

4. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

4.1 PRODUCTION

Cadmium is a widely but sparsely distributed element found in the earth's crust at concentrations ranging from 0.1 to 1 ppm, primarily in association with zinc ores (Elinder 1985a; IARC 1993). Approximately 3 kilograms of cadmium for each ton of zinc are produced (OECD 1994). As a by-product of zinc processing, cadmium production has closely followed the demand for zinc. Between 1993 and 1997, the annual cadmium production in the United States rose from 1,090 to 2,060 metric tons (USGS 1999). A strong demand for cadmium worldwide, particularly in the nickel-cadmium battery industry, contributed to increases in domestic cadmium production in the 1980s followed by lower production levels in the early 1990s (Llewellyn 1988; OECD 1994).

Two companies were listed as producing all of the primary cadmium in the United States during 1997: Big River Zinc Corporation (Korea Zinc Co., Ltd), Saugett, Illinois; and Savage Zinc Inc., Clarksville, Tennessee (Llewellyn 1988; USGS 1997). Approximately 20% of the ores processed in Illinois are imported; the Savage Zinc operation processes Tennessee and Kentucky ores. A third company in Pennsylvania, International Metals Reclamation Co. Inc., recovers cadmium from spent nickel-cadmium batteries (Ni-Cd) (USGS 1997); this company began reclaiming cadmium in 1995 and processes about 3,500 tons of spent Ni-Cd batteries annually. It is projected that 50% of Ni-Cd batteries will be recycled by 2002 (USGS 1997).

The following companies are currently cited as major producers of other cadmium compounds: Big River Zinc Corporation, Saugett, Illinois (cadmium oxide); Shepherd Chemical Company, Cincinnati, Ohio (cadmium carbonate); Engelhard Corporation, Cleveland, Ohio (cadmium chloride, cadmium sulfate, and cadmium sulfide/sulfoselenide pigments); and Eagle-Picher Industries, Inc., Milwaukee, Wisconsin (cadmium sulfide-orange cadmium) (SRI 1994). Companies specifically cited as major producers of cadmium sulfide/sulfoselenide pigments include Morton International, Inc., Danvers, Massachusetts; Cerac Incorporated, Milwaukee, Wisconsin; SCM Chemicals, Inc., Baltimore, Maryland; and Warner-Jenkinson Cosmetic Colors, South Plainfield, New Jersey (SRI 1994).

4. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

Table 4-1 lists the facilities in each state that manufacture or process cadmium, the intended use, and the range of maximum amounts of cadmium that are stored on site. The data listed in Table 4-1 are derived from the Toxics Release Inventory (TRI) (TRI961998). Because only certain types of facilities were required to report, this is not an exhaustive list.

Cadmium metal is available in purities ranging from 99.9 to 99.9999% in the following grades: technical, powder, pure sticks, ingots, slabs, high-purity crystals (<10 ppm impurities), and a form called mossy that is used in electroplating (NTP 1991). Cadmium (as cadmium oxide) is obtained mainly as a byproduct during the processing of zinc-bearing ores (e.g., sphalerites), and also from the refining of lead and copper from sulfide ores (e.g., galena and malachite) (HSDB 1990; IARC 1993; Muntau and Baudo 1992; U.S. Bureau of Mines 1990). Cadmium oxide produced during roasting of ores is reduced with coke, and cadmium metal is separated by distillation or electrodeposition (Elinder 1985a). Commercial-grade cadmium oxide is available in the United States with a purity of 99.7%; common impurities are lead and thallium (NTP 1991). Cadmium chloride is produced by reacting molten cadmium with chlorine gas at 600 °C or by dissolving cadmium metal or the oxide, carbonate, sulfide, or hydroxide in hydrochloric acid and subsequently vaporizing the solution to produce a hydrated crystal (HSDB 1994; IARC 1993). In preparing the anhydrous cadmium chloride salt, the hydrate is refluxed with thionyl chloride or calcined in a hydrogen chloride atmosphere (HSDB 1994; IARC 1993). The commercial grade available in the United States typically contains about 51% cadmium and 0.005% each of iron and copper; high purity grades (99.9%) are also available (NTP 1991).

