the collection of spent Ni-Cd batteries. 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. Large industrial batteries, containing 25% of the cadmium used for batteries, are easy to collect and presently are recycled at a rate of about 85%. Therefore, various organizations and government agencies are devising ways to improve the collection of small batteries. In the United States, the Portable Rechargeable Battery Association has set a goal of 70% recycling rate for small batteries by 2001. Another important aspect of recycling is the economic factor. Economies of scale are very important, and the larger a recycling operation, the lower its unit cost is likely to be. The small cells must be shredded and preheated at low temperature prior to the high temperature volatilization whereas the large industrial cells can usually be opened and disassembled. In addition to the pyrometallurgical process, where 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.

Another area of concern for the OECD is the amount of cadmium and other impurities contained in the phosphate rock used for production of fertilizers. The content of impurities depends on the phosphate rock's geologic origin and the mining and beneficiation technologies applied to upgrade it. An estimated 2,600 tons of cadmium per year is released into the ground through use of fertilizers. Excessive amounts of cadmium in phosphatic fertilizer could present ecological problems such as run-off pollution and a steady buildup of toxic amounts in the ground. There is a fear that the accumulated cadmium in the ground could be taken up by edible plants, thus entering the food chain. However, new evidence indicates that in most plants the uptake of cadmium is strongly affected by the presence of zinc in the ground. As a general rule, zinc inhibits cadmium uptake. Soil pH, clay content, and soil chloride levels also have a significant influence on uptake of cadmium. Despite the latest evidence, mainly in an effort to head off regulation, the European Fertilizer Manufacturers Association (EFMA) has voluntarily agreed to limit cadmium levels in its products to 60 milligrams of cadmium per kilogram of phosphorus pentoxide by 2005. The four most promising processes for removing cadmium from phosphoric acid are: cocrystallization of cadmium with anhydrite ($CaSO_4$), precipitation with inorganic sulfide salts, formation of complex cadmium chloride anions and subsequent removal by anion exchange, and removal by solvent extraction (Davister, 1996; Vermeul, 1996).

The OECD workshop also drafted a proposal for disposal of used cars, the so called end-of-life vehicles. Among other things, it will require that components containing lead (with the exception of lead solder in electronic circuit boards), mercury, cadmium, and hexavalent chromium in motor vehicles produced after 2003 be stripped from end-of-life vehicles before treatment. Since it is not practical to remove most of these components prior to shredding, this proposal would, in effect, ban most uses of these metals in automobiles.

Consumption

Apparent consumption of cadmium metal in the United States increased by nearly 12% in 1997. The U.S. Geological Survey (USGS) does not collect actual consumption data on either cadmium metal or cadmium compounds. However, for some time, the International Cadmium Association has been making annual estimates on end use for the Western World. Their breakdown for 1997 was as follows: batteries, 70%; pigments, 13%; coatings and plating, 8%; stabilizers for plastics and similar synthetic products, 7%; and alloys and other, 2%. All cadmium compounds are made from cadmium metal. While cadmium metal consumption for batteries has grown steadily over the past 15 years, other cadmium markets, such as pigments, stabilizers, coatings, and alloys, are regarded as mature markets—they are not expected to grow, and, in fact, have already started to decline. Consumption patterns vary significantly among countries because of differences in environmental regulations, industrial development, natural resources, and trading partnerships. Traditional uses of cadmium in easily dispersible products continued to decline in OECD countries because of increasing stringent environmental regulations, concerns of manufacturers about long-term liability, and the development of less toxic substitutes.

Cadmium compounds are still being used in the United States to stabilize polyvinyl chloride (PVC). Liquid stabilizers typically contain 1% to 8% cadmium in the form of cadmium 2-ethylhexanoate or cadmium oleate. Solid stabilizers contain 4% to 12% cadmium in the form of salts of saturated fatty acids (e.g., stearic acid and lauric acid). 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).

Cadmium metal forms stable alloys with copper, tin, and several other nonferrous metals. When aluminum, brass, copper, and steel are coated with cadmium metal, they become much more resistant to corrosion, especially in marine and alkaline environments. Few elements are superior to cadmium for coating and plating if cost and corrosion resistance are weighed equally. From 1940 until 1988, coating and plating constituted the largest use of the metal in the United States. However, already in 1965, consumption of cadmium for coatings and plating had begun to decline, because of human health and environmental concerns about the metal. By 1990, coatings and plating accounted for about 25% of total cadmium consumption in the United States. That same year, the corresponding figure for Europeans was estimated to be only 9%, and a mere 1% for Japan.

