



Phytoremediation: Selecting and Using Phytoremediation for Site Cleanup

An Online Continuing Education Course for Engineers

Course Number: EN-3012

Credit: 3 Hours / 3 PDH / 3 CPD

Phytoremediation: Selecting and Using Phytoremediation for Site Cleanup

Introduction

Purpose

This course is an educational tool for site owners, project managers, and regulators to help evaluate the applicability of the phytoremediation process at brownfields sites. Cleanup technologies that reduce costs, decrease time frames, or positively affect other decision considerations (for example, community acceptance) can have a significant effect on the redevelopment potential of brownfields sites. Increased attention to brownfields sites and the manner in which they are redeveloped places greater importance on the selection of cleanup technologies.

Phytoremediation represents a group of innovative technologies that use plants and natural processes to remediate or stabilize hazardous wastes in soil, sediments, surface water, or groundwater. Because it is based on natural processes, phytoremediation may be easily adaptable to many redevelopment plans for brownfields sites. Phytoremediation is being evaluated at a variety of sites and on myriad contaminants to determine the conditions under which phytoremediation systems are effective in reducing contamination. The course presents some of the advantages and technical limitations of phytoremediation that the evaluations indicate. The course illustrates the potential of phytoremediation to serve as:

- An interim approach for stabilizing sites while other cleanup strategies are being evaluated
- An approach that augments the overall effectiveness of other cleanup technologies
- A stand-alone approach for providing cost-effective, long-term cleanup solutions

The course also illustrates the potential limitations of phytoremediation and how such factors as levels of contaminants and properties of the soil, as well as concerns about potential risk of exposure may affect the use of phytoremediation at brownfields sites. Because phytoremediation is more than simply planting vegetation, brownfields decision makers must:

- 1) select the correct plants,
- 2) work effectively with regulators and the local community,
- 3) understand maintenance and monitoring requirements, and
- 4) compare the costs of phytoremediation with the costs of other technology options.

Until phytoremediation is a more proven and established technology, advocates for its use may find it necessary to demonstrate its potential applicability and efficacy on a site-specific basis. To do so may require an up-front commitment of time and resources to

demonstrate that the performance of phytoremediation is comparable to the performance of traditionally accepted technology options. Such an investment ultimately could save site owners significant amounts of money when they clean up their properties for redevelopment.

Background

The U.S. Environmental Protection Agency (EPA) has defined brownfields sites as “abandoned, idled or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination.” Numerous technology options are available to assist those involved in the cleanup of brownfields sites. EPA’s Technology Innovation Office (TIO) encourages the use of innovative, cost-effective technologies to characterize and clean up contaminated sites.

An innovative technology is a technology that has been field-tested and applied to a hazardous waste problem at a site, but that lacks a long history of full-scale use. Although readily available information about its cost and how well it works may be insufficient to encourage use under a wide variety of operating conditions, an innovative technology has the potential to significantly reduce the cost and time required to redevelop brownfields sites.

Historically, fear of contamination and its associated liability has hampered redevelopment of brownfields sites. Phytoremediation offers a unique advantage over other remediation technologies. It provides ecosystem restoration and “green areas” that may be desired by the local community.

The process of redeveloping brownfields sites provides an excellent framework for using innovative technologies because:

- 1) state and federal regulators tend to be flexible in approving cleanup plans for brownfields sites, particularly those sites for which voluntary cleanup plans have been submitted;
- 2) most of the current brownfields sites are not encumbered by a history of litigation or enforcement actions for which traditional technologies already may have been specified; and
- 3) re-development plans have been prepared for many brownfields sites and are used to establish site-specific cleanup targets and the time frames for cleanup – that information provides an excellent basis for tailoring innovative approaches to the investigation and cleanup of individual sites.

Approach

This course will assist brownfields decision makers in considering phytoremediation as an innovative treatment technology option for cleanup at brownfields sites. The course discusses the factors important in the selection of phytoremediation, such as regional climate and local growing conditions, location and type of contaminants to be treated, and site-specific

redevelopment objectives. The course illustrates how those factors can be potential advantages (or limitations) in the selection of phytoremediation at a brownfields site; presents examples that illustrate the field applications of phytoremediation at brownfields sites; and identifies additional resources to assist brownfields decision makers in evaluating phytoremediation as an option for their sites.

In addition, this course provides the following information in appendices:

- A list of **acronyms**
- A **glossary that explains technical terms** related to phytoremediation
- A **description of the processes of phytoremediation;**
- **Decision tree diagrams** developed by the Phytoremediation Work Group of the Interstate Technology and Regulatory Cooperation Work Group. The decision tree diagrams provide guidelines for determining the applicability of phytoremediation at a brownfields site after site characterization has been completed.

This course is not an authoritative or original source of research on phytoremediation. Instead, it is intended to briefly describe the phytoremediation process and its potential applicability in a brownfields setting in a tone appropriate for audiences who have only a limited technical background.

It is important to note that this course cannot be used as the sole basis for determining this technology's applicability to a specific site. That decision is based on many factors and must be made on a case-by-case basis. Technology expertise must be applied and treatability studies conducted to support a final remedy decision.

What is Phytoremediation?