The commercial preparation of cadmium sulfate usually involves dissolution of the metal oxide, carbonate, or sulfide in sulfuric acid with subsequent cooling or evaporation (HSDB 1994). Anhydrous cadmium sulfate is prepared by oxidation of the sulfide or sulfite at elevated temperatures; by the action of dimethyl sulfate on finely powdered cadmium nitrate, halides, oxide, or carbonate; or by melting cadmium with ammonium or sodium peroxodisulfate (IARC 1993). Cadmium sulfate monohydrate, which is the cadmium compound most often marketed, is produced by evaporating a cadmium sulfate solution above 41.5 °C (IARC 1993). Cadmium sulfate is available in technical and C.P. (chemically pure) grades (NTP 1991). Cadmium sulfide can be prepared by reacting hydrogen sulfide with cadmium vapor at 800 °C, or by heating a mixture of cadmium or cadmium oxide with sulfur (IARC 1993). Cadmium sulfide is available in technical, N.D., high-purity (single crystals), and commercial grades (NTP 1991). Cadmium carbonate is produced by absorption of carbon dioxide in a cadmium hydroxide solution (HSDB 1994).

Table 4-1. Facilities That Manufacture or Process Cadmium

FACILITY	LOCATION ^a	RANGE OF MAXIMUM AMOUNTS ON SITE	
		IN POUNDS	ACTIVITIES AND USES
BIRMINGHAM STEEL CORP.	BIRMINGHAM , AL	100 - 999	ARTICLE COMPONENT
HALL CHEMICAL CO.	ARAB , AL	10,000 - 99,999	PRODUCE , IMPORT , SALE/DISTRIBUTION , REACTANT
MONSANTO CO.	DECATUR , AL	10,000 - 99,999	CHEMICAL PROCESSING AID,PRODUCE , BYPRODUCT
SANDERS LEAD CO. INC.	TROY , AL	10,000 - 99,999	PRODUCE , BYPRODUCT , IMPURITY
TUSCALOOSA STEEL CORP.	TUSCALOOSA , AL	1,000 - 9,999	ARTICLE COMPONENT
GNB TECHS. INC.	FORT SMITH , AR	1,000 - 9,999	ARTICLE COMPONENT
NUCOR-YAMATO STEEL CO.	BLYTHEVILLE , AR	0 - 99	PRODUCE , BYPRODUCT
ASARCO INC.	HAYDEN , AZ	50,000,000 - 99,999,999	PRODUCE , IMPORT , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , BYPRODUCT IMPURITY , REACTANT
BHP COPPER METALS CO.	SAN MANUEL , AZ	1,000 - 9,999	PRODUCE , BYPRODUCT , IMPURITY
CYPRUS MIAMI MINING CORP.	CLAYPOOL , AZ	100 - 999	PRODUCE , IMPURITY
ALERT PLATING CO.	SUN VALLEY , CA	1,000 - 9,999	ARTICLE COMPONENT
BURBANK PLATING SERVICES CORP.	PACOIMA , CA	100 - 999	PRODUCE , ON-SITE USE/PROCESSING , ARTICLE COMPONENT , MANUFACTURING AID , ANCILLARY/OTHER USE
EME INC.	COMPTON , CA	100 - 999	CHEMICAL PROCESSING AID
EAGLE-PICHER IND. INC.	COLORADO SPRINGS , CO	10,000 - 99,999	REACTANT
