PECONIC RIVER REMEDIAL ALTERNATIVES

Phytoextraction

Introduction

Phytoremediation is the name given to technologies that use plants to clean up contaminated sites. Many techniques and applications are represented under phytoremediation. They differ in the way plants deal with contaminants (removal, immobilization, degradation), as well as in the type of contaminant that the plant species can target (organic or inorganic contaminant). This fact sheet describes the technique of phytoextraction, which is used to remove contaminants from soil or sediment by having plants take them up and store them in aboveground, harvestable tissues. A separate sheet describes phytostabilization, in which plants are used to immobilize contaminants in the soil.

Technology Description

Phytoextraction is the uptake of contaminants by plant roots and movement of the contaminants from the roots to aboveground parts of the plant (see Fig. 1). Contaminants are generally removed from the site by harvesting the plants. Phytoextraction accumulates the contaminants in a much smaller amount of material to be disposed of (the contaminated plants) than does excavation of soil or sediment. The technique is mostly applied to heavy metals and radionuclides in soil, sediment, and sludges. It may use plants that naturally take up and accumulate extremely elevated levels of contaminants in their stems and leaves. It can also entail the use of plants that take up and accumulate aboveground significant amounts of contaminants only when special soil amendments are used. Another approach is the use of plants that trap the contaminants in their root systems and are then harvested whole (including the roots). Mercury represents a special case of metal phytoremediation that is still being investigated. To remove this metal from soil and sediments, researchers propose to use genetically modified plants to take up the mercury and transform it into a less toxic form. The less toxic form is then vaporized out of the leaves, reducing the danger to the environment and humans.

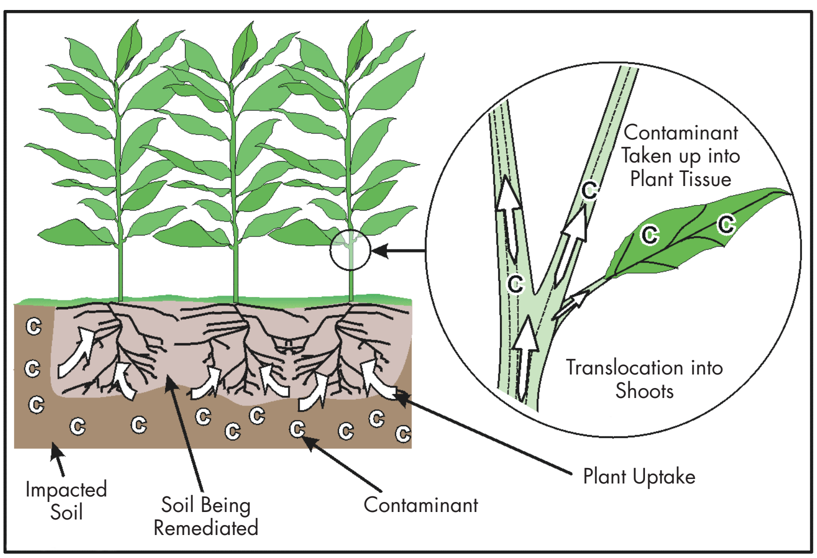

Figure 1. Phytoaccumulation of inorganic contaminants.

Source: Phytotechnology Technical and Regulatory Guidance Document, Interstate Technology and Regulatory Cooperation Work Group.

How Does the Technology Work?

Phytoextraction closely resembles the operations conducted in conventional agricultural farming. In the case of the Peconic River environment, the area must be sufficiently dry to allow equipment traffic (either by redirecting the river's flow or by conducting the work during the summer dry season). "Natural" phytoextraction (see Fig. 2) is usually conducted by planting (or transplanting) selected plant species in the contaminated soil. These plants are grown under normal farming conditions (fertilized and irrigated as necessary) until they reach their maximum size. The aboveground parts of the plants containing the contaminants are then harvested and disposed of appropriately. The plants are highly specialized, occur naturally, and can tolerate very elevated concentrations of metals that would be toxic to other plants. Typically, these plants are small, have a small and shallow root system, and grow relatively slowly.

Induced phytoextraction is conducted by growing selected fast-growing plants in the contaminated soil. Throughout the growth period, amendments are added to the soil to increase availability of metals to the plants. When the plants are mature, inducing agents (chemicals) are used to trigger accumulation of metals from the soil. The plants are then harvested and disposed appropriately. It is possible that two harvests will be conducted annually.

Phytoextraction by whole plant harvesting is conducted by growing the selected plants under normal conditions, including fertilization and irrigation as necessary. Modified agricultural implements typically used to harvest below-ground crops (potatoes, beets, carrots, peanuts, etc.) are used to harvest the whole plant, including the root (see Fig. 3).

