CADMIUM AND CADMIUM COMPOUNDS

Cadmium was identified as a toxic air contaminant under California's air toxics program (AB 1807) in 1986.

Cadmium compounds are federal hazardous air pollutants and were identified as toxic air contaminants in April 1993 under AB 2728.

CAS Registry Number: 7440-43-9 Cd

Molecular Formula: Cd

Cadmium is a malleable, silver-white, odorless metal. It is produced as a byproduct of zinc, lead or copper ore smelting, especially zinc (Sittig, 1991). Cadmium is insoluble in water. It is soluble in acid ammonium nitrate, but not in sulfuric acid (Merck, 1989; HSDB, 1995). Cadmium compounds range in solubility in water from quite soluble to practically insoluble (ATSDR, 1992). In its elemental form, cadmium is resistant to corrosion by alkalies and salt water, and retains its metallic luster in air. The most common oxidation state of cadmium is +2, although a few cadmium compounds occur in the +1 oxidation state (ARB, 1986c). See Table 1 for information about the physical properties of cadmium compounds.

Physical Properties of Cadmium

Synonyms: colloidal cadmium

Molecular Weight:	112.41
Valence:	+2
Boiling Point:	765 °C
Melting Point:	321 °C
Vapor Pressure:	1 mm Hg at 394 °C
Density/Specific Gravity:	8.65 at 25 °C (water = 1)

(HSDB, 1995; Merck, 1989; Sax, 1989; U.S. EPA, 1994a)

SOURCES AND EMISSIONS

A. Sources

Cadmium compounds are used in the metal plating and battery industry. Cadmium sulfide and sulfoselenide are used in pigments. Cadmium compounds are used as stabilizing agents in many polyvinyl chloride products. Cadmium sulfide and cadmium telluride are used in the electronics

industry to produce photocells and light emitting diodes. Cadmium metal alloyed with copper is used in the production of automobile radiators. Cadmium sulfide is used as a curing agent in tires (ARB, 1986c). Cadmium acetate is used in ceramics, textile dyeing, printing, and electroplating. Cadmium bromide is used in photography, engraving, and lithography. Cadmium chloride is used in dyeing and printing of fabrics, in electronics component manufacture, and in photography. Cadmium oxide is used in electroplating, manufacture of cadmium electrodes, in semiconductors, and in glass and ceramic glazes
(Sittig, 1991). Cadmium is a component of diesel fuel, gasoline, and lubricating oil. Also, it is present in vehicle tires and consequently in the particles resulting from tire wear (ARB, 1986c).

As of February 22, 1983, cadmium sebacate and cadmium succinate are no longer registered for pesticidal use in California. And, as of January 15, 1985, cadmium chloride is no longer registered for pesticidal use in California (DPR, 1996).

The primary stationary sources that have reported emissions of cadmium in California are electrical services, gold and silver ore mining, and structural clay products manufacturing (ARB, 1997b).

B. Emissions

The total emissions of cadmium from stationary sources in California are estimated to be at least 3,900 pounds per year based on data reported under the Air Toxics “Hot Spots” Program (AB 2588) (ARB, 1997b).

In January 1993, the Air Resources Board (ARB) adopted an airborne toxics control measure for non-ferrous metal melting operations. This control measure is expected to reduce emissions of arsenic, cadmium, and nickel by 99 percent (ARB, 1992f).

C. Natural Occurrence

Coal and other fossil fuels contain cadmium and their combustion releases the element into the environment. Cadmium occurs in sulfide ore (greenockite) containing zinc sulfide and with lead and copper ores containing zinc. Cadmium has been detected in carbonaceous shales and phosphatic rock. Volcanic emissions contain cadmium-enriched aerosols (HSDB, 1995).

AMBIENT CONCENTRATIONS

Cadmium and its compounds are routinely monitored by the statewide Air Resources Board (ARB) air toxics network. The network's mean concentration of cadmium including its species from July 1995 through June 1996 is estimated to be 0.411 nanogram per cubic meter (ng/m^3) (ARB, 1997c).

When cadmium and cadmium compounds were formally identified as a toxic air contaminant, the ARB estimated a population-weighted annual concentration for 10 million people of between 1.0 and 2.5 ng/m^3, of which 1 million people are exposed to an average cadmium concentration between 1.8 and 5.6 ng/m^3 (ARB, 1986c).

The United States Environmental Protection Agency (U.S. EPA) has also reported concentrations of cadmium from one study area during 1985. The overall range of concentrations from this area were from 0.3 to 4.1 ng/m^3, with an overall mean concentration of 1.2 ng/m^3 (U.S. EPA, 1993a).

INDOOR SOURCES AND CONCENTRATIONS

Environmental tobacco smoke is an indoor source of cadmium (NRC, 1986). In a field study conducted in southern California, investigators collected particles (PM_{10}) inside 178 homes and analyzed the particle samples for selected elements, including cadmium. Two consecutive 12-hour samples were collected inside and immediately outside each home. Cadmium was present in measurable amounts in less than 10 percent of the samples (Clayton et al., 1993).

A southern California in-vehicle study measured an average cadmium concentration of 1 ng/m^3 and a maximum concentration of 8 ng/m^3 (Shikiya et al., 1989).