ANSONIA COPPER & BRASS INC.	ANSONIA , CT	10,000 - 99,999	ARTICLE COMPONENT
FLOW POLYMERS INC.	STRATFORD , CT	10,000 - 99,999	IMPORT , ON-SITE USE/PROCESSING , FORMULATION COMPONENT , REPACKAGING
HANDY & HARMAN	FAIRFIELD , CT	10,000 - 99,999	ARTICLE COMPONENT
SYNTHETIC PRODS. CO.	STRATFORD , CT	100,000 - 999,999	PRODUCE , ON-SITE USE/PROCESSING , REACTANT , FORMULATION COMPONENT
EVEREADY BATTERY CO. INC.	ALACHUA , FL	100,000 - 999,999	PRODUCE , ON-SITE USE/PROCESSING , REACTANT , ARTICLE COMPONENT
JEFFERSON SMURFIT CORP.	JACKSONVILLE , FL	10,000 - 99,999	ANCILLARY/OTHER USE
ARMSTRONG GLASS CO. INC.	ATLANTA , GA	100 - 999	FORMULATION COMPONENT
SAFT AMERICA INC.	VALDOSTA , GA	100,000 - 999,999	PRODUCE , ON-SITE USE/PROCESSING , REACTANT , ARTICLE COMPONENT
TECHNICAL COATINGS CORP.	ALPHARETTA , GA	0 - 99	FORMULATION COMPONENT
BLOOMFIELD FNDY. INC.	BLOOMFIELD , IA	0 - 99	PRODUCE , IMPURITY
FMC CORP.	POCATELLO , ID	1,000,000 - 9,999,999	PRODUCE , BYPRODUCT
API IND. INC.	ELK GROVE VILLAGE , IL	10,000 - 99,999	PRODUCE , ON-SITE USE/PROCESSING , BYPRODUCT , ARTICLE COMPONENT , CHEMICAL PROCESSING AID
BIG RIVER ZINC CORP.	SAUGET , IL	100,000 - 999,999	PRODUCE , SALE/DISTRIBUTION , BYPRODUCT
CALUMET STEEL CO.	CHICAGO HEIGHTS , IL	10,000 - 99,999	FORMULATION COMPONENT
CHEMETCO INC.	HARTFORD , IL	100,000 - 999,999	PRODUCE , IMPORT , IMPURITY
GNB TECHS. INC.	KANKAKEE , IL	10,000 - 99,999	ARTICLE COMPONENT
THREE J'S IND. INC.	ELK GROVE VILLAGE , IL	1,000 - 9,999	PRODUCE , ON-SITE USE/PROCESSING , BYPRODUCT , CHEMICAL PROCESSING AID
GE PLASTICS CO.	MOUNT VERNON , IN	10,000 - 99,999	FORMULATION COMPONENT , ANCILLARY/OTHER USE
JUPITER ALUMINUM CORP.	HAMMOND , IN	1,000 - 9,999	ARTICLE COMPONENT
UNITED TECHS. AUTOMOTIVE INC.	EDINBURGH , IN	10,000 - 99,999	ARTICLE COMPONENT
ESSEX GROUP INC.	HOISINGTON , KS	10,000 - 99,999	ARTICLE COMPONENT
CONDEA VISTA CO.	JEFFERSONTOWN , KY	100,000 - 999,999	FORMULATION COMPONENT
ENGELHARD CORP.	LOUISVILLE , KY	10,000 - 99,999	PRODUCE , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , REACTANT
NEWPORT STEEL CORP.	WILDER , KY	10,000 - 99,999	ARTICLE COMPONENT
LIBBEY GLASS INC.	SHREVEPORT , LA	10,000 - 99,999	ARTICLE COMPONENT
NAN YA PLASTICS CORP. AMERICA	BATCHELOR , LA	100,000 - 999,999	FORMULATION COMPONENT
ATTLEBORO REFINING CO. INC.	ATTLEBORO , MA	0 - 99	ANCILLARY/OTHER USE

Table 4-1. Facilities That Manufacture or Process Cadmium (continued)