At the time when the consumption of cadmium for coatings and platings began to decline, The Cadmium Council, Inc. (now part of the International Cadmium Association) found that occupational exposures in most cadmium plating shops were below 2.5 micrograms of cadmium per cubic meter of air set by the Occupational Safety and Health Administration (OSHA). In addition to effluent cadmium, new safeguards were introduced in consequent years: plating waste water must now be treated to remove any cadmium and other heavy metals before the water can be discharged; electroplating sludges are no longer landfilled and are being shipped to EPA-approved reclamation facilities for metal recovery; and recycling of cadmium metal is encouraged and often required. These safety requirements were essential for continued use of cadmium plating in applications where the surface characteristics of the coating are critical (e.g., fasteners for aircraft, electrical connectors, parachute buckles). Cadmium coatings do not oxidize as readily as zinc coatings in marine or concentrated salt atmospheres. Cadmium coatings also have low electrical resistivity and good soldering characteristics. In 1992, the communications sector accounted for 31% of the cadmium coatings marketed in the United States, followed by fasteners (20%), aircraft (15%), and automotive (15%) (Morrow, 1996).

Cadmium pigments are more stable than other coloring agents at elevated temperatures and are not easily degraded by light. Because of their excellent coloring properties, cadmium pigments are widely used in thermoplastics, ceramics, glazes, and artists' colors. When cadmium sulfide is mixed in differing amounts with cadmium selenide and related inorganic pigments, a broad spectrum of brilliant colors with strong opacity can be generated. Organic alternatives still cannot match many of the more popular properties of cadmium pigments, especially color brightness, opacity, and processability.

A significant amount of cadmium is still being used worldwide to make colorants for plastics, despite regulatory pressures. The U.S. colorant and pigment industry has restructured almost every aspect of production in response to the new Federal and State regulations. Many producers of plastic colorants plan to phase out cadmium along with barium, chromium, and lead in order to make their products more environmentally acceptable. Among the recent actions that are encouraging this trend are: the proposed regulation by the OSHA to reduce workplace exposure to cadmium; an EPA study of municipal solid waste; proposed revision in EPA drinking-water standards; State actions; and a European Economic Community ban on cadmium-containing pigments. One of the latest noncadmium colorants is Neolor, a cerium sulfide alternative to cadmium pigments that is safe and recyclable. It was developed by the French pharmaceutical and chemical company Rhone-Poulenc and will be distributed in the United States by Ferro Corp., Cleveland, OH. One of the drawbacks of Neolor is its cost: it is three to four times the price of cadmium pigments for equal tint strength. However, for some applications there is no organic alternative on the market that can match the brilliant yellow provided by a cadmium pigment. Replacement of key cadmium pigments by organic substitutes is not straightforward, especially for molding applications that require high temperature or high pressure processing. Organic substitutes are not as stable and are more difficult to work with under these conditions.

Prices

The New York dealer price for cadmium metal in 1997 declined by nearly 60% compared with the 1996 price. 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 $0.51 per pound in 1997. Excessive exports of cadmium metal, mainly by Bulgaria and Russia, coupled with gradual replacement of Ni-Cd batteries with lithium-ion and nickel metal hydride batteries, caused prices to remain low. What little buying interest there was in the market was mainly from China and India, specifically for sticks of cadmium metal. Recovery of cadmium from spent Ni-Cd batteries, often required by local regulations, further depressed the market.

Some industry analysts attribute the volatility of cadmium prices to the fact that only about 5% of the cadmium shipped from producers is actually sold on the spot market. The remaining 95% is sold under long-term contracts which depend on price feedback from the spot market. This system amplifies the weight of published price changes associated with the limited spot sales.

Current Research and Technology

The use of vegetation to clean sites contaminated with heavy metals may now be on the brink of commercialization. At least three new companies have formed over the past few years to use this new technology, called phytoremediation. These plants are 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 concentration ofthe 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. It can accumulate significant amounts of zinc, cadmium, and, if certain chelators are added to soil, lead. Phytoextraction for only zinc and cadmium is more practical because they are usually co-occurring pollutants. Researchers are now working with plants that can accumulate up to 25,000 milligrams of zinc and 1,000 milligrams of cadmium per kilogram of dry plant matter. It has been estimated that phytoremediation would cost one-third the cost of using traditional methods of remediation (International Lead Zinc Research Organisation, 1998).

