

CADMIUM

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December 10, 2001

Cadmium (Cd.) - Introduction

- Cd. is result of natural and man-made processes.
- Cd. (pure metal) doesn't exist in nature.
- Cd. Metal is commercial by-product of primary metal industries
- Cd emitted in environ. During manufactruing and discarding of Cd. Containing materials
- Cd. Occurs in 8 forms:
 - Cd (1.22%)¹⁻⁶
 - Cd (0.88%)¹⁰⁸
 - Cd (12.39%)¹¹⁰
 - Cd (12.75%)¹¹¹
 - Cd 24.(07%)¹¹²
 - Cd (12.26%)¹¹³
 - Cd (28.86%)¹¹⁴
 - Cd (7.58%)¹¹⁶

Cadmium (Cd.) - Introduction

- Major causes of death: Pulmonary edema; Kidney failure and Liver failure
- Occupational exposure well documented in: Ore smelting;, battery manufacturing.; alloy production.
- Best age Groups to study CD effects are 40-49; 50-59 and 60-69.
- Cd reaches maximum accumulation around age 50.

Cadmium (Cd.) - Introduction

- International Cadmium Association is:
- The industry Trade Organization
 - Promotes, markets for Cd. Products
 - Provides information on safe use & handling
 - Maintains information on Cd. rules & regulations

Chemical and Physical Characteristics

- Cd and its salts are highly toxic
- Soft, silvery, white, ductile metal (faint bluish tinge)
- Atomic weight = 112.4
- Derived from mixture of 8 stable isotopes
- The radioactive isotopes are ^{106}Cd and ^{113}Cd .
- Bond strengths in diatomic molecules
- Density @ 20°C is 8.65 g/cm^3 .

Chemical and Physical Characteristics cont.

- Melting point 321°C (610°F) Boiling @ 765°C
- Surface tension 350°C is 586 dynes/cm
- Valence +2. Vapor pressure($1\text{ mm/Hg}=394^{\circ}\text{C}$)
- Always divalent in all stable cpds
- Cd oxidized in moist air & by steam
- Cd dissolves in most organic & inorganic acids,(particularly nitric acid.
- Cd not soluble in alkalies.

Chemical and Physical Characteristics cont.

- Cd is a rare element
- Cd is a chalcophilic element
- Cd mineral examples: greenockite (hexagonal Cd's); hawleyite (cubic Cd's); cadmoselite (CdSe) and monteponite (CdO).
- Cd occurs as isomorphic impurity in other sulfide minerals, esp. zinc sulfides.
- Primary Cd recovered as by product from residues obtained during smelting of zinc, lead, copper & ores.

Chemical and Physical Characteristics cont.

- Wide spread use in electro-plating include:
 - Low contact resistance
 - Ready deposition on intricately shaped objects
 - Good corrosion resistance to alkali & sea water
 - Good solder-ability of plated parts
 - High ductility so plated parts can be formed
 - Coating life that's straight-line function of coating
 - Ability to protect steel
 - Heat of fusion 13.6 cal/g or 1.53 kcal/mol.
 - Brinell hardness of 21
 - Vapor pressure 1.4mm@ 400 °C; 16mm@500°C

History of Cadmium

- Cd 1st produced in US in 1906 from Zn-plant blue powder
- Early uses included paint pigments, glassmaking, photography, dyeing, chemical reagents and low-melting alloys
- Nickel-cadmium battery invented 1900 by Waldemar Jungner & Karl Berg

Encounters in Modern Life

- Ni-Cd batteries used as sealed cells in radios, alarms, pacemakers, calculators, motor starters, walkie-talkies and portable appliances and tools.
- Nuclear engineering use – Isotope ^{113}Cd used as a shield against neutrons.
- Manufacture of the Ni-Cd storage battery is the fastest growing segment of Cd industry

Common Exposure Situations

- Inhalation of Cd fumes = acute cadmium poisoning.
- Ingestion of heavily contaminated food or H₂O.
- Exposure from production and consumption
- H₂O contamination from Cd product decomposition.
- Airborne Cd particles & Cd deposits on land add to H₂O contamination.
- Phosphate fertilizers contaminate H₂O.
- Cd ground contamination from waste dumping
- Cd from finely dispersed aerosol in cigarette smoke

Routes of Exposures

- Cadmium is released to air, land & H₂O by human activity.
- Contaminated H₂O leads to residues in drinking water
- Long term low exposure about 33% total body burden of Cd found in kidneys
- Inhalation and ingestion are major routes.