FACILITY	LOCATION ^a	RANGE OF MAXIMUM AMOUNTS ON SITE	
		IN POUNDS	ACTIVITIES AND USES
CHEMET CORP.	ATTLEBORO , MA	1,000 - 9,999	ARTICLE COMPONENT
SCM GLIDCO ORGANICS CORP.	BALTIMORE , MD	100,000 - 999,999	PRODUCE , IMPORT , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , REACTANT
AJAX METAL PROCESSING INC.	DETROIT , MI	1,000 - 9,999	CHEMICAL PROCESSING AID
DIECAST CORP.	JACKSON , MI	10,000 - 99,999	ARTICLE COMPONENT
ELM PLATING CO.	JACKSON , MI	0 - 99	ARTICLE COMPONENT
ROUGE STEEL CO.	DEARBORN , MI	1,000 - 9,999	FORMULATION COMPONENT
ASARCO INC.	ANNAPOLIS , MO	1,000 - 9,999	PRODUCE , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , BYPRODUCT , REACTANT
DOE RUN CO.	HERCULANEUM , MO	100,000 - 999,999	PRODUCE , IMPURITY
M. A. HANNA COLOR	SAINT PETERS , MO	1,000 - 9,999	FORMULATION COMPONENT
IPC CORINTH DIV. INC.	CORINTH , MS	1,000 - 9,999	ARTICLE COMPONENT
NORTH AMERICAN PLASTICS INC.	PRAIRIE , MS	100 - 999	FORMULATION COMPONENT
ASARCO INC.	EAST HELENA , MT	1,000,000 - 9,999,999	PRODUCE , IMPORT , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , BYPRODUCT IMPURITY , REACTANT
KOBE COPPER PRODS. INC.	PINE HALL , NC	1,000,000 - 9,999,999	REPACKAGING , ANCILLARY/OTHER USE
AMERICAN MICROTRACE CORP.	FAIRBURY , NE	10,000 - 99,999	PRODUCE , BYPRODUCT
LUCENT TECHS. INC.	OMAHA , NE	10,000 - 99,999	ARTICLE COMPONENT
YANKEE HILL BRICK MFG. CO.	LINCOLN , NE	1,000 - 9,999	IMPORT , BYPRODUCT
AKCROS CHEMICALS AMERICA	NEW BRUNSWICK , NJ	10,000 - 99,999	PRODUCE , IMPORT , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , REACTANT FORMULATION COMPONENT
DEGUSSA CORP.	SOUTH PLAINFIELD , NJ	1,000 - 9,999	SALE/DISTRIBUTION , FORMULATION COMPONENT , ARTICLE COMPONENT
DURAND GLASS MFG. CO.	MILLVILLE , NJ	100 - 999	IMPORT , ON-SITE USE/PROCESSING , ARTICLE COMPONENT
GENTEK BUILDING PRODS.	WOODBIDGE , NJ	100 - 999	ARTICLE COMPONENT
M.C. CANFIELD INC.	UNION , NJ	100 - 999	FORMULATION COMPONENT
METAL IND. CORP.	RIVERSIDE , NJ	100 - 999	PRODUCE , SALE/DISTRIBUTION , FORMULATION COMPONENT , REPACKAGING
CHINO MINES CO.	HURLEY , NM	100,000 - 999,999	PRODUCE , BYPRODUCT , IMPURITY
AMPHENOL CORP.	SIDNEY , NY	1,000 - 9,999	ARTICLE COMPONENT
BELMONT METALS INC.	BROOKLYN , NY	10,000 - 99,999	ARTICLE COMPONENT
H. M. QUACKENBUSH INC.	HERKIMER , NY	1,000 - 9,999	ARTICLE COMPONENT
NEY SMELTING & REFINING CO.	BROOKLYN , NY	1,000 - 9,999	FORMULATION COMPONENT , ARTICLE COMPONENT , REPACKAGING
THOMAS & BETTS	HORSEHEADS , NY	1,000 - 9,999	ARTICLE COMPONENT
AK STEEL CORP.	MIDDLETOWN , OH	1,000 - 9,999	ANCILLARY/OTHER USE
BARKER PRODS.	CLEVELAND , OH	1,000 - 9,999	IMPORT , REACTANT
DOVER CHEMICAL CORP.	DOVER , OH	10,000 - 99,999	IMPORT , ON-SITE USE/PROCESSING , FORMULATION COMPONENT
ERIEVIEW METAL TREATING CO.	CLEVELAND , OH	1,000 - 9,999	ARTICLE COMPONENT
FERRO CORP.	CLEVELAND , OH	100,000 - 999,999	PRODUCE , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , REACTANT , FORMULATION COMPONENT
FERRO CORP.	WALTON HILLS , OH	100,000 - 999,999	PRODUCE , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , REACTANT , FORMULATION COMPONENT
GENERAL COLOR & CHEMICAL CO.	MINERVA , OH	10,000 - 99,999	FORMULATION COMPONENT , REPACKAGING
HOHMAN PLATING & MFG. INC.	DAYTON , OH	10,000 - 99,999	ARTICLE COMPONENT
LIBBEY GLASS INC.	TOLEDO , OH	100,000 - 999,999	ARTICLE COMPONENT
N & W METAL FINISHING INC.	CLEVELAND , OH	1,000 - 9,999	ARTICLE COMPONENT
NORTH STAR STEEL	YOUNGSTOWN , OH	10,000 - 99,999	PRODUCE , BYPRODUCT , REPACKAGING

