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Effects of lead on the environment

by Deni Greene

This article is extracted from the interim report ("Revising Australian Guidelines for Lead", July 1993) to the NHMRC, of the RMIT (Royal Melbourne Institute of Technology) consultancy team, for which Deni Greene is the senior researcher. The final report is due out at the end of July '93.

Lead moves into and throughout ecosystems. Atmospheric lead is deposited in vegetation, ground and water surfaces. The chemical and physical properties of lead and the biogeochemical processes within ecosystems will influence the movement of lead through ecosystems. The metal can affect all components of the environment and can move through the ecosystem until it reaches an equilibrium. Lead accumulates in the environment, but in certain chemical environments it will be transformed in such a way as to increase its solubility (e.g., the formations of lead sulfate in soils), its bioavailability or its toxicity. The effects of lead at the ecosystem level are usually seen as a form of stress (US EPA 1986).

In general, there are three known ways in which lead can adversely affect ecosystems. Populations of micro-organisms may be wiped out at soil lead concentrations of 1,000 parts per million (ppm) or more, slowing the rate of decomposition of matter. Populations of plants, micro-organisms and invertebrates may be affected by lead concentrations of 500 to 1,000 ppm, allowing more lead-tolerant populations of the same or different species to take their place. This will change the type of ecosystem present. At all ambient atmospheric concentrations of lead, the addition of lead to vegetation and animal surfaces can prevent the normal biochemical process that purifies and repurifies the calcium pool in grazing animals and decomposer organisms (UNEP 1991).

Exposure routes for lead to the environment

The main sources of lead entering an ecosystem are atmospheric lead (primarily from automobile emissions), paint chips, used ammunition, fertilisers and pesticides and lead-acid batteries or other industrial products. The transport and distribution of lead from major emission sources, both fixed and mobile, are mainly through air (UNEP 1991). While most of the lead discharged into air falls out near the source, about 20 percent is widely dispersed. Studies have demonstrated that measurements of lead in Greenland rose and fell with the rise and decline of use of alkyl-leaded petrol in the United States Eurasia and Canada over the past century (Isotopic evidence for the source of lead in Greenland snows since the late 1960s; K. J. R. Rosman, W. Chisholm, C. F. Boutron, J. P. Candelone & U. Görlach; Nature 362, 333 - 335; 25 March 1993). The size of the lead particles will govern how far they move from the source.

Effects of lead on soil

It is known that lead accumulates in the soil, particularly soil with a high organic content (US EPA 1986). Lead deposited on the ground is transferred to the upper layers of the soil surface, where it may be retained for many years (up to 2000 years). In undisturbed ecosystems, organic matter in the upper layer of soil surface retains atmospheric lead. In cultivated soils, this lead is mixed with soil to a depth of 25C1ll (i.e., within the root zone). Atmospheric lead in the soil will continue to move into the micro-organism and grazing food chains, until an equilibrium is reached.

Given the chemistry of lead in soil, the US EPA (1986) suggests that the uneven distribution of lead in ecosystems can displace other metals from the binding sites on the organic matter. It may hinder the chemical breakdown of inorganic soil fragments and lead in the soil may become more soluble, thus being more readily available to be taken up by plants.

Effects of lead on plants

Plants on land tend to absorb lead from the soil and retain most of this in their roots. There is some evidence that plant foliage may also take up lead (and it is possible that this lead is moved to other parts of the plant). The uptake of lead by the roots of the plant may be reduced with the application of calcium and phosphorus to the soil. Some species of plant have the capacity to accumulate high concentrations of lead (UNEP, WHO and ILO 1991).

The pores in a plant's leaves let in carbon dioxide needed for photosynthesis and emit oxygen. Lead pollution coats the surface of the leaf and reduces the amount of light reaching it. This results in stunting the growth or killing the plants by reducing the rate of photosynthesis, inhibiting respiration, encouraging an elongation of plant cells influencing root development 0; by causing pre-mature aging. Some evidence suggests that lead can affect population genetics. All these effects have been observed in isolated cells or in hydroponically grown plants in solutions of around 1-2 ppm of lead in soil moisture e.g., the lead levels experienced by ecosystems near smelters or roadsides).

Lead in air may be transferred to plants directly through fallout or indirectly through up-take from the soil. The pattern and degree of lead accumulation are largely influenced by the state of growth of the vegetation; i.e., active growth periods in spring as compared to low growth periods through autumn and winter.

Effects of lead on micro-organisms

Evidence exists to show that lead at the concentrations occasionally found near roadsides (i.e., 10,000 - 40,000 ppm dry weight), can wipe out populations of bacteria and fungi on leaf surfaces and in soil. This can have a significant impact, given that many of these micro-organisms are an essential part of the decomposing food chain. The micro-organism populations affected are likely to be replaced by others of the same or different species, although these may be less efficient at decomposing organic matter. Evidence also suggests that micro-organisms can make lead more soluble and hence more easily absorbed by plants. That is, bacteria exude organic acids that lower the pH in the immediate vicinity of the plant root.

Effects of lead on animals

Lead affects the central nervous system of animals and inhibits their ability to synthesize red blood cells. Lead blood concentrations of above 40 µg/dl can produce observable clinical symptoms in domestic animals. Calcium and phosphorus can reduce the intestinal absorption of lead (US EPA 1986). The US EPA report generalizes that a regular diet of 2-8 mg of lead per kilogram of body weight per day, over an extended period of time, will cause death in most animals. Grazing animals are directly affected by the consumption of forage and feed contaminated by airborne lead and somewhat indirectly by the up-take of lead through plant roots. Invertebrates may also accumulate lead at levels toxic to their predators.

Lead shot and lead weight can severely affect individual organisms and threaten ecosystems (WHO 1989). After three to ten days of waterfowl ingesting lead shot, the poison will reach the bloodstream and be carried to major organs, like the heart, liver and kidneys. By the 17th to 21st day the bird falls into a coma and dies. Following the ingestion of lead shot, lead toxicosis has been observed in Magpie geese, Black swans, several species of duck (including Black duck and Musk duck) and Hardhead species (OECD 1993).Organic lead is much more readily taken up by birds and fish (WHO 1989). Aquatic organisms take up inorganic lead through a transfer of lead from water and sediments; this is a relatively slow process. Organic lead is rapidly taken up by aquatic organisms from water and sediment. Aquatic animals are affected by lead at water concentrations lower than previously thought safe for wildlife. These concentrations occur often, but the impact of atmospheric lead on specific sites with high aquatic lead levels is not clear (US EPA 1986).

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