Phytoremediation is the direct use of living green plants for in situ (in-place or on-site) risk reduction for contaminated soil, sludges, sediments, and groundwater, through removal, degradation, or containment of Phytodegradation - The breakdown of contaminants taken up by the plant through metabolic processes within the plant, or the

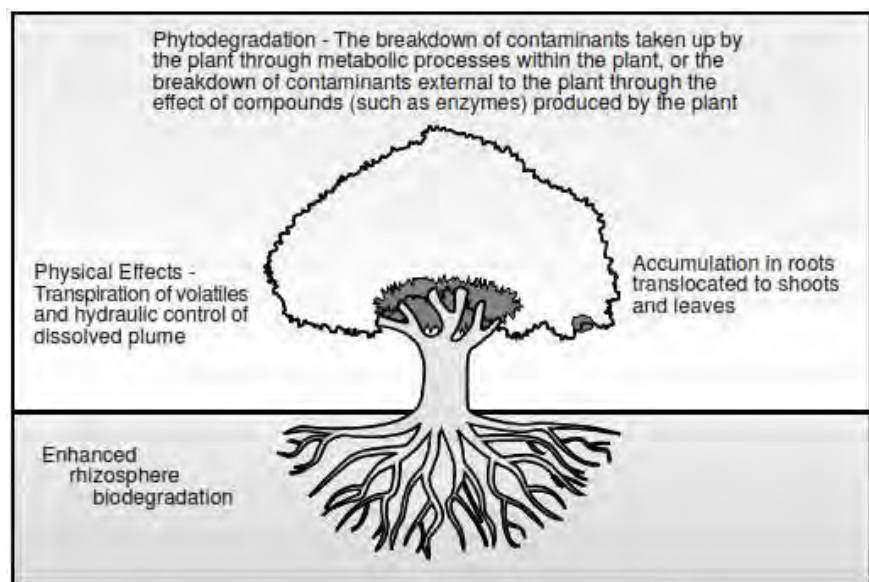


Figure 1: Examples of Mechanisms Involved in Phytoremediation

breakdown of contaminants external to the plant through the effect of compounds (such as enzymes) produced by the plant the contaminant (synonyms: green remediation and botano-remediation). Figure 1 illustrates the mechanisms involved in the phytoremediation process.

Phytoremediation warrants consideration for cleaning up brownfields sites at which there are relatively low concentrations of contaminants (that is, organics, nutrients, or metals) over a large cleanup area and at shallow depths.

Another potential application for phytoremediation is at sites that currently are “mothballed” and may be redeveloped in the future. Phytoremediation can be a cost-effective alternative approach for reducing the leaching of contaminants through soil or groundwater, reducing the run-off of contaminated storm water, beginning an initial level of cleanup, and improving the aesthetic condition of a site. Phytoremediation warrants consideration for use in conjunction with other technologies when the redevelopment and land use plans for the site include the use of vegetation.

Successful Reduction of Lead Contamination

Phytoextraction was demonstrated at a site in Trenton New Jersey that had been used for the manufacture of lead acid batteries. Phytoextraction using Indian mustard (*Brassica juncea*) and ethylenediaminetetraacetic acid (EDTA) soil amendment reduced the average surface lead concentration by 13 percent in one growing season. The target soil concentration of 400 milligrams per kilogram (mg/kg) was achieved in approximately 72 percent of a 4,500 square-foot area. (Some of the reduction may be attributed to dilution as a result of tilling and spreading contaminants deeper into the soil column.)

Phytoremediation is distinct from Monitored Natural Attenuation (MNA), that is, a controlled and monitored site cleanup approach that relies on natural attenuation processes to achieve remediation objectives within time frames that are reasonable vis-à-vis more active methods. Though both processes involve some similar elements such as biodegradation, sorption, volatilization, stabilization, phytoremediation technologies represent active processes that are designed and implemented to control and eliminate contamination. MNA and phytoremediation also are similar in that both might be considered significant components of a treatment-train approach to hazardous waste cleanup at brownfield sites.

Types of Sites and Contaminants Treated by Phytoremediation

There is potential to use phytoremediation beneficially under a wide variety of site conditions. Types of sites at which phytoremediation has been applied or evaluated include: pipelines; industrial and municipal landfills; agricultural fields; wood treating sites; military bases; fuel storage tank farms; gas stations; army ammunition plants; sewage treatment plants; and mining sites.

Phytoremediation is being tested and evaluated for its effectiveness in containing and treating a wide array of contaminants found at brownfields sites. While much more testing is needed, current results indicate that plants have the potential to enhance remediation of the following types of contaminants:

- Petroleum hydrocarbons
- Benzene, toluene, ethylbenzene, and xylene (BTEX)
- Polycyclic aromatic hydrocarbons (PAH)
- Polychlorinated biphenyls (PCB)
- Trichloroethene (TCE) and other chlorinated hydrocarbons
- Ammunition wastes and explosives
- Heavy metals
- Pesticides
- Radionuclides
- Nutrient

One of the more common methods of remediation is containment technology. Since many brownfields sites have low concentrations of contaminants, containment is a good alternative if geologic conditions are favorable.

Table 1 lists types of contaminants and the level of success in remediation for a sample of sites and methods.

Plants Species Used

Plants species are selected based on their ability to treat the contaminants of concern and achieve the remediation goals for site redevelopment (for example, time frame and risk management), and for their adaptability to other site-specific factors such as adaptation to local climates, depth of the plant's root structure, and the ability of the species to flourish in the type of soil present. Often the preferred vegetation characteristics include: an ability to extract or degrade the contaminants of concern to nontoxic or less toxic products, fast growth rate, adaptability to local conditions, ease of planting and maintenance, and the uptake of large quantities of water by evapotranspiration (see the glossary of terms in Appendix 1 for definitions of technical terms). The selection and use of plant species must be conducted with care to prevent the introduction of non-native species into areas where those species are not already present. Plant species that are benign under most circumstances may become a problem when introduced into a new area. For example, water hyacinth is considered a noxious aquatic weed that should be used only in isolated bodies of water from which there are no risks of unintentional transport (for example, by flood).

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course. Close this window and click "Add to cart" on the product page.