Table 4-1. Facilities That Manufacture or Process Cadmium (continued)

FACILITY	LOCATION ^a	RANGE OF MAXIMUM AMOUNTS ON SITE	
		IN POUNDS	ACTIVITIES AND USES
RIVER RECYCLING IND. INC.	CLEVELAND , OH	10,000 - 99,999	ARTICLE COMPONENT , REPACKAGING
BARTLETT-COLLINS GLASS CO.	SAPULPA , OK	10,000 - 99,999	ARTICLE COMPONENT
SHEFFIELD STEEL CORP.	SAND SPRINGS , OK	1,000 - 9,999	ARTICLE COMPONENT
SINCLAIR OIL CORP.	TULSA , OK	0 - 99	PRODUCE , BYPRODUCT
YAFFE IRON & METAL CO. INC.	MUSKOGEE , OK	10,000 - 99,999	ARTICLE COMPONENT
ZINC CORP. OF AMERICA	BARTLESVILLE , OK	1,000,000 - 9,999,999	PRODUCE , SALE/DISTRIBUTION , BYPRODUCT , REACTANT
CERDEC CORP.	WASHINGTON , PA	100,000 - 999,999	PRODUCE , IMPORT , ON-SITE USE/PROCESSING , SALE/DISTRIBUTION , FORMULATION COMPONENT ARTICLE COMPONENT , REPACKAGING
FERRO CORP.	PITTSBURGH , PA	10,000 - 99,999	REACTANT , FORMULATION COMPONENT
FRANKLIN SMELTING & REFINING GE CO.	PHILADELPHIA , PA	10,000 - 99,999	PRODUCE , BYPRODUCT
GENCORP INC.	BRIDGEVILLE , PA	10,000 - 99,999	ARTICLE COMPONENT
GENERAL BATTERY CORP.	JEANNETTE , PA	10,000 - 99,999	IMPORT , ON-SITE USE/PROCESSING , IMPURITY , FORMULATION COMPONENT
	READING , PA	100 - 999	PRODUCE , IMPORT , ON-SITE USE/PROCESSING , BYPRODUCT , FORMULATION COMPONENT
HPG INTL. INC.	MOUNTAIN TOP , PA	10,000 - 99,999	ARTICLE COMPONENT
INTERNATIONAL METALS	ELLWOOD CITY , PA	100,000 - 999,999	PRODUCE , SALE/DISTRIBUTION , BYPRODUCT , REACTANT
JOHNSTOWN CORP.	JOHNSTOWN , PA	0 - 99	ARTICLE COMPONENT
SPARTECH VY-CAL PLASTICS	CONSHOHOCKEN , PA	1,000 - 9,999	FORMULATION COMPONENT
WORLD RESOURCES CO.	POTTSVILLE , PA	1,000 - 9,999	IMPORT , ON-SITE USE/PROCESSING , FORMULATION COMPONENT , ARTICLE COMPONENT
ZINC CORP. OF AMERICA	MONACA , PA	100,000 - 999,999	PRODUCE , SALE/DISTRIBUTION , BYPRODUCT , IMPURITY
CUTLER-HAMMER DE PUERTO RICO	ARECIBO , PR	100 - 999	ARTICLE COMPONENT
COOLEY INC.	PAWTUCKET , RI	100 - 999	FORMULATION COMPONENT
ENGELHARD CORP.	WARWICK , RI	10,000 - 99,999	FORMULATION COMPONENT
NUCOR STEEL	DARLINGTON , SC	10,000 - 99,999	REACTANT
PIRELLI CABLE CORP.	ABBEVILLE , SC	1,000 - 9,999	ARTICLE COMPONENT
ALLIED-SIGNAL INC.	SPARTA , TN	10,000 - 99,999	FORMULATION COMPONENT , ARTICLE COMPONENT
AMERISTEEL CORP.	JACKSON , TN	100 - 999	PRODUCE , BYPRODUCT , REACTANT , ARTICLE COMPONENT
ASARCO INC.	EL PASO , TX	100,000 - 999,999	PRODUCE , IMPURITY
MARATHON POWER TECHS. CO.	WACO , TX	10,000 - 99,999	IMPORT , ON-SITE USE/PROCESSING , ARTICLE COMPONENT
NUCOR STEEL	JEWETT , TX	1,000 - 9,999	ANCILLARY/OTHER USE
SOUTHWEST CHEMICAL SERVICES	SEABROOK , TX	1,000 - 9,999	FORMULATION COMPONENT
SOUTHWESTERN PLATING CO. INC.	HOUSTON , TX	1,000 - 9,999	ARTICLE COMPONENT
TANDY WIRE & CABLE	FORT WORTH , TX	1,000 - 9,999	ARTICLE COMPONENT
GENEVA STEEL	VINEYARD , UT	10,000 - 99,999	FORMULATION COMPONENT
KENNECOTT UTAH COPPER	MAGNA , UT	10,000 - 99,999	PRODUCE , BYPRODUCT
NUCOR STEEL	PLYMOUTH , UT	1,000 - 9,999	PRODUCE , IMPURITY
DU PONT FRONT ROYAL PLANT	FRONT ROYAL , VA	10,000 - 99,999	FORMULATION COMPONENT
FEDERAL-MOGUL CORP.	BLACKSBURG , VA	1,000 - 9,999	ARTICLE COMPONENT
BOC GASES	VANCOUVER , WA	0 - 99	PRODUCE , IMPURITY
MASTER LOCK CO.	MILWAUKEE , WI	1,000 - 9,999	FORMULATION COMPONENT , ARTICLE COMPONENT

