Fact or Fiction?

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Phytoremediation

"From Condiment to Toxic Cleanup"[1]

"How About a Jar of the World's Heaviest Mustard?"[2]

"Business is Blooming"[3]

Sources of metal contamination abound in the global ecosystem. Smelting, mining operations, fertilizer factories, urban runoff, and automobile emissions account for most of the metal related environmental pollution.[4] Waste from some metal finishing operations also falls in this category. Sewage disposal practices and pesticides containing metals also are significant sources for metal contamination. The current technologies used for removal of heavy metals for soils involve expensive processes requiring sophisticated equipment and removal, transportation, and purification of the soil.

A new approach for soil remediation is the use of plants. Studies have shown that metal tolerant hyperaccumulator plants can extract and accumulate high concentrations of toxic metals. The process is called phytoremediation. "Phyto" is from the Greek word for plant, and phytoremediation is the use of selected crop plants or trees to extract or promote degradation of toxic substances in soils, groundwater, surface water, wastewater and sediments. In some cases, it appears possible to "harvest" such contaminants as heavy metals that have been taken up by plants and recover them for recycling.[5] For example, ash from plant material grown on a contaminated Pennsylvania site yielded 30 to 40 percent zinc, the same as high-grade ore.[6]

Contaminated sites frequently cost from $400,00 to $1 million an acre to clean up.[6,7] Dr. I. Raskin, one of the leading researchers in this new field, and his colleagues at Rutgers University estimate that plants would cost $60,000 to $100,000 to clean an acre of soil to a depth of about 20 inches,[8] while R. Chaney, a U. S. Department of Agriculture researcher, predicted that plants could do the job for $200,000 to $300,000 an acre, not counting possible returns from the recovered ore.[6] Regardless of who is correct, plants could be considerably less expensive than methods currently being used. The cleanup of metal contaminated sites is a market estimated at 34 billion over the next five years.[8]

Removing heavy metal contaminated soil from 2½ acres to a depth of 18 in. creates about 5000 tons of soil that must be disposed of in a hazardous landfill. By comparison, plants that take up the metal and are burned lease a residue of between 25 and 30 tons of ash for disposal.[9]

Some varieties of plants thrive in toxic metal soils. Raskin, has commented on remembering reading Russian papers from the 1930s and 1940s about geobotany, wherein people were prospecting for minerals by looking at plants. He noted that some plants have a high capability for accumulating metals from the soils, and thereby provide clues to what lies just below the surface.[7] Murchie[10] reports on other examples. If one is looking for gold, for instance, it would behoove them to note where horsetails grow, because these ancient plants have a fondness for it. One botanist recently reported a case of horsetails absorbing gold in proportion of four ounces per ton of plant material. In Russia, a kind of mold was recently discovered that can extract up to 98 percent of gold in liquid solution. Wild buckwheat, which is native to the western U.S., has a similar affinity for silver and is known to be abundant near silver mines. Similarly, wild poppy and dandelion are clues to copper in the southwestern U.S., locoweed often marks uranium deposits, and selenium is indicated by tumbleweed and milk vetch.[10]

Plants that have shown the most promise include the Indian mustard plant (*Brassica juncea*) and sunflower (*Helianthus annuus*). These, and various grasses, have effectively removed toxic metals such as Cr (hexavalent), Co, Cu, Cd, Mn, Ni, Pb, Se and Zn from aqueous solutions.[9,11-13] The chart shows the effectiveness of mustard plants in removing Cd, Ni, Cu, Zn, Cr^{6+} and Pb from aqueous solutions.[11] Pennycress was shown effective at taking up cadmium and zinc in a landfill in St. Paul, MN.[6] It has been reported that poplar trees can break down between 10 and 20 percent of the pesticide *atrazine* in soil, and this is being evaluated in more detail in Iowa.[9]

Phytotech, one of at least five companies devoted to commercial applications of phytoremediation, is participating in an evaluation at a former electroplating facility in Findlay, OH, where the technology is being evaluated for its effectiveness in removing chromium, cadmium, nickel, zinc and lead from soils.[5] In the summer of 1996, Phytotech conducted an investigation of the lead-removing capabilities of mustard plants at a former pen manufacturing site.

