# CADMIUM

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Compared with 2001, estimated cadmium metal production in the United States increased by about 3% in 2002. Apparent domestic consumption more than doubled due to National Defense Stockpile (NDS) sales, but actual consumption was about the same as in 2001. Sales from the NDS, operated by the U.S. Department of Defense, increased twentyfold. Cadmium prices increased for the third consecutive year (table 1).

In the United States, only two companies produced cadmium in 2002—Pasminco Ltd. produced primary cadmium as a byproduct of the smelting and refining of zinc concentrates, and International Metals Reclamation Company Inc. (INMETCO) produced secondary cadmium from scrap, almost entirely from spent nickel-cadmium (NiCd) batteries. Near the end of 2000, Big River Zinc Corp. (owned by Korea Zinc Co. Ltd.) ceased production of cadmium at its zinc smelter in Sauget, IL, in response to low cadmium prices. It was more financially efficient for the company to sell cadmium sponge than to process it. The total value of cadmium produced in the United States in 2002 was calculated to be about $477,000. Although definitive consumption data do not exist, the International Cadmium Association (ICdA) made the following estimates of cadmium consumption for various end uses in 2002: batteries, 78%; pigments, 12%; coatings and plating, 8%; stabilizers for plastics and similar synthetic products, 1.5%; and nonferrous alloys and other uses, 0.5% (Hugh Morrow, President, International Cadmium Association, oral commun., April 2003).

Worldwide cadmium market prices rose in 2002 owing to increased demand (mainly from the Chinese NiCd battery industry), decreased primary production, and decreasing stocks. The decrease in primary production was partly offset by increased secondary production, mainly from the recycled NiCd batteries.

## Legislation and Government Programs

During the past decade, regulatory pressure to reduce or even eliminate the use of cadmium, a metal that is toxic in certain forms and concentrations, has gained momentum—mainly in the European Union (EU) and some other developed countries, such as the United States. 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. Cadmium, together with other nonferrous metals, was also included in a draft list of persistent, bioaccumulative, and toxic (PBT) pollutants prepared by the U.S. Environmental Protection Agency (EPA) in 1999. The list has been significantly modified since then; many previously listed metals have been excluded. However, cadmium, lead, and mercury are still on the EPA list, known as the Waste Minimization Prioritization List.

An unusual lawsuit was filed in 2002 by the California-based American Environmental Safety Institute (AESI) against chocolate manufacturers in the United States. According to its own research, the AESI claims that "levels of cadmium and lead present in chocolate products pose a clear and present danger to children's health." The lawsuit seeks in part to force the manufacturers to include warning labels on their chocolate products in accord with provisions of California's Proposition 65, which requires warnings to be given to individuals before they are exposed to hazardous and dangerous chemicals (American Environmental Safety Institute, 2002§[1]).

Tough restrictions on the use of cadmium in Austria and Sweden are likely to be abandoned after the European Court of Justice ruled that amendments to EU legislation allowing retention of these restrictions were illegal. The ruling responded to a lawsuit filed by the Netherlands against the European Commission (EC), which had given Austria and Sweden permission to maintain their restrictions that had been in effect before they joined the EU in 1995 (Metal Bulletin, 2002a).

## Production

Worldwide production of cadmium in 2002 declined to about 15,800 metric tons (t) from 18,000 t in 2001. In some countries, the decline in the output of cadmium, a byproduct of zinc production, has been the result of reduced zinc mining and smelting; some of the cutbacks will be permanent. In other countries, some zinc producers have chosen not to process their cadmium due to low cadmium prices. One of these countries is Belgium, where one of the world's largest producers, Umicore SA (previously known as Union Miniere SA), ceased production of cadmium in 2002, taking about 1,700 metric tons per year (t/yr) out of the market. Most of the primary cadmium production in 2002 continued to originate in Asia, followed by Europe and the Americas. Appropriately, the three largest cadmium-producing countries in the world are in Asia—China, Japan, and the Republic of Korea. Most of Europe's share of about 23% of world production was supplied by Russia, followed by the Netherlands and Germany. North America supplied about 18% of world production. With production of 1,200 t, Mexico was the leading cadmium producer, followed by Canada and the United States. Australian production has declined significantly from its high levels in the early 1990s and now accounts for only 2.2%

[1]References that include a section mark (§) are found in the Internet References Cited section.

of world production. Since Namibia ceased production in 1998, there is virtually no cadmium production in Africa (table 7).