A number of patents regarding specific plants and processes have been awarded to various companies that specialize in phytoextraction.

Advantages

- Phytoextraction is able to trap metal and radionuclide contaminants that are in mobile chemical forms. These forms are the most threatening to human and environmental health.

Figure 3. Phytoextraction by whole plant harvesting.

- Compared with other remediation technologies, such as excavation, materials handling is limited (similar to that in normal agricultural processes), and costs are typically lower. Usually the technology leaves the soil fertile and able to support subsequent vegetation.

Disadvantages

- This technology takes longer than other technologies: several to many crops are usually required to remove all the contaminants to the desired levels.

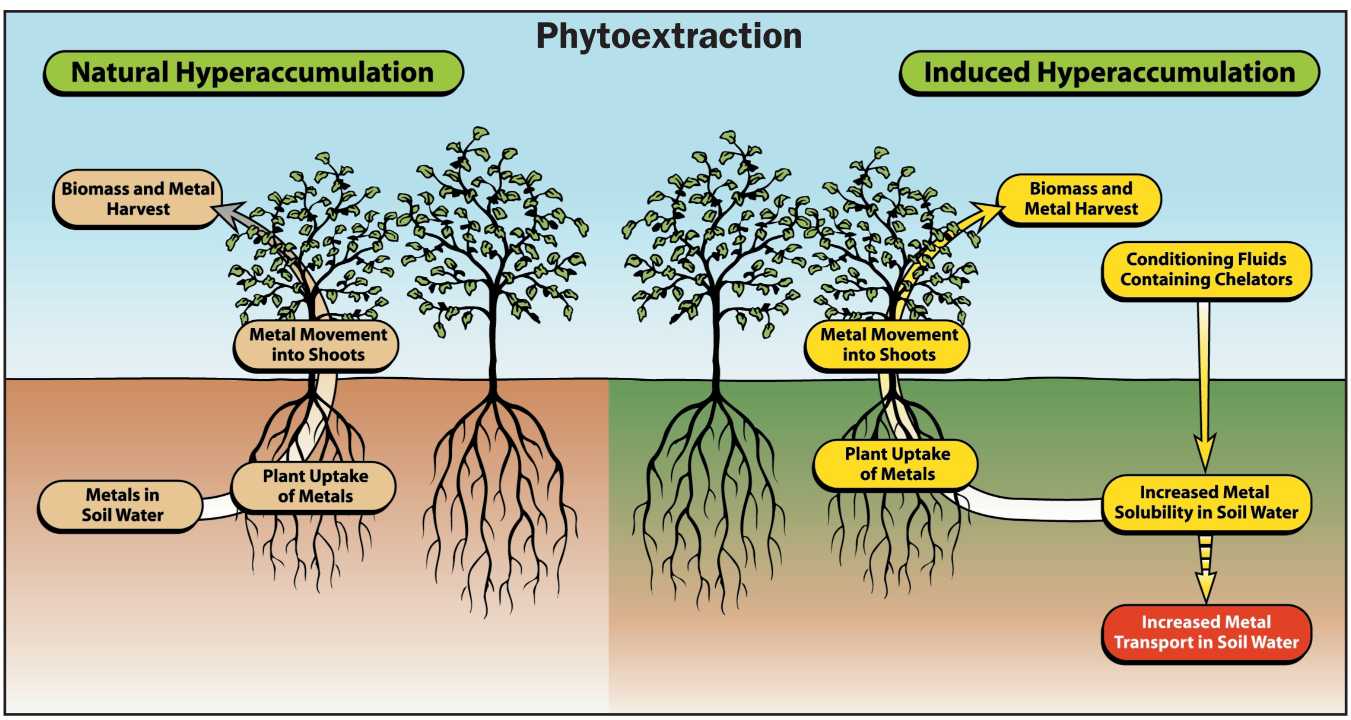

Figure 2. Natural and induced phytoextraction.

Source: Pierzynski et al., 2001, Copyright Kansas State University

- This technology is relatively untested at the field scale for the contaminants found in the Peconic River sediments.
- Mercury removal is considered experimental and has shown promise using genetically modified plants that vaporize mercury.
- Most of the plants that are considered good candidates for use with this technology do not grow well under submerged (wetland) conditions. Phytoextraction has not been applied to wetlands.
- Extensive treatability studies are needed before this technology can be considered for implementation in wetlands.
- Portions of the river may have to be re-routed for the duration of the treatment.
- Plants that are good phytoextraction candidates are not native to the area.
- Plants used for phytoextraction will have to be harvested over multiple growing seasons.
- If soil additives are used, additional precautions must be taken to avoid leaching of the mobilized contaminants outside the area where roots can take them up.
- Accumulation of contaminants in the aboveground part of the plants may pose a risk to animals eating these plants and fences may be needed to deter grazing animals.
- Phytoextraction will not directly remove organic contaminants (PCBs, DDD) from soils and sediments. However, microbial activity associated with plant roots may accelerate the degradation of these contaminants to non-toxic forms.