This project showed that about three quarters of the 4500 ft^2 site project area had been cleaned to

below the 400 ppm regulatory limit in the first growing season. Originally, lead levels on some parts of the site ranged as high as 50,000 ppm.[5]

Mustard plants are being used to extract chromium from dirt at an old chromate smelter in New Jersey and to leach radioactive strontium and cesium from soil contaminated by the nuclear reactor disaster at Chernobyl. In England, a test plot of mustard plants is extracting cadmium from tailings of a lead mine dating back to Roman times.[7] Native aquatic plants—pondweed, arrowroot, and coontail—are being evaluated at the Iowa Army Ammunition Plant to actively degrade TNT and RDX explosives.[14]

There are three distinct approaches to phytoremediation of toxic metals and radionuclides:[3]

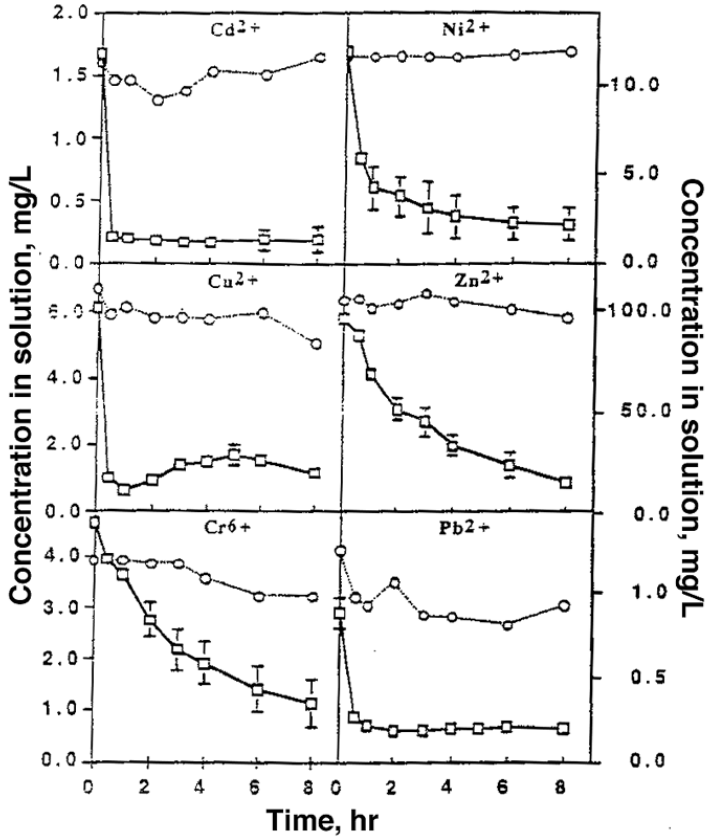
- Phytoextraction—The use of metal accumulating plants, which can extract metals from the soil and concentrate them in the roots and above ground shoots.
- Rhizofiltration—The use of plant roots to absorb, concentrate and precipitate toxic metals from aqueous streams.
- Phytostabilization—The use of plants to eliminate the availability of toxic metals in soils.

Phytoextraction is the process that has received the most attention to date.[3] This is where the Indian mustard plant is being used. Rhizofiltration, from the Greek word for root, is being used to clean up water contaminated with uranium from a DOE facility in Astabula, OH.[7] For rhizofiltration, sunflowers are particularly adept since they can be suspended over a body of water by affixing them to perforated plates. The roots, which dangle in the water, serve to filter out metals and other contaminants.[3]

At the Astabula facility, with uranium-contaminated water at concentrations as high as 350 ppb, use of sunflowers reduced uranium concentrations by 95 percent within the first 24 hr. Uranium concentration in the outlet water never exceeded 5 ppb and, in most cases, was 1 ppb, or less. Sunflower crops have been shown to extract 95 percent of the radionuclides in about ten days from a small pond in Chernobyl.[5] Phytotech researchers estimate the costs of removing radionuclides from water with sunflowers range from $2 to $6 per thousand gal of water treated, including capital and waste disposal costs. By comparison, microfiltration and precipitation processes run about $80 for the same amount of water treated.[15] Phytostabilization doesn't actually remove contaminants from soil or water but serves to collect contaminants in a root system to prevent migration, ingestion, or other paths of exposure. This technique is more at the concept phase than the other types of phytoremediation.[3]

Concerns

One concern is preventing insects and grazing animals from feeding on the bioaccumulative plants when they are deployed against contaminants;[3] another is that phytoremediation is a time-consuming process, and therefore it can take several growing seasons to clean a site.[9] **P&SF**



Removal of different metals from aqueous solutions by Indian mustard roots (squares). Control treatments (circles) did not contain roots. (Reprinted with permission of V. Dushenkov.[11])

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