At its Clarksville, TN, zinc smelter, Pasminco is using an electrolytic process in which cadmium is recovered as a byproduct during the roasting and leaching of zinc concentrate. After removing various impurities, cadmium is processed to its final form by either refining or electrowinning. The whole process consists of heating the zinc concentrate 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 volatilized 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 a 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 and then dissolved in another sulfuric acid bath; the solution, if sufficiently pure, is passed into electrolytic cells where the cadmium is deposited on cathodes. The resulting cadmium metal (more than 99.99% pure) is melted and cast into 50-millimeter (mm)-diameter ball anodes or 250-mm-long sticks or is oxidized in a controlled atmosphere to produce 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, p. 9).

Although primary cadmium production is declining, production of secondary cadmium is increasing. The amount of cadmium that is recycled, however, is difficult to estimate for a number of reasons. For example, cadmium from baghouse dust, which is 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. The reported amount of NiCd batteries collected is fairly accurate, but there are no firm data on the amounts of cadmium recovered from recycled batteries and other sources, such as electric arc furnace (EAF) dust, electroplating wastes, filter cakes, sludges, and other cadmium-containing materials. EAF dust, which contains about 0.05% cadmium, is recovered only because it is mandated by environmental regulations.

In 1995, INMETCO (a subsidiary of International Nickel Co.) began reclaiming cadmium from spent batteries at its Ellwood City plant, northwest of Pittsburgh, PA. The $5 million high-temperature metal recovery plant addition was the first facility of its kind in the world. It is capable of processing more than 2,500 t/yr of spent NiCd batteries. Cadmium recycling at the facility thus far has been practical only for NiCd batteries, some alloys, and EAF dust.

The most difficult aspect of NiCd battery recycling has been the development of spent-battery collection programs. Like all elements, cadmium is subject to physical and chemical laws that make its processing predictable and dependable. On the other hand, efforts to change the attitudes and habits of the public about recycling have proven to be much more complicated and difficult. Although large industrial batteries (containing 20% of the cadmium used for batteries) are easy to collect and are recycled at a rate of about 80%, the small consumer NiCd batteries, are usually discarded by the public. Therefore, voluntary industry-sponsored collection programs and Government agency programs are being devised to improve the collection of these small consumer batteries because, in addition to improving the environment, economies of scale are very important—larger recycling operations lower unit costs. Several different collection programs have been developed by INMETCO to meet the varied needs of battery manufacturers and the numerous consumers, firms, organizations, and agencies that use the many diverse products that contain NiCd batteries (power tools, cordless phones, personal computers, etc.). The most successful recycling program in the United States is operated by Rechargeable Battery Recycling Corp. (RBRC). Established when INMETCO began cadmium recycling in 1995, RBRC has organized a multifaceted collection program financed with proceeds from licensing its seal of approval to individual companies involved in the manufacturing, importation, and distribution of rechargeable batteries or battery-operated products. The RBRC recycling program contains several key elements that are specified both in EPA regulations (40 CFR part 273), Federal law (Mercury-Containing and Rechargeable Battery Management Act of 1996), and in various State laws. These elements include uniform battery labeling, removability from appliances, a national network of collection systems, regulatory relief to facilitate battery collection, and widespread publicity to encourage public participation. For that purpose, RBRC has undertaken an extensive public education campaign and has established several collection sites in the United States and Canada. Another successful collection program is INMETCO's prepaid container program in which companies that generate spent batteries purchase a 14-kilogram (kg) container for collection and shipment of spent batteries. The fee for the container includes shipping by United Parcel Service of America Inc., handling, sorting, and processing. Additional collection programs, initiated by INMETCO, include mail-back envelopes, a small package program, and so-called "milk runs." Because most of the industrial NiCd batteries are not allowed to be discarded in municipal waste dumps, they are recycled through collection programs in which producers of these batteries collect and send their spent batteries to INMETCO (Money, Tomaszewski, and Bleakney, undated).