Outlook

The future of the cadmium industry is tied to the development of new recycling technologies, not only for batteries, but also for other principal end products. The first step for effective recycling is the establishment of global collection of spent small batteries, because they are 100% recyclable. This is rapidly becoming a reality. Recycling of other cadmium products will be considerably more difficult; it must be viable, resilient, economic, and—above all—be able to allay the environmental and health concerns that the general public currently has about the metal and its components. The proper disposal of discarded plastics, obsolete electronic parts, incinerator residues, and municipal sewer sludge—all of which often contain relatively 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 program is administered by the Rechargeable Battery Recycling

Corporation (RBRC), a nonprofit public service corporation. 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. More than 175 companies are currently participating in the program. The Portable Rechargeable Battery Association (PRBA) is also a sponsor and has helped to enlist the participation of county and municipal governments, hospitals, and fire departments. Spent Ni-Cd, Ni-MH, lithium-ion, and small sealed lead-acid batteries are all being collected under the program. PRBA believes that, by 2001, roughly 70% of the spent Ni-Cd batteries being generated in the United States will be recycled. The current recycling rate is about 15% for small batteries. An estimated 85% of industrial Ni-Cd batteries are recycled. If the new RBRC program grows as expected, INMETCO could be handling 10,000 tons of batteries by 2002.

As to the production aspect, the U.S. cadmium industry already has taken a number of steps to minimize occupational exposure and has upgraded its facilities so that almost all more than meet the new Federal standards adopted in 1992.

The future of the cadmium industry may be jeopardized by the news that Chrysler, one of the world's leading car manufacturers, has entered a joint-venture program with Westinghouse Electric Corp. for development of electric vehicles fueled by lead-acid battery packs. Competition from a rival consortium group, the "Big Three" and the Electric Power Research Institute, is based upon Ni-MH and lithium ion and polymer batteries. The prospect of Ni-Cd batteries ever being developed for electric vehicles now seems remote.

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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)

	1993	1994	1995	1996	1997
United States:					
Production of metal 2/	1,090	1,010	1,270	1,530	2,060 p/
Shipments of metal by producers 3/	1,320	1,290	1,280	1,310	1,370 p/
Exports of metal, alloys, and scrap	38	1,450	1,050	201	554
Imports for consumption, metal	1,420	1,110	848	843	790
Stocks of metal, Government, yearend	2,690	2,480	2,260	2,030	1,870
Apparent consumption of metal	3,010	1,040	1,160	2,250	2,510
Price, average per pound, New York dealer 4/	$0.45	$1.13	$1.84	$1.24	$0.51
World: Refinery production	18,400 r/	18,200 r/	20,000 r/	19,200 r/	18,900 e/

e/ Estimated. p/ Preliminary. r/ Revised.
1/ Data are rounded to 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%.

TABLE 2
U.S. PRODUCTION OF CADMIUM COMPOUNDS

(Metric tons, cadmium content)

Year	Cadmium sulfide 1/	Other cadmium compounds 2/
1996	119	720
1997	113	607

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)

	1996	1997
Industry stocks, Jan. 1	990 r/	1,140
Production	1,530	2,060
Imports for consumption, metal	843	790
Shipments from Government stockpile excesses	230	161
Total supply	3,590	4,150
Exports of metal, alloys, and scrap	201	554
Industry stocks, Dec. 31	1,140 r/	1,090
Consumption, apparent 2/	2,250	2,510

r/ Revised.
1/ Data are rounded to 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)

	1996		1997	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	993 r/	W	989	W
Compound manufacturers	147 r/	214	97	35
Distributors	W	(1/)	W	(1/)
Total	1,140 r/	214	1,090	35

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	1996 Quantity (kilograms)	1996 Value	1997 Quantity (kilograms)	1997 Value
Cadmium metal: 2/				
Belgium	18,100	$75,000	--	--
Brazil	500	12,400	--	--
Canada	2,920	20,800	1,600	$15,000
Chile	--	--	929	34,400
China	7,060	18,400	--	--
Finland	--	--	8,220	18,100
France	52,200	121,000	116,000	80,700
Germany	225	32,300	77	47,900
Hong Kong	--	--	16,500	45,100
India	18,000	25,400	100,000	125,000
Israel	215	34,100	14	4,790
Italy	5,620	13,600	11,200	27,300
Japan	18	10,600	249,000	690,000
Korea, Republic of	33,400	297,000	--	--
Mexico	2,070	42,600	669	18,300
Netherlands	17,900	43,000	24,300	60,600
Singapore	1,500	12,700	1,910	17,200
Sweden	1,790	126,000	--	--
Taiwan	47	19,000	766	8,700
United Kingdom	1,380	21,900	20,200	50,100
Uzbekistan	31,800	14,100	--	--
Other	6,070	88,800	2,810	11,400
Total	201,000	1,030,000	554,000	1,250,000
Cadmium sulfide: (gross weight)				
Australia	17,800	6,680	--	--
Belgium	6,330	3,290	--	--
Canada	659,000	349,000	375,000	173,000
Colombia	45,600	23,700	--	--
Italy	--	--	17,300	9,000
Korea, Republic of	10,200	5,310	--	--
Taiwan	--	--	7,110	3,700
Other	57,400	11,500	--	--
Total	797,000	399,000	399,000	186,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes exports of cadmium in alloys, dross, flue dust, residues, and scrap.

