Cadmium (Cd)

In a nutshell

Cadmium is a naturally occurring soft metal, chemically similar to zinc and mercury. Rock phosphate used for the manufacture of phosphate (P) mineral fertilizers can contain cadmium, which could contaminate soil and water, animal feed and food. Ingested cadmium is excreted slowly and so may accumulate in the human body, particularly the kidney. Kidney and bone disease are the most sensitive toxicological effects of excessive oral cadmium exposure. Reducing cadmium in P mineral fertilizers would help reduce cadmium exposure and thus human health risk.

What is cadmium?

Cadmium is a naturally occurring soft metal, chemically similar to zinc and mercury. It is resistant to corrosion and so is used as a protective layer when deposited on other metals. The average concentration of cadmium in Earth's crust is low; it occurs as a minor component in most zinc ores and therefore is a by-product of zinc production. It can be found at relatively high concentrations in some phosphate rocks, depending on the geological deposit type, and thus as a contaminant in commercial phosphate (P) mineral fertilizers.

Industrial-scale production of cadmium started in the 1930s. The major applications were coating of iron and steel to prevent corrosion, use in red, orange and yellow pigments, stabilization of PVC plastic, and more recently rechargeable nickel-cadmium batteries. The industrial use of cadmium has markedly decreased since the 1990s due to its toxicity. One of its few new uses is in cadmium telluride solar panels.

Contamination from different sources

Cadmium in soils may come from a number of different sources, including naturally-occurring background levels (from rock), atmospheric deposition, sewage sludge, and P mineral fertilizers. The cadmium content of P mineral fertilizers depends on its concentration in the rock phosphate used for their manufacture. It was estimated that in Switzerland in 1990, about 1.1 tonnes of cadmium per year was added to agricultural soil by use of mineral fertilizers, compared to 0.5 tonnes from sewage sludge and 1 tonne from organic fertilizers, and 8.9 tonnes from atmospheric deposition. Since cadmium can be taken up by crops such as cereals, potatoes and vegetables, increased levels in soil can result in increased levels in animal feed and in food. It has been argued that, depending on the background levels, increased cadmium levels in soils may be primarily related to the application of phosphate-based mineral fertilizers. Whether or not cadmium accumulates in soil is critically dependent on soil pH; at low pH, both leaching and crop uptake of Cd are increased. Soil pH is generally higher in agricultural soil than in natural vegetation and forest soil. Monitoring cadmium content in soils and water, as well as in input sources, can help to establish whether cadmium from mineral fertilizer use presents an additional risk to the environment and human health.

Human health effects

Ingested cadmium is excreted slowly and so after long-term exposure may accumulate in the human body, particularly the kidney, resulting in toxicity. Kidney and bone disease are the most sensitive toxicological effects of excessive oral cadmium exposure.

Consumption of crops grown in highly cadmium-contaminated soils or drinking water may lead to accumulation of toxic levels in the body. Such toxicity was reported in the 1950s in Japan, resulting from the consumption of rice grown in a contaminated floodplain downstream of lead-zinc mining activities. This produced kidney damage and painful and debilitating bone disease, known as Itai-Itai disease.

Dietary exposure

Cadmium exposure in the general population (i.e. consumers, non-occupational) is mainly via diet and tobacco smoking. Smokers have about twice the exposure of non-smokers, because tobacco bioaccumulates cadmium. The major dietary sources of cadmium are cereals (mainly wheat), potatoes and vegetables. Milk contains the smallest amount of cadmium (1 mg/kg). Meat, fish and fruit can contain from 1 to 50 mg/kg, whereas wheat, rice and potatoes from 10 to 300 mg/kg. The highest cadmium content (100-1000 mg/kg) is found in the inner organs of animals (kidneys and liver), in certain types of mussels as well as in deep-sea scallops and oysters. Certain crops, such as rice, can accumulate over 1000 mg/kg of cadmium when cultivated on contaminated soil.

For Codex Alimentarius, the WHO JECFA has established a safe exposure level (provisional Tolerable Monthly Intake, pTMI) of 25 µg/kg bw/month, based on urinary biomarkers of kidney damage. Based on the same data but a different statistical approach, the EU European Food Safety Authority (EFSA) has established a guideline value for weekly cadmium intake of 2.5 µg Cd/kg bw/week (body weight). At this level, no adverse health effects are expected. Highly exposed groups of the population such as children, vegetarians or smokers may exceed this level by up to two-fold. Because mean dietary exposure in the EU is close to or slightly exceeds the tolerable weekly intake level, EFSA recommends reducing exposure.

Potential solutions

It has been suggested that the most efficient measure to deal with hazardous contents of phosphate-based mineral fertilizers such as Cd would be to apply products with low content of cadmium, to promote the industry practice of blending rocks with different levels of cadmium, or to implement technologies to purify the fertilizers during the production process. This would prevent cadmium from being widely dispersed into the environment in concentrations that could increase human exposure and thus health risk.

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