The process of cadmium recovery from industrial and consumer sealed batteries differs only in the manner of battery preparation. Processing of industrial batteries that contain up to 7% cadmium consists of draining the sodium hydroxide electrolyte, cutting the tops off the batteries, and separating the nickel and cadmium plates. Small batteries that containing up to 16% cadmium must be handsorted because only newer batteries are color coded; very few of them 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 casing has been removed in INMETCO's patented thermal oxidizer, are charged into a cadmium recovery furnace. In the furnace, carbon is added as a reductant.

The charge is heated, and the cadmium is distilled and then collected in a water bath. The final products, called Cadmet shots, are small flattened discs, 4 to 6 mm in diameter, to facilitate handling and to reduce erratic rolling, and have a purity of greater than 99.95% cadmium, some as high as 99.999% cadmium. Cadmet is drummed, weighted, assayed, and shipped to NiCd battery manufacturers for reuse in new batteries, but may also be used in the manufacture of corrosion-resistant coatings or in the manufacture of cadmium-containing stabilizers, alloys, or pigments.

In addition to the primary and secondary production, the availability of cadmium metal during the past decade was greatly affected by material available from stockpiles. The largest stocks during the past decade were held by the U.S. Defense Logistics Agency (DLA). However, after the sale of 693 t in 2002, the remaining DLA stock should be sold by the beginning of 2003. Less certain is the amount of stockpiled cadmium held by producers and traders. Because of low prices since 1996, many producers curtailed production of refined cadmium and may have stockpiled impure cadmium sponge against expectations of future improvements in price. For the same reason, many traders and investors stockpiled cadmium (purchased mainly from the DLA) owing to low production in the United States and worldwide.

## Consumption

According to the World Bureau of Metal Statistics, cadmium consumption in 2002 increased by about 5% compared with that of 2001. Growth of cadmium consumption in the 1990s was fueled by the growth in the NiCd rechargeable battery market. The 1990s were also characterized by the relocation of several manufacturing facilities from developed countries in Europe and North America to countries with fewer environmental restrictions and lower labor cost. The main beneficiary of this transfer was China, which emerged as the leading cadmium consumer in the world, followed by Japan. This increase reflected a shift of some Japanese battery production to China (two of the world's leading producers of small portable batteries, Sanyo and Matsushita/Panasonic, relocated to China); it also was due to increased domestic consumption and growing exports of cadmium and NiCd batteries by China. Together, China and Japan consumed more that one-half of the total world cadmium production.

The U.S. Geological Survey (USGS) does not collect consumption data on either cadmium metal or cadmium compounds. Apparent consumption of cadmium metal in the United States is calculated by the USGS from production, trade, and stock changes. Owing to large sales from DLA and low industry stocks, apparent consumption in 2002 more than doubled compared with that of 2001. Actual consumption, however, is more likely to be about the same as in 2001 because traders and investors purchased DLA stocks in anticipation of higher prices in 2003, which would be due to diminishing supply and increasing consumption, mainly in Asia.

Worldwide consumption of cadmium for production of rechargeable batteries, which is the dominant use of cadmium, has been growing steadily for more than 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 contract. Consumption of cadmium for these dispersible and dissipative applications probably will continue to decline because of increasingly stringent environmental regulations, concerns of manufacturers about long-term liability, and the development of less toxic substitutes. Use of organic cadmium compounds as stabilizers in polyvinyl chloride (PVC) continues to decline because the barium-cadmium stabilizers used in the past can now readily be substituted by barium-zinc, calcium-zinc, or organo-tin stabilizers. Consumption patterns of cadmium compounds varied significantly among countries because of differences in environmental regulations, industrial development, natural resources, and trading patterns. In the United States, rechargeable NiCd batteries provided the power for about three-fourths of the most common portable products, such as power tools, cordless telephones, portable household appliances, battery-powered toys, and sources of emergency and remote-area electric power. The rechargeable battery market has seen some dramatic technology shifts in recent years. The rapid development of personal communication devices is pushing the demand for more powerful, reliable, and less expensive batteries. The most common chemistry used in rechargeable batteries is nickel-based, including nickel-cadmium, which, however, is being replaced by nickel metal-hydride (NiMH). The reason for the substitution is that NiMH prices have become comparable to NiCd batteries and because of the so-called memory effect—as NiCd batteries continue to be recharged, the life span between charges becomes progressively shorter (Advanced Battery Technology, 2002).