Toxicokinetics

- Absorption

- The body accumulates cadmium almost completely by intestinal and respiratory absorption
- Proportionately larger amounts of cadmium are absorbed by lungs
- Alveolar absorption rates vary based on the difference in particulate forms of airborne cadmium
- Smaller particles are more soluble and increases absorption
- Cadmium compounds are poorly absorbed orally but well absorbed through the lungs
- Absorbed cadmium sequesters in the liver/kidneys

Toxicokinetics – con't

- Ingestion
 - Contamination of hands may contaminate foods
 - Direct contamination of water is the most significant source of human exposure
- Metabolism
 - Metabolic changes that may cause loss of cadmium include the number of pregnancies and lactation periods

Toxicokinetics-con't

- Excretion

- Excretion mainly related to kidney or body burden
- Excretion increases with length of exposure
- Excretion of excessive protein in urine causes kidney damage

- Major Routes of Excretion:

Renal – Kidney --Urine

Hepatobiliary --- Liver --- Feces

Respiratory --- lung --- Expired air

Critical Thresholds for Toxicity

- 1st evidence of chronic toxicity is renal tubular dysfunction manifested by excretion of protein metallothionein.
- Examples of lethal doses of various chemical forms of cadmium listed by NIOSH
 - Cadmium (fume), 9mg/m³ human beings
 - Cadmium oxide, 50mg/m³ (43.8) human beings
 - Cadmium chloride, 88mg/kg (54.0)

Critical Thresholds for Toxicity

- 10 minute exposure to 190 mg/m³ cadmium fumes or less than 8mg/m³ for four hours can be lethal
- ACGIH threshold limit values for cadmium are 10ug/m³ for total inhalable particulate

Critical thresholds for Carcinogenicity

- Cadmium and Cadmium compounds are carcinogenic to humans (Group 1)
- Sufficient evidence of carcinogenicity in rats and mice by inhalation, intramuscular injection and subcutaneous injection
- Cadmium causes genotoxic effects in variety of eukaryotic cells in humans.

Toxicity Health Outcomes

- Acute symptoms following exposure include: severe abdominal pain; nausea & vomiting; diarrhea; fever
- Short time after exposure: sore eyes, nose and throat; coughing; headache; dizziness; weakness; chill; fever; chest pains and breathlessness.
- High Inhalation exposure: acute pneumonitis with pulmonary edema.
- High ingestion exposure: acute gastroenteritis
- Long term occupational exposure: severe chronic effects in lungs and kidney
- High exposure combined with nutritional lead deficiency: osteoporosis &/or osteomalacia.

Appropriate Treatments

- Control Cadmium emissions
- Primary control should focus on inhalation
- Substitute substance in question
- Change productive techniques
- End of pipe measures
- Prevent fumes
- Avoid dust particulates

Biomarkers

- Cadmium concentrations found in blood
 - Cadmium levels in whole blood mainly reflect exposure during recent weeks/months
 - Cadmium concentrations in whole blood are found to be greatly influenced by smoking habits
 - Occupational exposure increases cadmium levels in blood with years of exposure

Biomarkers-con't

- Cadmium concentrations found in urine
 - Cadmium excretion in urine increases with age
 - Urinary cadmium level is an indicator of body burden

Special Issues Related to Exposure and Regulation

- OSHA regulates cadmium under 29CFR 1910.1027 (general industry) and 29 CFR 1926.1127 for construction
- Over 90% of the total global cadmium emission comes from sources like smelters processing plants as well as incinerators
- Agency for Toxic Substance and Disease Registry provides exposure risks, exposure limits and health effects

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