Phytoextraction and mining

Phytoextraction and hyperaccumulators

All plants absorb metal ions from soil. This is how they obtain micronutrients from soil that are essential for healthy growth. It also explains how plants may be used to remediate contaminated land.

Figure 1 From 1890 to 1980 this site in Pennyslvania was used for smelting zinc. The land has been left barren because of high zinc content and low pH.

Source of Figures 1 and 2: USDA ARS; photographer Keith Weller

Figure 2 Recent research has shown that alpine pennycress is a zinc and cadmium hyperaccumulator. It thrives on soils contaminated with these metals, removing them from the soil. It may help remediate sites such as the one in Pennsylvania.

Effective phytoremediation requires hyperaccumulator plants. These are plants that contain over 100 times higher metal concentrations of non-accumulator plants grown under the same conditions.

Natural hyperaccumulation

Some plants have evolved to become hyperaccumulators. They can accumulate very high metal ion concentrations of, for example, antimony, arsenic, cadmium, copper, nickel, selenium, thallium, manganese and zinc. The first recorded example was a perennial shrub called *Alyssum bertolinii*. Researchers reported a nickel content of 0.79% by mass in dried leaves. The soil contained only 0.42% nickel.

The modern definition of a natural hyperaccumulator is one that accumulates 100 times greater than non-accumulator plants.

A good example was the use of the nickel hyperaccumulator *Berkheya coddii* to decontaminate land near the Rustenburg smelter (South Africa) in the late 1990s. The nickel uptake was 2-3% by mass of dried plant. Ashes of dried plants, containing about 15% by mass, were added to the bulk metal ore and returned to the smelter.

Induced hyperaccumulation

Although around 400 hyperaccumulator plants have been identified, hyperaccumulation is quite rare. However, it can be induced by adding chemical compounds to the soil that will form soluble metal complex metals ions, increasing the bioavailability of the metal to plants. This is called induced hyperaccumulation.

Ethylenediaminetetraactetic acid (EDTA) is an example. It has been used to hyperaccumulate lead by chelating and forming a complex ion. There are many examples in which EDTA has been used, the plant used being Indian mustard (*Brassica juncea*). The lead originated from historical industrial activity such as the manufacture of paint, cables, car batteries and ammunition.

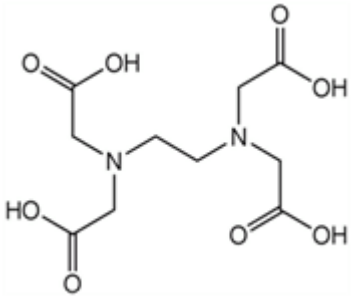

Figure 3 An EDTA molecule. It can complex with lead ions and increase their solubility and, therefore, their bioavailability to plants.

Research has shown that ammonium thiocyanate may be used to extract gold. It was demonstrated using ores and tailings from three mines in New Zealand and studied in detail by using an artificial gold ore made by dripping gold chloride solution into finely sieved sand. *Brassica juncea* was used for the pot trials because of its high biomass and rapid growth rate. Different concentrations of ammonium thiocyanate solutions were added.

Phytomining

An interesting scenario is to follow phytoextraction by recovering the metal, a process that has been called phytomining.

The principle is straightforward:

- phytoextract the metal from land that has been contaminated or has high natural levels of the metal, using hyperaccumulators or induced hyperaccumulation;
- harvest the plants and ash them at high temperatures to produce ‘bio-ore’;
- reduce bio-ores in the same way mineral ores are reduced – chemically or electrolytically.

Considerable numbers of research reports have been published, exploring both the techniques and the economics of the processes. In contrast, there are no recorded examples of commercial applications.

Nonetheless, phytomining is an area that attracts much interest and if prices of metals continue to increase it may become economically viable. The economics become more attractive if mining can be combined with other technologies such as phytoremediation and biofuel production (burning biomass to produce an ash from which to extract the metal and harnessing the energy released by combustion).

Finding out

Design an experiment to investigate the use of EDTA to hyperaccumulate lead in a variety of plants, using Indian mustard as the control plant.

What are the advantages and disadvantages of phytomining compared to conventional mining methods?