The cadmium industry hopes that the consumption of cadmium for industrial batteries will receive a boost from manufacturers of hybrid electric vehicles and from providers of telecommunications equipment for remote areas. The preference for NiCd batteries over other types of batteries in hybrid vehicles, however, has not been indisputably established owing to environmental concerns; moreover, with the EU proposal to ban the use of cadmium batteries in electric vehicles starting at yearend 2005, the hope for greater use is quickly fading. According to the EU commission, there are already viable alternatives to cadmium on the market, and that the transition to cadmium-free vehicles should be completed by December 31, 2005 (Metal Bulletin, 2002b). Consequently, the hopes of the cadmium industry are focusing on the application of NiCd batteries as a power source for telecommunications in remote areas. The security of fragile modern telecom networks would be jeopardized without reliable power backup, especially in hot or otherwise extreme environments. Compared with traditional valve-regulated lead acid batteries, the NiCd batteries have a longer life, are more reliable, require less maintenance, have unlimited shelf life, and have the lowest life cycle cost. Replacement and new production of these batteries for telecommunications could translate into a requirement of about 2,000 t/yr of cadmium, or about 10% of current world production (Vigerstol, 1998).

Another promising application from the cadmium industry's perspective is the use of cadmium telluride solar cells to convert sunlight into electricity and the use of NiCd batteries to store that electrical energy for remote power systems. Consumption for this application could be as high as 5,000 t/yr (Hugh Morrow, President, International Cadmium Association, oral commun., May 2001).

Other uses of cadmium, in addition to its prominent use in NiCd batteries, are based on certain physical and chemical attributes of the metal. It 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 as a corrosion-resistant coating on steel, aluminum, and other nonferrous metals, especially where low friction or low electrical resistivity is needed. Cadmium metal is also added to some nonferrous alloys to improve such properties as strength, hardness, wear resistance, castability, and electrochemical behavior. All cadmium compounds are made from cadmium metal and are primarily used, in addition to batteries, in pigments, plastic stabilizers, and semiconductor applications.

## Prices

As a byproduct of the production of other metals, cadmium is not subject to the normal supply-and-demand dynamics of most metals. The inelastic supply-and-demand situation associated with byproduct commodities invariably leads to volatile pricing, and such has been the case for cadmium during the past 20 to 30 years. Until the late 1980s, cadmium was used mainly in pigments and alloys. After the NiCd 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 1990s were marked by a steady decline in cadmium prices, due to more strict regulatory controls that reduced consumption in such traditional cadmium markets as coatings, pigments, and stabilizers. The closure of Metaleurop SA's cadmium facility at its Noyelles-Godault smelter in France in the third quarter of 2002 widened the deficit in the cadmium market to 4,100 t. This deficit was the main reason behind the cadmium price increase to as high as 90 cents per pound for 4N material (99.99% purity cadmium), from 25 cents per pound at the beginning of the year (Metal-Pages, 2003§). Celebration by the cadmium producers was short-lived, however, as the price failed to pass the critical $1 per pound mark and move up above the cost of production. A larger deficit that could push the price above production cost was partially offset by increased recycling of NiCd batteries. Although a cadmium price increase stalled at yearend 2002, cadmium producers hoped that it was only the result of the quiet period in the battery production cycle that traditionally occurs between December and March; the production of NiCd batteries was expected to increase afterward.

## Environmental Issues

Although cadmium can be toxic in some of its forms, dermal contact with cadmium metal results in negligible absorption. However, prolonged exposure to high concentrations of the respirable and soluble forms of cadmium are known to have toxic health effects and adverse environmental impacts. Inhaled cadmium fumes or fine dust are much more readily absorbed than is ingested cadmium. The atmosphere contains small, usually harmless amounts of cadmium, released by some electric powerplants and smelters. In fact, most of the cadmium released into the environment results from the burning of fossil fuels and from iron and steel production (Metal Bulletin, 1999). Repeated exposure to excessive levels of dust or fumes, found usually at cadmium producing and/or consuming plants, can have irreversible effects on kidneys and lead to reduced lung capacity and emphysema. Because of these potential adverse effects, occupational exposure to cadmium in the United States is stringently regulated by the U.S. Occupational Safety and Health Administration (OSHA). The OSHA's permissible limit for cadmium exposure through inhalation is 5 micrograms per cubic meter of air breathed (Golden Artist Colors, undated§). Similarly, strict air and water emission limits on cadmium as well as land disposal restrictions on the metal are in effect in the United States and other countries. In the United States, any cadmium-containing waste that leaches more than 1 milligram per liter is considered hazardous waste. Any discharge of cadmium chemicals above a specific threshold level into navigable waters is subject to reporting requirements. The reference dose for cadmium in drinking water is 0.0005 milligram per kilogram per day, and in food it is 0.001 milligram per kilogram per day (U.S. Environmental Protection Agency, undated§).

