Cadmium

Cadmium is a relatively rare soft metal that occurs in the natural environment typically in association with zinc ores and, to a lesser extent, with lead and copper ores. Some inorganic cadmium compounds are soluble in water, while cadmium oxide and cadmium sulfide are almost insoluble. In the air, cadmium vapor is rapidly oxidized. Wet and dry deposition transfers cadmium from the ambient air to soil, where it is absorbed by plants and enters the food chain. This process may be influenced by acidification that increases the availability of cadmium in soil.

Atmospheric levels of cadmium range up to 5 nanograms per cubic meter (ng / m^3) in rural areas, from 0.005 to 0.015 micrograms per cubic meter (µ / m^3) in urban areas, and up to 0.06 µg / m^3 in industrial areas (WHO 1992). Concentrations may reach 0.3 µg / m^3 weekly mean values near metal smelters (WHO 1987). Atmospheric cadmium is generally associated with particulate matter of respirable size. Fresh water typically contain levels of cadmium below 1 microgram per liter (µg / l), but concentrations up to 10 µg / l may occur on rare occasions due to environmental disturbances such as acid rain. Concentration in nonpolluted agricultural soils varies between 0.01 and 0.7 micrograms per gram (µg / g); see WHO 1975).

Food contains cadmium as a result of uptake from the soil by plants and bioaccumulation in terrestrial and aquatic animals. The highest concentrations of cadmium are found in shellfish (over 1 µg / g) and in the liver and kidneys of farm animals (0.1–1 µg / g); see Kazantzis (1987).

Sources and Uses

Cadmium is emitted into the atmosphere from natural sources, mainly volcanic activities, and from anthropogenic sources. Metal production (drying of zinc concentrates and roasting, smelting, and refining of ores) is the largest source of anthropogenic atmospheric cadmium emissions, followed by waste incineration and by other sources, including the production of nickel-cadmium batteries, fossil fuel combustion, and generation of dust by industrial processes such as cement manufacturing (Kazantzis 1987).

The largest contributors to the contamination of water are mines (mine water, concentrate processing water, and leakages from mine tailings); process water from smelters; phosphate mining and related fertilizer production; and electroplating wastes.

The largest sources of cadmium in landfills are smelters, iron and steel plants, electroplating wastes, and battery production. Mine tailings generated as the result of zinc mining also have the potential to transfer cadmium to the ambient environment.

Cadmium is mainly used as an anticorrosion coating in electroplating, as an alloying metal in solders, as a stabilizer in plastics (organic cadmium), as a pigment, and as a component of nickel-cadmium batteries. Cadmium production may use by-products and wastes from the primary production of zinc.

Health Impacts of Exposure

Ingestion via food, especially plant-based foodstuffs, is the major route by which cadmium enters the human body from the environment. Average human daily intake of cadmium from food has been estimated at around 10–50 µg. This may increase to several hundred micrograms per day in polluted areas. The intake of cadmium through inhalation is generally less than half that via ingestion, while daily intake from drinking water ranges from below 1 µg to over 10 µg (WHO 1987). The kidney, especially the renal tract, is the critical organ of intoxication after exposure to cadmium. Excretion is slow, and renal accumulation of cadmium may result in irreversible impairment in the reabsorption capacity of renal tubules.

Only a small proportion (5–10%) of ingested cadmium is absorbed by humans (FAO and WHO, 1972), and large variations exist among individuals. Severe renal dysfunction and damage to the bone structure, a syndrome termed itai-itai disease, have been associated with long-term exposure to cadmium in food (mainly rice) and water in Japan. WHO (1987) estimated that long-term daily ingestion of 200 µg of cadmium via food can be connected with 10% prevalence of adverse health effects. Deficiencies of iron, zinc, and calcium in the human body generally facilitate cadmium absorption. Since most crops, with the exception of rice, contain zinc that inhibits the uptake of cadmium by animals and humans, there is no scientific proof that populations in general are at risk of cadmium exposure via the food chain (Chaney et al. 1995).

Less than 50% of inhaled cadmium is absorbed from the lungs. Acute and chronic exposure to cadmium dust and fumes, occurring mainly under working conditions, can result in cadmium poisoning. Acute respiratory effects can be expected at cadmium fume concentrations above 1 mg / m^3. Chronic effects occur at exposures to 20 µg / m^3 cadmium concentrations after about 20 years. Because of the cadmium content of tobacco, heavy smokers have elevated absorption of airborne cadmium. Cigarettes containing 0.5–3 µg cadmium per gram of tobacco can result in up to 3 µg daily cadmium absorption via the lungs, assuming a 25% absorption factor (WHO 1987). Considering various sources of exposure and applying a safety factor, WHO (1987) estimated that 0.2 µg / m^3 was a safe level of atmospheric cadmium concentrations with regard to renal effects through inhalation.

Animal studies have yielded sufficient evidence of the carcinogenicity of cadmium in animals (IARC 1976). Limited evidence of human carcinogenicity is also available in studies (reviewed in WHO 1992a, b) linking long-term occupational exposure to cadmium to increased occurrence of prostate and lung cancer cases. USEPA (1985) estimated the incremental cancer risk from continuous lifetime exposure to 1 µg / m^3 concentrations to be 0.0018.

