Phytotechnologies

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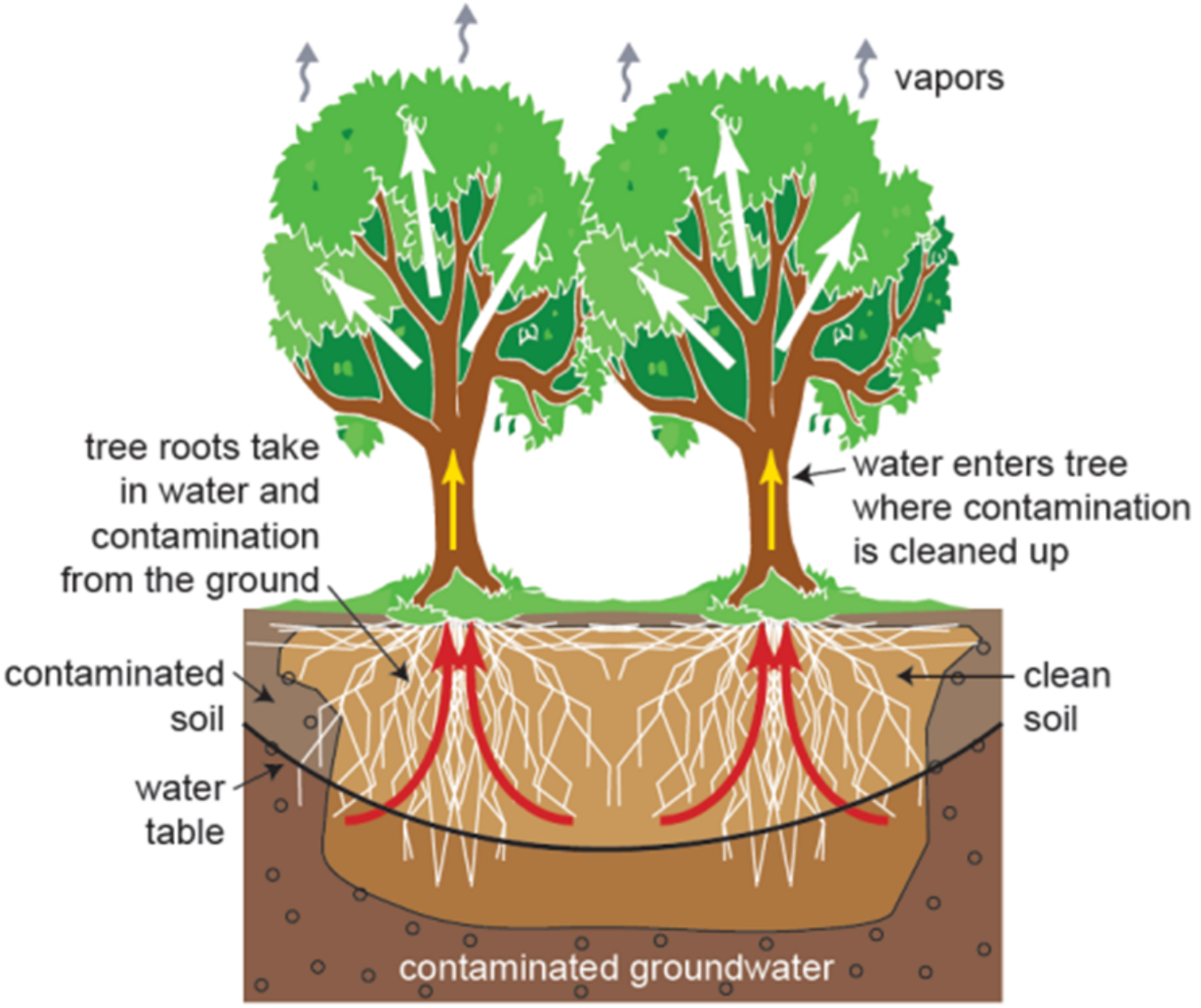


Arsenic Phytoremediation at Superfund Sites

- Many Superfund sites have arsenic-contaminated soils.
- Phytoremediation of arsenic demonstrated at two Superfund sites.
  - Chinese brake fern

Chinese brake fern (*Pteris vittata)*

Site Case Studies

Site Name	Contaminated Media	Phytoremediation Species	Remedy	Final Use
Crozet Township Orchard, Crozet VA	Soil contaminated with lead and arsenic from lead arsenate pesticide	Chinese brake ferns. 20,000 ferns planted the first year.	Phytoremediation with brake ferns was used to treat soil in Area 2, which was not accessible to excavators. Added a very mild nitrogen- based fertilizer, slow-release formula, and put a little lime in to neutralize some of the soil. Ferns were grown for about 5 months until night temps dropped below freezing and plant growth and biomass production ceased. Harvested plants disposed in municipal landfill.	Restored Habitat
Ryland Road Arsenic, Heidelberg Township, VA	Soil and sediment bordering spring-fed creek. Contaminated by past operations of chemical and pesticides companies	Chinese Brake Fern (5,000 ferns in 10 different areas along creek in 2009; 7,200 ferns in 2010; undetermined number of ferns in 2011-2014)	Phytoremediation with Chinese brake ferns used to treat soil and sediment in 10 plots along the spring-fed creek. The plots were located near groundwater seeps.	Restored Habitat