Source: TRI96 1998

^a Post Office state abbreviations used

4.2 IMPORT/EXPORT

Imports of cadmium into the United States declined steadily from 1994 through 1998, dropping from 1,110 metric tons per year to an estimated 650 metric tons in 1998 (USGS 1999). In 1986, imports of cadmium metal for consumption increased significantly to 3,000 metric tons, but continually decreased into the 1990s. The principal supplying countries were Canada, Mexico, Belgium, and Australia (USGS 1999).

Export volumes of cadmium (reported as cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap) varied widely from year to year during the 1980s ranging from 10 tons in 1982 to about 450 metric tons in 1988 (ABMS 1994; Llewellyn 1988; NTP 1989, 1991; U.S. Bureau of Mines 1990). In the mid 1990s, exports also varied widely from 38 metric tons in 1993, to 1,450 metric tons in 1994, to 550 metric tons in 1997.

4.3 USE

Cadmium, its alloys, and its compounds are used in a variety of consumer and industrial materials. The use of cadmium compounds falls into five categories: active electrode materials in nickel-cadmium batteries (70% of total cadmium use); pigments used mainly in plastics, ceramics, and glasses (12%); stabilizers for polyvinyl chloride (PVC) against heat and light (17%); engineering coatings on steel and some nonferrous metals (8%); and components of various specialized alloys (2%) (Elinder 1992; IARC 1993; Thornton 1992; USGS 1997). Cadmium carbonate and cadmium chloride were used as fungicides for golf courses and lawns, but were banned by EPA in the late 1980s (Farm Chemicals Handbook 1997). The significance of cadmium chloride as a commercial product is declining; however, it is used in the preparation of cadmium sulfide, in the manufacture of special mirrors, and in dyeing and calico printing (IARC 1993). Cadmium-based colorants are used mainly in engineering plastics, ceramics, glasses and enamels. Cadmium sulfide and cadmium telluride are primarily used in solar cells and a variety of electronic devices which depend on cadmium's semiconducting properties (IARC 1993; OECD 1994) The photoconductive and electroluminescent properties of cadmium sulfide have been applied in manufacturing a variety of consumer goods (IARC 1993).