Source: Bureau of the Census.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF CADMIUM PRODUCTS, BY COUNTRY 1/

Country	1996 Quantity (kilograms)	1996 Value	1997 Quantity (kilograms)	1997 Value
Cadmium metal:				
Algeria	2,000	$8,380	--	--
Australia	48,000	93,500	76,000	$65,000
Belgium	37,600	302,000	36,300	270,000
Canada	451,000	1,260,000	436,000	965,000
China	5,220	14,800	20	2,060
Finland	3,000	9,260	--	--
France	3,540	29,600	--	--
Germany	50,700	110,000	101,000	190,000
Italy	--	--	402	7,070
Japan	492	62,600	90	614,000
Mexico	96,800	234,000	104,000	78,800
Netherlands	143,000	268,000	--	--
Norway	--	--	3,000	12,600
Peru	1,390	1,600	32,900	38,900
Russia	1	1,900	--	--
United Kingdom	15	3,430	50	6,460
Total	843,000	2,400,000	790,000	2,250,000
Cadmium sulfide: (gross weight)				
Belgium	455	1,300	--	--
Brazil	1,600	20,100	--	--
Japan	455	37,300	10,100	63,300
Russia	12	2,360	87	11,800
Switzerland	--	--	10	4,680
United Kingdom	11,100	94,900	30,000	295,000
Total	13,600	156,000	40,100	375,000

1/ Data are rounded to 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	1993	1994	1995	1996	1997 e/
Algeria	18 r/	15 r/	15 r/	15 r/ e/	15
Argentina	25 r/	21 r/	25 r/	39 r/	35
Australia	951	910	838	639 r/	632 3/
Belgium	1,573	1,556	1,710	1,580 e/	1,600
Brazil e/	200	300	300	300	300
Bulgaria	265	286	250 e/	250 e/	250
Canada	1,944	2,173	2,349	2,537	1,320 p/
China e/	1,160	1,280	1,450 r/	1,570 r/	1,600
Congo (Kinshasa) e/ 4/	12	1	--	--	--
Finland 5/	785	548	539	648	650
France	137	6	-- e/	205 r/	309 3/
Germany	1,056	1,145	1,150 e/	1,150 e/	1,140
India	255	216	254	269 r/	298 3/
Italy	517	475	308	296	300
Japan	2,832	2,629	2,652	2,343 r/	2,460
Kazakstan	800 r/	1,100 r/	1,209	1,200	1,200
Korea, North e/	100	100	100	100	100
Korea, Republic of	400 r/ e/	400 r/ e/	1,665 r/	501 r/	570 3/
Macedonia e/	(6/)	(6/)	(6/)	(6/)	(6/)
Mexico 7/	797	646	689	784 r/	800
Namibia	13	19	15	15 r/	10
Netherlands	526	387	300 e/	300 e/	300
Norway	213	288	317	274	275
Peru	472	507	560 r/	550 r/	562 3/
Poland	149	61	--	--	--
Romania	10 e/	4	5	5 e/	4
Russia	700 e/	600 r/	725 r/	730 r/	790
Serbia and Montenegro	6	3 r/	11	79 r/	80
South Africa e/ 8/	70 r/	-- r/	-- r/	-- r/	--
Spain	365 r/	387	397	307	325
Thailand	449	643	365 r/	385 r/	400
Turkey e/	31 3/	22	23	33 r/	33
Ukraine e/	7	10 3/	15	25 r/	25
United Kingdom 9/	458	469	549	541 e/	500
United States 9/	1,090	1,010	1,270	1,530	2,060
Total	18,400 r/	18,200 r/	20,000 r/	19,200 r/	18,900

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

1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.

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 13, 1998.

3/ Reported figure.

4/ Formerly Zaire.

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

6/ Less than 1/2 unit.

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

8/ Cadmium content of cadmium cake.

9/ Includes secondary.