Relative Cost

Phytoextraction is typically less costly than excavation; however, actual costs depend on site-specific conditions. Current estimates range from $16 to $62 per cubic yard of soil treated.

Maturity of the Technology

Most of the technology development has focused on lead, zinc, and cesium-137. No data are available on copper. Of the contaminants present in the Peconic River, cesium-137 and mercury have been tested before at different sites with different degrees of success. Silver has been field-tested once, with no definitive results. While several companies employ phytoextraction commercially, it is not widely used. In particular, it has not been tested in conditions similar to those at the Peconic River.

Project Histories

The technology has been applied at a number of sites nationwide, all of them upland areas. Examples include the Magic Marker site in New Jersey and a DaimlerChrysler site in Detroit, Michigan (induced accumulation of lead in soil); Argonne National Laboratory-West (mercury, silver, chromium, cesium-137 in soil/sediment removed by whole plant harvesting); and various firing ranges (e.g., Fort Dix, New Jersey, lead removal by induced accumulation). Natural accumulation of elevated contaminant levels has been tested at the SBC site in Butte, Montana, for the removal of zinc. Some field testing has been conducted on contaminated soil at Brookhaven National Laboratory.

Performance Data

Some degree of success has been claimed at the various locations where phytoextraction has been tested. Times expected to complete cleanup vary, depending on the initial contaminant concentration and local soil conditions. Cesium-137 was removed at a rate of 4.5% per year at the Argonne site, where 5 to 6 years would be required to complete the cleanup. Removal of other metal contaminants at the same site would require much longer times. Concerns over leaching of metals (mobilized by induced accumulation techniques) into the groundwater have been raised at several sites.

Potential Technology Applicability – Peconic River

Phytoextraction has been demonstrated to be an effective treatment technology when site conditions are appropriate. Deployment of a phytoextraction treatment system would be less disruptive to the environment than excavation. However, this technology has not been demonstrated, on a full scale basis, on wetland environments similar to those which exist along the Peconic River.

Infrastructure Requirements

The areas to be treated will need to be accessible to farm implements (tractors with tilling/plowing, fertilizing, seeding, and harvesting equipment) and sufficiently dry to allow for cultivation and avoiding waterlogged conditions. This may involve the redirection of water flow. Irrigation may, however, be needed to supplement rainfall.

Long-Term Remedy

In the long term, the area will look like a restored wetland/upland area. During active remediation, the area will look like a cultivated field.

Impact to Wetlands/Adjacent Areas

Phytoextraction in the typical configuration has only been applied to upland soil and not to wetland areas. Significant impact on the wetland is expected if this technology is used; the plants will need access to sunlight, nonsubmersed soil, and the implementation of farming techniques. The plants used during remediation may not be native to the Peconic River.

Site Restoration Requirements

The soil generated from the phytoextraction process will be fertile and will be able to support the growth of plants used in a restoration program once removal of contaminants is complete.

Process Residuals Management

The harvested biomass will be analyzed and disposed of according to its composition. Disposal may involve air drying, processing for volume reduction (cutting and baling, or composting as appropriate), and, ultimately, either landfilling or incinerating in approved facilities.

Ability to Meet Site Closure Requirements

The ability to meet closure requirements needs to be determined by conducting site-specific treatability studies.

Need for Site-Specific Testing

Bench-scale testing will be necessary, because phytoextraction has not been tried in an environment with objectives similar to those for the Peconic River. Removal rates are highly dependent on the specific soil chemistry at the site. If bench-scale tests generate encouraging results, pilot-scale testing will be conducted on the contaminated areas where phytoextraction is applicable. Usually, pilot tests have a duration of about 18 months.

Need for Long-Term Monitoring

Monitoring the technology's performance (removal rates) will be continuous until cleanup is complete and the site has been restored. No further monitoring will be needed.

Synergy with Other Technologies

Phytoextraction may be conducted at selected upland locations where more localized treatment is necessary; constructed wetland technologies could be used to control contaminant migration. Phytoextraction may be used in conjunction with electrochemical technology to remove contaminants (such as cesium-137) that technology alone cannot remove; however, the effectiveness of this approach has yet to be demonstrated.

Resources

A Citizen's Guide to Phytoremediation, USEPA, Office of Solid Waste and Emergency Response, August 1998.

Introduction to Phytoremediation, USEPA, Office of Research and Development, EPA/600/R99/107, February 2000.

http://www.itrcweb.org/PHYTO2.pdf.

http://faculty.washington.edu/clh/wet.html.

Contact

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