Ryland Road video

Guidance on Soil Bioavailability at Superfund Sites

- May 2017 - EPA released guidance:
  - SOP for In Vitro Bioaccessibility Assay for Pb and As in Soils
  - Validation Assessment of Assay for Predicting Relative Bioavailability of As in Soils at Superfund Sites
- Rapid and inexpensive way to determine arsenic bioavailability and remedy selection
- Both documents online at:

Resources

- CLU-IN Phytotechnologies Focus Area

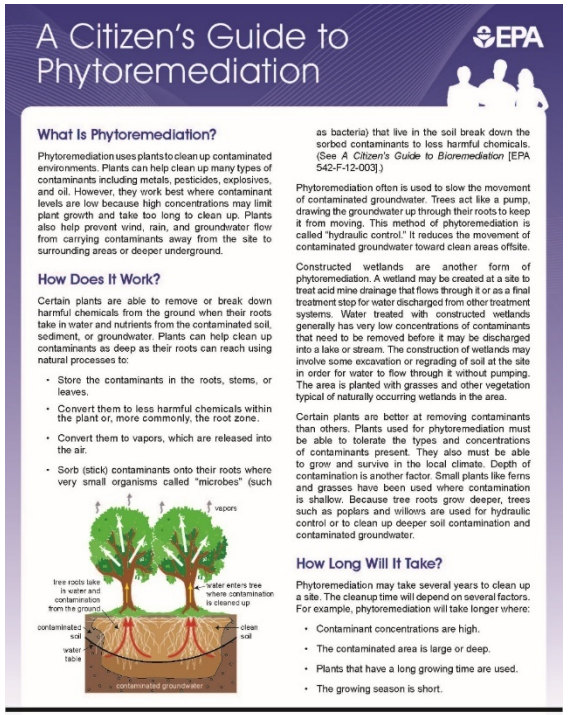
https://clu-in.org/techfocus/default.focus/sec/Phytotechnologies/cat/Overview/

- CLU-IN Ecotools Focus Area

https://clu-in.org/ecotools/

- Guidance on Soil Bioavailability at Superfund Sites

https://www.epa.gov/superfund/soil-bioavailability-superfund-sites-guidance



A Citizen's Guide to Phytoremediation

EPA

What Is Phytoremediation?

Phytoremediation uses plants to clean up contaminated environments. Plants can help clean up many types of contaminants including metals, pesticides, explosives, and oil. However, they work best where contaminant levels are low because high concentrations may limit plant growth and take too long to clean up. Plants also help prevent wind, rain, and groundwater flow from carrying contaminants away from the site to surrounding areas or deeper underground.

How Does It Work?

Certain plants are able to remove or break down harmful chemicals from the ground when their roots take in water and nutrients from the contaminated soil, sediment, or groundwater. Plants can help clean up contaminants as deep as their roots can reach using natural processes to:

- Store the contaminants in the roots, stems, or leaves.
- Convert them to less harmful chemicals within the plant or, more commonly, the root zone.
- Convert them to vapors, which are released into the air.
- Sorb (stick) contaminants onto their roots where very small organisms called "microbes" (such as bacteria) that live in the soil break down the sorbed contaminants to less harmful chemicals. (See *A Citizen's Guide to Bioremediation* [EPA 542-F-12-003].)

Phytoremediation often is used to slow the movement of contaminated groundwater. Trees act like a pump, drawing the groundwater up through their roots to keep it from moving. This method of phytoremediation is called "hydraulic control." It reduces the movement of contaminated groundwater toward clean areas offsite.

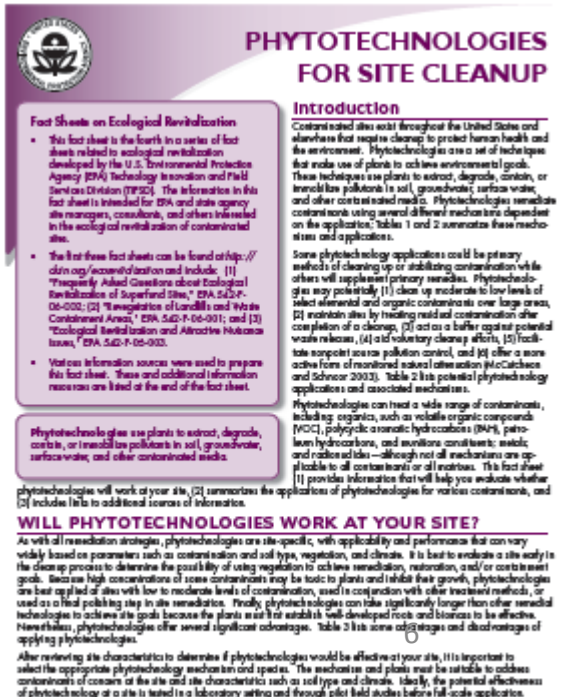
Constructed wetlands are another form of phytoremediation. A wetland may be created at a site to treat acid mine drainage that flows through it or as a final treatment step for water discharged from other treatment systems. Water treated with constructed wetlands generally has very low concentrations of contaminants that need to be removed before it may be discharged into a lake or stream. The construction of wetlands may involve some excavation or regrading of soil at the site in order for water to flow through it without pumping. The area is planted with grasses and other vegetation typical of naturally occurring wetlands in the area.

