

PREVENTING DISEASE THROUGH HEALTHY ENVIRONMENTS

EXPOSURE TO CADMIUM: A MAJOR PUBLIC HEALTH CONCERN

Cadmium exerts toxic effects on the kidney, the skeletal system and the respiratory system and is classified as a human carcinogen.¹⁻⁴ It is generally present in the environment at low levels; however, human activity has greatly increased levels in environmental media relevant to population exposure.⁵ Cadmium can travel long distances from the source of emission by atmospheric transport.⁶ It is readily accumulated in many organisms, notably mollusks and crustaceans. Lower concentrations are found in vegetables, cereals and starchy roots. Human exposure occurs mainly from consumption of contaminated food, active and passive inhalation of tobacco smoke, and inhalation by workers in a range of industries.^{3,7} National, regional and global actions are needed to decrease global environmental cadmium releases and reduce occupational and environmental exposure.

Sources of exposure to cadmium

Cadmium can be released to the environment in a number of ways, including:

- natural activities, such as volcanic activity (both on land and in the deep sea), weathering and erosion, and river transport;
- human activities, such as tobacco smoking, mining, smelting and refining of non-ferrous metals,⁸ fossil fuel combustion, incineration of municipal waste (especially cadmium-containing batteries and plastics), manufacture of phosphate fertilizers, and recycling of cadmium-plated steel scrap and electric and electronic waste^{9,10};
- remobilization of historic sources, such as the contamination of watercourses by drainage water from metal mines or from waste sites.⁹

Cadmium releases can be carried to and deposited on areas remote from the sources of emission by means of long-range atmospheric transport.^{8,9}

Industrial processes

Commercial cadmium production started only at the beginning of the 20th century. Its main use was initially in electroplating, but principal uses currently are in nickel-cadmium batteries, pigments, coatings and plating, as a stabilizer in plastics and other (including non-ferrous alloys, semiconductors and photovoltaic devices).³ The highest potential occupational exposures occur in cadmium production and refining, nickel-cadmium battery manufacture, cadmium pigment manufacture and formulation, cadmium alloy production, mechanical plating, zinc smelting, brazing with silver-cadmium-silver alloy solder and polyvinylchloride compounding.³ The main anthropogenic sources of cadmium present in the atmosphere are smelting of non-ferrous metal ores, fossil fuel combustion, ferrous metal production, municipal waste incineration and cement production.^{3,6} In many countries, atmospheric deposition of cadmium on arable soils exceeds its elimination, resulting in a gradual increase in cadmium levels in soils and crops.⁶ Application of municipal sewage sludge to agricultural

soil can also be a significant source of cadmium.⁷ The disposal and recycling of electronic and electrical waste (e-waste) has also been identified as a potentially important source of exposure to cadmium, particularly for children.^{10–12} Smelting and mining operations contaminate the aquatic environment, as does the effluent produced by air pollution control (gas scrubbers, in the absence of strict control measures).²

Food and drinking-water

Cadmium contained in soil and water can be taken up by certain crops and aquatic organisms and accumulate in the food chain.⁶ Food constitutes the main environmental source of cadmium for non-smokers. Highest cadmium levels are found in the kidney and liver of mammals fed with cadmium-rich diets and in certain species of oysters, scallops, mussels and crustaceans. Lower cadmium concentrations are found in vegetables, cereals and starchy roots. However, when consumption is taken into account, the food categories that contribute most to cadmium exposure in several countries are cereals/grains, vegetables, meat and poultry organ meats and seafood (especially mollusks).⁷ Some crops, such as rice, can accumulate high concentrations of cadmium if grown on cadmium-polluted soil. Acidification of cadmium-containing soils may increase the cadmium concentrations in crops. Application of sewage sludge, farmyard manure or some commercial fertilizers may also increase cadmium levels in soil.⁷

Cadmium exposure from drinking-water is relatively unimportant compared with exposure from diet. However, impurities in the zinc of galvanized pipes and cadmium-containing solders in fittings, water heaters, water coolers and taps can sometimes lead to increased cadmium levels in drinking-water, particularly in areas supplied with soft water of low pH, which would be more corrosive in plumbing systems containing cadmium.¹³

Smoking²

The tobacco plant naturally accumulates relatively high concentrations of cadmium in its leaves. Thus, smoking tobacco is an important source of exposure and – in the case of heavy smokers – daily intake may exceed that from food. Cigarette smoking can cause significant increases in the concentration of cadmium in the kidney, the main target organ for cadmium toxicity.