ATMOSPHERIC PERSISTENCE

Cadmium and cadmium compounds are expected to be particle-associated in the atmosphere, and hence subject to wet and dry deposition. The average half-life and lifetime life for particles and particle-associated chemicals in the atmosphere is estimated to be about 3.5 to 10 days and 5 to 15 days, respectively (Balkanski et al., 1993; Atkinson, 1995).

AB 2588 RISK ASSESSMENT INFORMATION

The Office of Environmental Health Hazard Assessment reviews risk assessments submitted under the Air Toxics "Hot Spots" Program (AB 2588). Of the risk assessments reviewed as of April 1996, cadmium and cadmium compounds were the major contributors to the overall cancer risk in 14 of the approximately 550 risk assessments reporting a total cancer risk equal to or greater than 1 in 1 million and contributed to the total cancer risk in 222 of the these risk assessments. Cadmium and cadmium compounds also were also the major contributors to the overall cancer risk in 4 of the approximately 130 risk assessments reporting a total cancer risk equal to or greater than 10 in 1 million, and contributed to the total cancer risk in 70 of these risk assessments (OEHHA, 1996a).

For non-cancer health effects, cadmium and cadmium compounds contributed to the total hazard index in 31 of the approximately 89 risk assessments reporting a total chronic hazard

index greater than 1. Cadmium and cadmium compounds also contributed to the total hazard index in 5 of the approximately 107 risk assessments reporting a total acute hazard index greater than 1 (OEHHA, 1996b).

HEALTH EFFECTS

Probable routes of human exposure to cadmium are inhalation and ingestion.

Non-Cancer: Although ingestion is the major source of exposure, only 1 to 10 percent of ingested cadmium appears to be absorbed systemically. Pulmonary absorption of inhaled cadmium is estimated to range from 10 to 50 percent of deposited cadmium. The biological half-life of cadmium in humans has been estimated to range from 10 to 30 years. Cadmium has moderate acute toxicity, producing gastrointestinal or pulmonary irritation effects from ingestion or inhalation, respectively. Subchronic and chronic exposures to cadmium have been associated with renal, cardiovascular, endocrine, hepatic, bone, hematological, and immunological effects. Respiratory conditions include bronchiolitis and emphysema. The U.S. EPA's Office of Air Quality Planning and Standards, for a hazard ranking under Section 112(g) of the Clean Air Act Amendments, considers cadmium oxide to be a "high concern" pollutant based on severe acute toxicity (ARB, 1986c; U.S. EPA, 1994a).

A chronic non-cancer Reference Exposure Level (REL) of 3.5 $\mu g/m^3$ is listed for cadmium in the California Air Pollution Control Officers Association Air Toxics "Hot Spots" Program, Revised 1992 Risk Assessment Guidelines. The toxicological endpoints considered for chronic toxicity are the kidney and respiratory system (CAPCOA, 1993). The U.S. EPA has not established a Reference Concentration (RfC) but has determined an oral Reference Dose (RfD) for cadmium in drinking water of 5×10^{-4} milligram per kilogram per day (mg/kg/d) and the RfD in food is 0.001 mg/kg/d, both based on significant proteinuria in humans. The U.S. EPA estimates that consumption of these levels or less, over a lifetime, would not likely result in the occurrence of chronic non-cancer effects (U.S. EPA, 1994a).

Human developmental studies are limited, although there is some evidence to suggest that maternal cadmium exposure may result in decreased birthweights (U.S. EPA, 1994a). Cadmium oral exposure induces testicular necrosis in experimental animals, ovarian damage, infertility, placental toxicity and embryo and fetotoxicity and teratogenicity. Developmental effects such as decreased weight gain and neurobehavioral deficits have been reported in animal studies (ARB, 1986c). The State of California under Proposition 65 has determined that cadmium is a male reproductive and developmental toxicant (CCR, 1997).

Cancer: Epidemiological evidence strongly supports an association between cadmium exposure and neoplasia, including respiratory and renal cancers (ARB, 1986c). Cancer resulting from inhalation exposure to several forms of cadmium has been reported in animal studies, while animal ingestion studies have usually proved negative (U.S. EPA, 1994a).

The U.S. EPA classified cadmium in Group B1: Probable human carcinogen, based on human and animal studies showing an increase of lung cancer, and has established an inhalation potency value of 1.8×10^{-3} (microgram per cubic meter)$^{-1}$. The U.S. EPA estimates that if an individual were to breathe air containing cadmium at 6×10^{-4} $\mu g/m^3$, over a lifetime, that person would theoretically have no more than a 1 in 1 million increased chance of developing cancer (U.S. EPA, 1994a). The International Agency for Research on Cancer classified cadmium and cadmium compounds in Group 1: Human carcinogen based on epidemiological evidence of carcinogenicity in humans and carcinogenic effects observed in animals (IARC, 1993b). There is limited evidence in experimental animals for the carcinogenicity of cadmium metal (HSDB, 1995).

The State of California has determined under AB 1807 and Proposition 65 that cadmium and cadmium compounds are carcinogens (ARB, 1986c; CCR, 1996). The inhalation potency factor that has been used as a basis for regulatory action in California is 4.2×10^{-3} (micrograms per cubic meter)$^{-1}$ (OEHHA, 1994). In other words, the potential excess cancer risk for a person exposed over a lifetime to 1 microgram per cubic meter of cadmium is estimated to be no greater than 4,200 in 1 million (OEHHA, 1994).

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