Though cadmium metal consumption for batteries has grown steadily since the 1980s other uses of cadmium began declining in the mid 1990s. Pigment, stabilizer, coating, and alloy markets have peaked in

cadmium consumption (USGS 1997). Excessive exports from Bulgaria and Russia in 1997 caused a drop in the average price of cadmium from \$1.84 per pound in 1995 to \$0.51 per pound in 1997. Also, Ni-Cd batteries have been replaced in some markets by lithium-ion and nickel metal hydride batteries (USGS 1997). Regulations by local authorities have forced the recycling of cadmium in Ni-Cd batteries, further depressing the demand for primary cadmium metal (USGS 1999).

4.4 DISPOSAL

Cadmium-containing wastes are subject to regulations concerning their treatment, storage, and disposal (see Chapter 7) (EPA 1982a; HSDB 1994; U.S. Bureau of Mines 1990). Incineration of municipal wastes, particularly from older, poorly controlled facilities, is a potential environmental source of cadmium. In modern incineration plants, about 99.9% of cadmium was captured in boilers and control equipment (OECD 1994).

A range of physicochemical processes is available for treatment of cadmium in liquid waste process streams, including ion exchange, electrolysis, cementation, and adsorption. Both ion exchange and sulfide precipitation are used as alternate processes aimed at achieving low cadmium residuals in liquid wastes (UN 1985). Combining processes, for example, conducting the primary precipitation of cadmium as hydroxide followed by secondary precipitation of residual cadmium as sulfide, has also been adopted. The more general application of the sulfide precipitation technique, however, is constrained due to a tendency for formation of colloidal precipitate, the toxicity and odor of hydrogen sulfide, and the necessity to oxidize residual sulfide occurring in emissions prior to discharge (UN 1985).

The most widely used treatment process involves the alkaline precipitation of cadmium as hydroxide or basic salts (UN 1985). Removal of specific metal species during hydroxide precipitation is pH-dependent, and some components of the waste stream can influence the solubility of cadmium hydroxide. After filtration, the sludge formed from the conversion of soluble cadmium compounds to insoluble compounds can be deposited in a suitable landfill (UN 1985).

Various cadmium-bearing wastes are subject to aggressive leaching in refuse media, particularly under aerobic conditions (UN 1985). While liquid wastes are banned from land disposal, the leaching tendency is accentuated in the presence of brine solutions. Also, the mobility of cadmium in landfill conditions could be enhanced in the presence of mineral acids, which tend to solubilize cadmium compounds, or amine-

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containing materials, which tend to complex cadmium ions. Waste containing mineral acids, cyanides, organic solvents, and amine-type substances should not be landfilled near cadmium-bearing wastes (UN 1985). According to the data compiled in the TRI (TRI961998), in 1996, about 3,100 pounds of cadmium were sent to publicly owned treatment works (POTWs). The data regarding manufacturing and processing facilities which reported releases to the environment indicate that 1,000 metric tons of cadmium-bearing wastes were transferred off-site, presumably for disposal or recovery (TRI961998). Releases to other environmental media are discussed in Chapter 5.

As an alternative to land disposal, scrap metals and batteries containing cadmium may be recycled (HSDB 1994; UN 1985). In the laboratory, a recommended method for recovering cadmium from small quantities of cadmium oxide wastes uses a minimum amount of concentrated nitric acid to form nitrates. The solution is evaporated in a hood to form a thin paste, then diluted with water and saturated with hydrogen sulfide. After the filtration, the precipitate is washed, dried, and returned to the supplier (UN 1985). No information was located regarding the quantity of cadmium currently being recycled in the United States.