CRC CARE FACT SHEET 7

Toxic metals

Toxic metals are metals that form poisonous soluble compounds and are of no benefit to humans, plants or animals even in small amounts. In other words they are not minerals essential to life, or else they occur in forms that are harmful when consumed or contacted.

Cadmium, lead, mercury and arsenic are commonly thought of as toxic metals, although arsenic is not strictly a metal, but a metalloid. None of these are of known benefit to humans or other living creatures, though some plants and microbes can tolerate them.

One of the reasons why some metals are toxic is that they closely resemble in molecular structure an essential nutrient which the organism relies on for its internal processes. The toxic metal occupies the sites reserved for the essential substance – and unleashes a chain of harmful consequences which we know as 'poisoning'.

Some metals are beneficial or innocuous in one form and toxic in another. Chrome III for example is an essential micronutrient, whereas Chrome VI is extremely toxic.

Which metals are toxic?

Toxic metals include barium, beryllium, aluminium, cadmium, lead, mercury, osmium, silver, thallium and vanadium. Radioactive metals are both chemically and radiologically toxic and include thorium, uranium, radium, plutonium, americium and the metalloid, polonium.

Some metals can have both beneficial and toxic effects on humans, animals and plants, depending on their form or the dose. These include chromium, some salts of nickel, copper and iron.

Arsenic, selenium and antimony are in fact not metals at all but metalloids, although they are often misdescribed as metals.

Living organisms need small amounts of certain metals to carry out their bodily processes at the cellular level. Iron, cobalt, copper, manganese, molybdenum and zinc are all essential nutrients for humans – but can be poisonous in excess or in the wrong form. Metals such as mercury, plutonium and lead are toxic and have no known benefit for organisms. Their accumulation in the bodies of people or animals can cause disease and death.

Toxic metals are of no benefit to humans, plants or animals even in small amounts

Toxic metal pollution

Toxic metal pollution can arise from both industrial and natural causes. Among the most common is the smelting of metals such as lead, copper and gold, which concentrates the toxic substances often found in their ores, and which can contaminate air, soil and water through smelter 'fallout' or via the dumping of wastes. Electroplating is another common source of contamination with chromium, cadmium, silver, copper and zinc. Fly ash from coal-fired power stations and 'red mud' from bauxite refining to make alumina are both rich in aluminium, iron and silicates. Power station fallout can also contain toxic metals. Gold mining is often accompanied by waste dumps which are high in arsenic. Industrial wastes, especially from old battery factories and metal shops, often contain high levels of toxic metals.

A famous disaster associated with metals is Minamata disease, which was caused by mercury poisoning. The mercury contamination of Minamata Bay, Japan, was due to wastewater discharged into the bay by factories producing acetaldehyde and vinyl in which inorganic Hg compounds were used as catalysts. This led to mercury contamination in fish, an important local food, resulting in many thousands of cases of methyl mercury poisonings in the population of Minamata City - the so-called 'Minamata disease'.

Sewage is high in valuable nutrients and organic matter, but is seldom used as fertiliser because of both disease risk and the presence of metals which humans concentrate and excrete. These can emerge on contact with humus and contaminate food crops grown in them. Certain phosphatic fertilisers are also contaminated by cadmium which was present in the rock phosphate from which they were first extracted.

Metals often have an affinity for heavy soils, muds and clays. The risk they pose relates to how easily they can dissolve out of the soil matrix into the soil water, and so make their way into food crops or drinking water supplies. The chemistry of this is very complex and depends on a range of factors such as soil type, its acidity and organic matter levels, the electrical charges on soil particle surfaces, interactions between the various metals present and microbial activity. It is not always easy to predict if a contaminated soil is also a dangerous soil.

However, once in soil metals can be dormant for many years. They can also gradually concentrate in certain areas. They do not decay and so pose a continuing threat should they ever be mobilised and become available to plants and thus people.

Toxicity also occurs naturally, as is the case with arsenic which is currently blamed for poisoning more than 100 million people worldwide. The poisoning is worst in Bangladesh, where an estimated 35–77 million people are at risk from drinking groundwater contaminated by naturally occurring arsenic, released by the drying and wetting of clay layers containing the metalloid. Another six million are at risk in West Bengal, India and several other Indian States. Other populations at risk of being exposed to elevated levels of arsenic have also been reported from China, Chile, Cambodia, Laos, Burma, Pakistan, Nepal, Vietnam, Taiwan, Iran, Argentina, Finland and the United States.

Killer metals

Toxic metals kill by different means. Arsenic, for example, kills acutely by inhibiting certain essential metabolic enzymes, leading to death from multiple organ failure. However it can also cause cancer of the skin, lung, bladder, kidney, liver and uterus and is linked to several skin diseases, nerve disorders, diabetes, lung disease, heart disease, suspected birth defects, and liver and blood disorders.

Mercury poisoning may begin with itching, pain, swelling and peeling skin. It can proceed to salivation, a racing heart, high blood pressure, nerve and vision disorders, paralysis and death.

Lead can cause brain damage, especially in young children, as well as nausea, chest pain, lethargy, insomnia, diarrhoea and vomiting. It can attack the kidneys, heart and central nervous system. Chronic poisoning is associated with learning difficulties in exposed populations.

Remediation

Remediation of soils contaminated by toxic metals can be carried out using several techniques. These include excavating and treating the soil chemically, phytoremediation (the use of special plants or microbes to extract the target toxic metals from the soil), the use of special clays and other substances to bind the metal or lock it in the soil matrix where it can do no harm, and the experimental use of electrical conductivity to extract metals from soil or water. Toxic metals can also be stabilised in soils by natural processes involving soil chemistry and physics or plants and microbes.

CRC CARE's role

CRC CARE carries out leading-edge research into the identification, risk assessment and remediation of soils and water contaminated with metals – ranging from sites occupied by heavy industry and mine tailings dumps to soils which are naturally high in toxic substances.

We are exploring a range of novel techniques for preventing, assessing and cleaning up contamination by metals, including novel applications of clay minerals and new forms of bacterial and plant-based bioremediation.

Our researchers have also been closely involved in understanding and developing possible solutions to arsenic poisoning in Bangladesh and India.

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