The four main environmental and human health concerns involved with NiCd 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 NiCd 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. 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 unprocessed cadmium that is disposed in landfills by zinc producers. Therefore, an effective collection and recycling system for spent batteries would probably protect the environment more than a ban on cadmium in batteries.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendment and Reauthorization Act, requires the Agency for Toxic Substances and Disease Registry (ATSDR) and the EPA to prepare a priority list of hazardous substances that are most commonly found at facilities on the National Priorities List and which pose the most significant potential threat to human health. This CERCLA priority list is revised and published on a 2-year schedule and then becomes the basis for preparing or updating the ATSDR Toxicological Profiles for these substances. According to the ATSDR, the list is not an enumeration of the most toxic substances, but is rather a prioritization of substances based on the combination of their frequency of occurrence, toxicity, and potential for human exposure. Consequently, it is possible for substances with low toxicity but high frequency of incidents and exposure to be on the list. Presently, arsenic is listed as the number one priority substance, while cadmium is listed as seventh (Advanced Battery Technology, 2002).

Because spent batteries are one of many sources of heavy-metals emissions when incinerated or disposed of in landfills, certain European countries have adopted individual environmental standards on batteries containing cadmium, lead, and mercury. To avoid trade barriers created by disparities among countries in such restrictions, the EC in 1991 unified these individual measures into its

Directive 91/157/EEC, which is binding for all EU member countries. The latest directive, EU's Directive 2000/60/EC, recommended that the use of 32 chemicals be phased out during the next 20 years. According to the recommendation, the ban on NiCd batteries was to start in 2008 (ILZRO Environmental Update, 2001). Because of strong opposition (by other directorates of the EU, some EU member countries, countries outside the EU who contended that this directive would be a violation of World Trade Organization agreements, and the international industry), the proposed directive was revised in 2001 and in 2002. Rather than directly banning cadmium, the EC is trying to determine the most appropriate measures that would reduce risk to human health and environment posed by NiCd batteries. Potential measures include mandatory take-back systems, deposit schemes, and/or marketing and use restrictions. Selection of the best measure is to be based on the analysis of the relative benefits of a cadmium ban in comparison with other economic instruments, including a deposit system. At yearend 2002, the EC was awaiting the final results of a risk analysis, which is expected to be completed in mid-2003 and published by end of that year, at which time a new debate on risk management options will likely ensue (Hugh Morrow, President, International Cadmium Association, written commun., April 2003).

## Outlook

Until significant technological advances are made in NiMH and lithium ion batteries, NiCd batteries will remain dominant in cordless power tools and telecommunication devices. Since the 1980s, the cadmium industry has hoped that development of electric vehicles, powered with NiCd batteries, would become the major consumer of rechargeable batteries. In light of environmental concerns and a probable ban on NiCd in the EU, that hope is quickly fading. Consumption of NiCd batteries in the foreseeable future will be driven by Chinese and Indian markets, which are free of stringent environmental controls on the use of the metal in both batteries and pigments. With continued increases in consumption by Asian countries and further reduction of production due to the closing of zinc smelters in Europe, the cadmium price in 2003 may increase to more than $1 per pound, which is considered a breakeven production price. On the supply side, wide-ranging production cuts in the zinc industry and discontinued cadmium production by some of the remaining smelters will likely limit the availability of high-purity cadmium. Furthermore, stocks have been nearly depleted, particularly in Commonwealth of Independent States countries (which had previously seemed to have unlimited supply) and in the NDS, which at the end of 2002 held 80 t of cadmium. These factors point to strong markets for cadmium producers in the near future. However, despite the best efforts of industry and consumers, regulations on cadmium use are unlikely to be rolled back in years to come, constricting production and consumption of the metal.