Ambient Standards and Guidelines

Ambient environmental standards and guidelines are meant to protect human health and natural resources by limiting exposure. Table 1 presents EU, USEPA, and WHO reference standards and guidelines. The WHO ambient air quality guidelines take into account the impact of atmospheric cadmium on deposition and accumulation in soil used for agricultural production and set different acceptable levels in urban and rural areas. Ambient water quality guidelines focus on drinking water and other water resources intended for drinking, to protect human health.

Conclusion

Because of the indirect route of exposure to cadmium through the food chain, the accumulation of cadmium without natural degradation, and incomplete understanding of the relationship between emissions into the different media and

Table 1. Reference Standards and Guidelines for Ambient Levels of Cadmium in Air and Water

Medium	*EU limit values*	*EU guide values*	*USEPA standard*	*WHO guide values*
Air (milligrams per cubic meter)				
Not to be exceeded in rural areas				0.001–0.005
Not to be exceeded in urban areas				0.01–0.02
Drinking water and surface water intended for drinking (milligrams per liter)	5	1	10	3

Sources: Air: WHO 1987. Water: CEC 1975, 1980 (EU limit and EU guide); United States, CFR, vol. 21, no. 52 (USEPA); WHO 1993.

long-term environmental and biological impacts, ambient environmental standards may not be the best tools for protecting human health from the effects of exposure to environmental cadmium. Targeted policy intervention should concentrate on areas where populations may be at high risk due to multiple sources of exposure and the uptake of cadmium without the accompanying uptake of zinc, and due to nutritional deficiencies in iron and zinc.

Recommendations

Stationary sources that contribute to the increase of cadmium in the environment should not exceed the cadmium emissions referred to in the relevant industry section of this *Handbook.* These emissions are normally achievable through good industrial practices.

In addition, the impacts of new sources on ambient concentrations of cadmium should be considered. When the use of certain fuels results in emissions that contribute to a significant increase in ambient cadmium concentrations, or in areas where agricultural crops affected by such emissions are a main dietary source of the population, the environmental assessment should ensure that cadmium emissions are properly abated, taking into consideration alternative fuels, technologies, and control measures. Intermittent monitoring of the surrounding soil and plants should ensure that cadmium concentrations do not pose an increased health threat to the population in the vicinity of the industrial plant.

References and Sources

CEC (Commission of the European Communities). 1975. *Official Journal of the European Communities* 194. Luxembourg.

————. 1980. *Official Journal of the European Communities* L229. Luxembourg.

Chaney, L. Rufus, et al. 1995. "A New Paradigm for Soil Cadmium Risk to Humans." Paper presented at the OECD Cadmium Workshop in Stockholm, Sweden, October 15–22. Organisation for Economic Co-operation and Development, Paris.

FAO (Food and Agriculture Organization of the United Nations) and WHO (World Health Organization). 1972. *Evaluation of Certain Food Additives and the Contaminants Mercury, Lead, and Cadmium.* 16th report of the Joint FAO / WHO Expert Committee on Food Additives. Geneva: World Health Organization.

Huppes, Gjalt. 1993. *Macro-Environmental Policy: Principles and Design.* Amsterdam: Elsevier.

IARC (International Agency for Research on Cancer). 1987. "Cadmium and Cadmium Compounds." In *Overall Evaluations of Carcinogenicity: An Updating of IARC Monographs.* Vols. 1–42. Lyon, France.

Kazantzis, G. 1987. "Cadmium." In Lawrence Fishbein, Arthur Furst, and Myron A. Mehlman, eds., *Genotoxic and Carcinogenic Metals: Environmental and Occupational Occurrence and Exposure.* Advances in Modern Environmental Toxicology, vol. 11. Princeton, N.J.: Princeton Scientific Publishing Co.

Krishna Murti, C. R., et al. 1987. "Group Report: Cadmium." In T. C. Hutchinson and K. M. Meema, eds., *Lead, Mercury, Cadmium, and Arsenic in the Environment.* Scientific Committee on Problems of the Environment (SCOPE) 31. New York: John Wiley & Sons.

United States. CFR (*Code of Federal Regulations*). Washington, D.C.: Government Printing Office.

USEPA (United States Environmental Protection Agency). 1985. *Updated Mutagenicity and Carcinogenicity Assessment of Cadmium. Addendum to the Health Assessment Document of Cadmium.* May 1981. EPA-600 / 8-83-025F. Washington, D.C.

WHO (World Health Organization). 1971. *International Standards for Drinking Water,* vol. 3. 3d ed. Geneva.

————. 1975. "Environmental Hazards of Heavy Metals: Summary Evaluation of Lead, Cadmium and Mercury." *Environmental Health Criteria* 20. Geneva.

————. 1987. *Air Quality Guidelines.* Copenhagen: WHO Regional Office for Europe.

————. 1992a. "Cadmium." *Environmental Health Criteria* 134. Geneva.

————. 1992b. "Cadmium: Environmental Aspects." *Environmental Health Criteria* 135. Geneva.

————. 1993. *Guidelines for Drinking Water Quality.* Vol. 1: *Recommendations.* 2d ed. Geneva.

Yamagata, N. 1970. *Cadmium Pollution in Perspective.* Koshu Eiseiin Kenkyi Hokuku (Institute of Public Health, Tokyo) 19(1): 1–27.