Products

Inexpensive jewellery, toys and plastics can be significant sources of exposure to cadmium, especially for children; however, many countries have moved to restrict or ban cadmium in such products.^{14–15}

World Health Organization (WHO) cadmium guidelines	
Provisional tolerable monthly intake	The Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable monthly intake for cadmium in 2010 of 25 µg/kg body weight, based on meta-analysis of epidemiological studies on the relationship between urinary cadmium and beta-2-microglobulin (a marker of renal tubular effects). In light of the long half-life of cadmium in humans, the Committee decided to express the tolerable intake as a monthly value. ⁷
Drinking-water	The guideline for cadmium in drinking-water is 3 µg/L. ^{13,16}
Air	The guideline for cadmium in air is 5 ng/m ³ (annual average). ⁸

Health effects²

- The kidney is the critical target organ following long-term exposure to cadmium. Cadmium accumulates primarily in the kidneys and its biological half-life in humans is 10–35 years.¹⁶ This accumulation may lead to renal tubular dysfunction, which results in increased excretion of low-molecular-weight proteins in the urine. While a modest increase in urinary excretion of these proteins is generally reversible, an increase of more than an order of magnitude causes irreversible tubular dysfunction, which progresses to overt nephropathy.⁷
- High intake of cadmium can lead to disturbances in calcium metabolism, the formation of kidney stones and effects on bone. Osteomalacia (softening of the bones) and osteoporosis may occur in those exposed through living or working in cadmium-contaminated areas; for example, in an area of Japan where soil was contaminated with cadmium from zinc/lead mines, itai-itai disease (characterized by osteomalacia, osteoporosis, painful bone fractures and kidney dysfunction) used to be widespread. Earlier studies indicated that decreased bone mineral density and increased risk of fracture were associated with exposure to cadmium, which generally arose after cadmium-induced kidney damage, and were likely secondary to changes in metabolism of calcium, phosphorus and vitamin D. However, in more recent studies, bone effects have been observed in the absence of renal tubular dysfunction. Therefore, although the overall evidence suggests an association between cadmium exposure and a decrease in bone mineral density, the dose-response relationship is difficult to characterize.⁷
- High inhalation exposure to cadmium oxide fumes results in acute pneumonitis with pulmonary oedema, which may be lethal. Long-term, high-level occupational exposure is associated with lung changes, primarily characterized by chronic obstructive pulmonary disease.² There is also some indication that cadmium may contribute to smoking-related lung disease.¹⁷
- There is sufficient evidence that exposure to cadmium and cadmium compounds

(e.g. through cadmium fumes) causes lung cancer; results from a study in a population residing in a cadmium-polluted area provide supporting evidence for a link between cadmium exposure and lung cancer. There is limited evidence in epidemiological studies that cadmium may also cause cancers of the kidney and prostate. There is also sufficient evidence in animal studies that cadmium compounds are carcinogenic and limited evidence for the carcinogenicity of cadmium metal. The International Agency for Research on Cancer (IARC) has therefore classified cadmium and cadmium compounds as *carcinogenic to humans* (Group 1), meaning that there is sufficient evidence for their carcinogenicity in humans. Although cadmium has been shown to cause genetic and related effects, including chromosomal damage, genomic instability and epigenetic alterations, direct binding to DNA appears to be of minor importance.^{3,4} Cadmium alters DNA repair and tumour-suppressor proteins, leading to chromosomal damage and genomic instability.^{3,4} Cadmium also induces alterations in epigenetic and signal-transduction processes, which may contribute to the deregulation of cell growth.^{3,4}

Risk mitigation recommendations

To decrease global environmental cadmium releases and reduce occupational and environmental exposure to cadmium and associated health effects, the following actions are needed:

- Implement the WHO Framework Convention on Tobacco Control,¹⁸ including providing for protection from exposure to tobacco smoke in indoor workplaces, public transport, indoor public places and, as appropriate, other public places.
- Reduce, as far as is practicable, emissions of cadmium – particularly into surface waters – from mining and smelting, waste incineration, application of sewage sludge to the land, and use of phosphate fertilizers and cadmium-containing manure. Develop techniques for the safe disposal of cadmium-containing wastes and effluents.
- Washing fruits and vegetables and peeling roots and tubers can reduce cadmium contamination to some extent.
- Promote safe and effective measures to increase recycling of cadmium and to restrict non-recyclable uses.
- Promote the elimination of use of cadmium in products such as toys, jewellery and plastics.
- Reduce cadmium exposure by, for instance, improving working conditions in the non-ferrous smelting industry and disseminating information on the proper use of fertilizers (which sometimes contain high levels of cadmium).
- Raise global awareness on the importance of minimizing waste discharges of cadmium.

References

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