The growing supply deficit will likely be somewhat offset by increased availability of recycled cadmium. The recent survey conducted by the RBRC highlighted the growing reliance of the United States on cordless electronic products (there is an average of five or more cordless products to a household, such as cordless and cellular phones, cordless power tools, laptop computers, electric toothbrushes, camcorders, handheld mini vacuums, and remote-controlled toys). The survey found that more than one-half of respondents would recycle their rechargeable batteries with other recyclables through curbside collection programs, at their place of business, or at the retail store when purchasing replacement batteries (Rechargeable Battery Recycling Corp., 2002§). According to an earlier survey, also conducted by the RBRC, 95% of Americans own cordless electronic products, but only about 16% recycle their power sources (American Metal Market, 1999).

## References Cited


Advanced Battery Technology, 2002, Changes in rechargeable batteries: Advanced Battery Technology, v. 38, no. 2, February, p. 14-19.
American Metal Market, 1999, Most NiCd batteries wind up in landfills, trade group claims: American Metal Market, v. 107, no. 223, November 18, p. 7.
ILZRO Environmental Update, 2001, Global organizations issue new directives on chemicals in the environment: ILZRO Environmental Update, v. 11, no. 2, February, p. 1.
Metal Bulletin, 1999, Battery scrap collection "key to prevent Cd ban": Metal Bulletin, no. 8378, May 24, p. 17.
Metal Bulletin, 2002a, Cadmium ban in Austria and Sweden is overturned: Metal Bulletin, no. 8695, August 1, p. 7.
Metal Bulletin, 2002b, EU ban on cadmium batteries in vehicles: Metal Bulletin, no. 8656, March 11, p. 14.
Money, Kenneth, Tomaszewski, Mark, and Bleakney, Russel, [undated], Pyrometallurgical battery reclamation at the International Metals Reclamation Company: Ellwood City, PA, International Metals Information Company Inc., 16 p.
U.S. Environmental Protection Agency, 1987, Cadmium emission from cadmium refining and primary zinc/zinc oxide smelting—Phase I technical report: U.S. Environmental Protection Agency, 212 p.
Vigerstol, Ole, 1998, NiCd batteries for telecommunications, in International Nickel Cadmium Conference, 8th, Prague, Czech Republic, September 21-22, 1998, Proceedings: Brussels, Belgium, International Cadmium Association, 7 p.


## Internet References Cited


American Environmental Safety Institute, 2002, American Environmental Safety Institute files public health lawsuit against chocolate manufacturers, accessed May 1, 2003, at URL http://www.aesi.ws/public_ed.htm.
Golden Artist Colors, [undated], Will cadmium always be on the palette?, accessed March 7, 2001, at URL http://www.goldenacrylics.com/cadmiums.htm.
Metal-Pages, 2003 (March 5), Cadmium price unmoved by widening deficit, accessed March 6, 2003, at URL http://www.metal-pages.com.
Rechargeable Battery Recycling Corp., 2002, 54% of consumers power their daily life with four or more cordless electronic products, accessed May 7, 2002, at URL http://www.rbrc.org.
U.S. Environmental Protection Agency, [undated], Cadmium and compounds, accessed March 7, 2001, at URL http://epa.gov/ttnuatw1/hlthef/cadmium.html.

## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

Cadmium. Ch. in Mineral Commodity Summaries, annual.
Cadmium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

### Other

American Metal Market.
Cadmium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Engineering and Mining Journal.
International Cadmium Association technical publications.
Metal Bulletin.
Mining Journal.
Platts Metals Week.