Certain plants are better at removing contaminants than others. Plants used for phytoremediation must be able to tolerate the types and concentrations of contaminants present. They also must be able to grow and survive in the local climate. Depth of contamination is another factor. Small plants like ferns and grasses have been used where contamination is shallow. Because tree roots grow deeper, trees such as poplars and willows are used for hydraulic control or to clean up deeper soil contamination and contaminated groundwater.

How Long Will It Take?

Phytoremediation may take several years to clean up a site. The cleanup time will depend on several factors. For example, phytoremediation will take longer where:

- Contaminant concentrations are high.
- The contaminated area is large or deep.
- Plants that have a long growing time are used.
- The growing season is short.



PHYTOTECHNOLOGIES FOR SITE CLEANUP

Fact Sheets on Ecological Revitalization

- This fact sheet is the fourth in a series of fact sheets related to ecological revitalization developed by the U.S. Environmental Protection Agency (EPA) Technology Innovation and Field Services Division (TIFSD). The information in this fact sheet is intended for EPA and state agency site managers, consultants, and others interested in the ecological revitalization of contaminated sites.
- The first three fact sheets can be found at http://clu-in.org/ecorevitalization and include: (1) "Frequently Asked Questions about Ecological Revitalization of Superfund Sites," EPA 542-F-06-002; (2) "Revegetation of Landfill and Waste Containment Areas," EPA 542-F-06-001; and (3) "Ecological Revitalization and Attractive Nuisance Issues," EPA 542-F-06-003.
- Various information sources were used to prepare this fact sheet. These and additional information resources are listed at the end of the fact sheet.

Phytotechnologies use plants to extract, degrade, contain, or immobilize pollutants in soil, groundwater, surface water, and other contaminated media.

Introduction

Contaminated sites exist throughout the United States and elsewhere that require cleanup to protect human health and the environment. Phytotechnologies are a set of technologies that make use of plants to achieve environmental goals. These technologies use plants to extract, degrade, contain, or immobilize pollutants in soil, groundwater, surface water, and other contaminated media. Phytotechnologies remediate contaminants using several different mechanisms dependent on the application. Tables 1 and 2 summarize these mechanisms and applications.

Some phytotechnology applications could be primary methods of cleaning up or stabilizing contamination while others will supplement primary remedies. Phytotechnologies may potentially (1) clean up moderate to low levels of select elemental and organic contaminants over large areas, (2) maintain sites by treating residual contamination after completion of a cleanup, (3) act as a buffer against potential waste releases, (4) aid voluntary cleanup efforts, (5) facilitate nonpoint source pollution control, and (6) offer a more active form of monitored natural attenuation (McCutcheon and Schnoor 2003). Table 2 lists potential phytotechnology applications and associated mechanisms.

Phytotechnologies can treat a wide range of contaminants, including organics, such as volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH), petroleum hydrocarbons, and munitions constituents; metals; and radionuclides—although not all mechanisms are applicable to all contaminants or all matrixes. This fact sheet (1) provides information that will help you evaluate whether phytotechnologies will work at your site, (2) summarizes the applications of phytotechnologies for various contaminants, and (3) includes links to additional sources of information.

WILL PHYTOTECHNOLOGIES WORK AT YOUR SITE?

As with all remediation strategies, phytotechnologies are site-specific, with applicability and performance that can vary widely based on parameters such as contamination and soil type, vegetation, and climate. It is best to evaluate a site early in the cleanup process to determine the possibility of using vegetation to achieve remediation, restoration, and/or containment goals. Because high concentrations of some contaminants may be toxic to plants and inhibit their growth, phytotechnologies are best applied at sites with low to moderate levels of contamination, used in conjunction with other treatment methods, or used as a final polishing step in site remediation. Finally, phytotechnologies can take significantly longer than other remedial technologies to achieve site goals because the plants must first establish well-developed roots and biomass to be effective. Nevertheless, phytotechnologies offer several significant advantages. Table 3 lists some advantages and disadvantages of applying phytotechnologies.

After reviewing site characteristics to determine if phytotechnologies would be effective at your site, it is important to select the appropriate phytotechnology mechanism and species. The mechanisms and plants must be suitable to address contaminants of concern at the site and site characteristics such as soil type and climate. Ideally, the potential effectiveness of phytotechnology at a site is tested in a laboratory setting and through pilot field studies before full-scale application.