TABLE 1
SALIENT CADMIUM STATISTICS[1]

(Metric tons, cadmium content, unless otherwise specified)

| | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|
| United States: | | | | | |
| Production of metal[2] | 1,240 | 1,190 | 1,890 | 680 [e] | 700 [e] |
| Shipments of metal by producers[3] | 1,570 | 1,020 | 1,580 | 954 | 776 |
| Exports of metal, alloys, scrap | 180 | 20 | 314 | 272 | 194 |
| Imports for consumption, metal | 514 | 294 | 425 | 107 | 25 |
| Stocks of metal, Government, yearend | 1,680 | 1,130 | 807 | 773 [r] | 80 |
| Apparent consumption of metal | 2,100 | 1,850 | 2,010 | 659 [r] | 2,250 |
| Price, average per pound, New York dealer[4] | $0.28 | $0.14 | $0.16 | $0.23 | $0.29 |
| World, refinery production | 20,200 | 20,200 [r] | 20,100 | 18,000 [r] | 15,800 [e] |

[e]Estimated. [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% (Platts Metals Week).

TABLE 2
U.S. PRODUCTION OF CADMIUM COMPOUNDS

(Metric tons, cadmium content)

| Year | Cadmium sulfide[1] | Other cadmium compounds[2] |
|---|---|---|
| 2001 | 31 | -- |
| 2002 | 33 | -- |

-- Zero.

[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)

| | 2001 | 2002 |
|---|---|---|
| Industry stocks, January 1 | 1,200 | 1,090 |
| Production | 680 e | 700 e |
| Imports for consumption of metal, alloy, scrap | 107 | 25 |
| Shipments from Government stockpile excesses | 34 r | 693 |
| Total supply | 2,020 r | 2,510 |
| Exports of metal, alloys, scrap | 272 | 194 |
| Industry stocks, December 31 | 1,110 r | 63 |
| Consumption, apparent[2] | 659 r | 2,250 |

[e]Estimated. [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[1]

(Metric tons)

| | 2001 | | 2002 | |
|---|---|---|---|---|
| | Cadmium metal | Cadmium in compounds | Cadmium metal | Cadmium in compounds |
| Metal producers | 1,090 r | -- | 34 | -- |
| Compound manufacturers | 12 | 17 | 29 | 7 |
| Distributors | W | W | W | W |
| Total | 1,110 r | 17 | 63 | 7 |

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Compound manufactuers." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 5

U.S. EXPORTS OF CADMIUM PRODUCTS, BY COUNTRY[1]

| Country | 2001 Quantity (kilograms) | 2001 Value | 2002 Quantity (kilograms) | 2002 Value |
|---|---|---|---|---|
| Cadmium metal:[2] | | | | |
| Brazil | 9,110 | $1,180,000 | -- | -- |
| Canada | 19,700 | 284,000 | 32,500 | $501,000 |
| Chile | -- | -- | 1,150 | 11,700 |
| China | 88,200 | 206,000 | 60,500 | 74,600 |
| Costa Rica | -- | -- | 6,610 | 15,200 |
| Ecuador | -- | -- | 121 | 2,840 |
| Egypt | 4,540 | 5,960 | -- | -- |
| France | 26,500 | 35,300 | 21,300 | 31,600 |
| Germany | 7,600 | 258,000 | 8,330 | 354,000 |
| Hong Kong | 40,000 | 38,900 | -- | -- |
| India | -- | -- | 14,500 | 8,810 |
| Japan | 4,210 | 17,100 | -- | -- |
| Jordan | 9,550 | 16,000 | 21,900 | 19,200 |
| Mexico | 1,160 | 324,000 | 297 | 47,900 |
| New Zealand | 85 | 8,440 | -- | -- |
| Pakistan | 37,600 | 76,000 | -- | -- |
| South Africa | 5,200 | 17,700 | 1,000 | 101,000 |
| Sweden | 10 | 12,100 | 232 | 106,000 |
| Taiwan | 36 | 3,060 | -- | -- |
| United Kingdom | 18,200 | 71,700 | -- | -- |
| Total | 272,000 | 2,560,000 | 194,000 | 1,290,000 |
| Cadmium sulfide, gross weight: | | | | |
| Germany | 13,500 | 7,000 | 12,100 | 6,300 |
| Japan | -- | -- | 13,300 | 6,900 |
| Philippines | 30,800 | 16,000 | -- | -- |
| Saudi Arabia | 5,100 | 2,650 | -- | -- |
| Singapore | 3,000 | 6,000 | -- | -- |
| Total | 52,400 | 31,700 | 25,400 | 13,200 |

-- 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: U.S. Census Bureau.

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

| Country | 2001 Quantity (kilograms) | 2001 Value | 2002 Quantity (kilograms) | 2002 Value |
|---|---|---|---|---|
| Cadmium metal: | | | | |
| Australia | 58,900 | $40,100 | -- | -- |
| Belgium | 15,700 | 126,000 | -- | -- |
| Canada | 13,200 | 1,630,000 | 8,260 | $947,000 |
| China | -- | -- | 34 | 16,200 |
| Germany | 2 | 2,490 | -- | -- |
| Hong Kong | 32 | 4,300 | -- | -- |
| Mexico | 16,400 | 13,600 | 16,400 | 8,820 |
| United Kingdom | 3,200 | 17,600 | 22 | 6,360 |
| Total | 107,000 | 1,830,000 | 24,700 | 978,000 |
| Cadmium sulfide, gross weight: | | | | |
| China | -- | -- | 20 | 9,280 |
| Japan | 5,160 | 24,000 | -- | -- |
| Russia | 106 | 11,600 | -- | -- |
| United Kingdom | 2,280 | 26,600 | 6,690 | 78,500 |
| Total | 7,550 | 62,200 | 6,710 | 87,700 |

-- Zero.

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

Source: U.S. Census Bureau.

TABLE 7

CADMIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

| Country | 1998 | 1999 | 2000 | 2001 | 2002e |
|---|---|---|---|---|---|
| Algeria[e] | 70 | 10 r | 10 r | 10 r | 10 |
| Argentina | 34 | -- | -- | 34 r | -- p |
| Australia | 585 | 462 | 552 r | 378 | 350 |
| Belgium | 1,318 | 1,235 | 1,148 | 1,236 | 117 [3] |
| Brazil[e] | 300 | 300 | 300 | 300 | 300 |
| Bulgaria[e] | 250 | 150 | 150 | 150 | 150 |
| Canada | 2,090 | 1,911 | 2,024 | 1,429 | 896 p |
| China[e] | 2,130 | 2,150 | 2,370 | 2,510 r | 2,500 |
| Finland[4] | 520 | 700 e | 683 r | 604 r | -- |
| France | 177 | 195 | 160 | 176 | 175 [3] |
| Germany | 1,020 | 1,145 | 1,130 | 540 r | 422 [3] |
| India | 304 | 269 | 314 | 436 | 450 |
| Italy | 328 | 360 | 284 | 312 | 300 |
| Japan | 2,337 | 2,567 | 2,472 | 2,486 | 2,500 |
| Kazakhstan | 1,622 | 1,246 | 257 | 170 | 600 |
| Korea, North[e] | 100 | 100 | 100 | 100 r | 100 |
| Korea, Republic of | 1,178 | 1,791 | 1,911 | 1,879 r | 1,900 |
| Macedonia[e] | (5) | (5) | (5) | (5) | (5) |
| Mexico[6] | 1,218 | 1,275 | 1,268 | 1,241 r | 1,200 |
| Netherlands | 739 | 731 | 628 | 455 | 485 [3] |
| Norway | 270 e | 211 | 298 | 372 r | 209 [3] |
| Peru | 535 | 466 r | 483 r | 456 r | 422 [3] |
| Poland, metal, primary refined | -- | -- | 6 r | 330 r | 330 |
| Russia[e] | 800 | 900 | 925 [3] | 950 | 950 |
| Serbia and Montenegro | 17 | -- | -- | -- e | -- |
| Spain | 196 | -- | -- e | -- e | -- |
| Thailand | 238 | 238 | 238 | 240 e | 240 |
| Turkey | 69 | 64 | -- | -- e | -- |
| Ukraine[e] | 25 | 25 | 25 | 25 | 25 |
| United Kingdom[7] | 440 e | 547 | 503 | 485 | 450 |
| United States[7] | 1,240 | 1,190 | 1,890 | 680 e | 700 |
| Total | 20,200 | 20,200 r | 20,100 | 18,000 r | 15,800 |

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]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, United Kingdom) and from Metal Statistics (published jointly by Metallgesellschaft AG of Frankfurt am Maine, 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, 2003.

[2]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[3]Reported figure.

[4]Excludes secondary production from recycled nickel-cadmium batteries.

[5]Less than 1/2 unit.

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

[7]Includes secondary.