Phytoremediation of Wood Preservatives

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RESEARCH ADVANCES

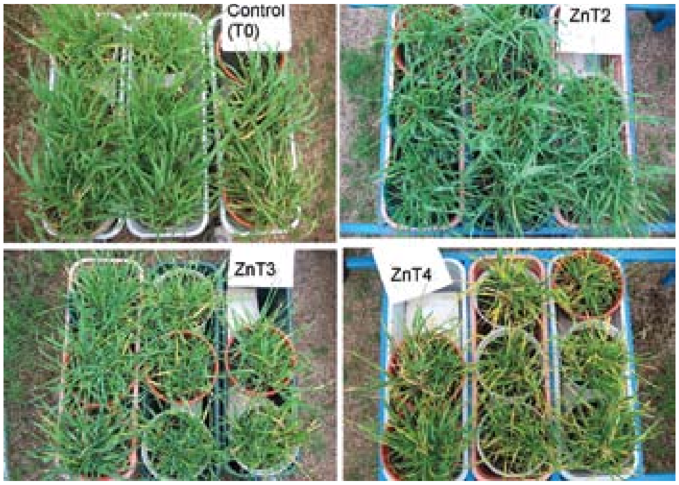
Forest & Wildlife Research Center

Soil and waste contaminated with wood preservatives have been found in many former and active wood treating plants, resulting from past practices and accidental spillage. During the spring of 2001, newspaper articles in Florida raised a public alarm over the perception that arsenate from CCA (chromated copper arsenate) treated wood–used in playground equipment– was leaching into soils and potentially into groundwater reserves. As a result, CCA treated wood was voluntarily taken off the market by the industry. Physical removal of contaminated soils followed by treatment technologies–soil washing, solidification and stabilization, chemical treatment,vitrification, thermal desorption, electrokinetics, and incineration–is not a cost effective soil cleanup method for heavy metal contaminated water. The most common technologies include: coagulation/ filtration (activated carbon), lime softening, chemical treatment, reverse osmosis, ion exchange, electrochemical reduction, and activated alumina, all of which are expensive and in some cases sludge disposal could create additional problems.

Phytoremediation is a promising clean-up method which uses plants for soil and water decontamination. Results from phytoremediation studies appear to be comparable to traditional cleanup methods such as land farming and offers protection against erosion, maintains proper soil conditions, and is less laborious than land farming. Phytoremediation provides four avenues of approach for contaminated areas: 1) enhanced microbial degradation of contaminants within the rhizosphere, 2) hyperaccumulators where plants uptake and store harmful contaminants, commonly heavy metals, in their roots and shoots, 3) rhizofiltration where plant roots absorb, concentrate, or precipitate heavy metal ions from water and, 4) phytovolatilization where plants uptake volatile organic compounds (VOCs) in groundwater allowing them to be released into the atmosphere via the stomata openings.

Surface waters and shallow aquifers were the first sites where plants were applied as a method of cleanup. Many different plants and trees can remove or degrade toxic pollutants. The primary disadvantage in using trees for environmental cleanup is the time needed for tree growth. Faster growing flora like grasses may be suited for some situations. Although the roots of grasses do not penetrate the soil at the same depths as tree roots, they can proliferate within the topsoil. Most herbaceous plants only produce roots within the first three feet of soil. Alfalfa, in contrast, can produce roots that will extend to a depth of six feet.

Phytoextraction could provide an alternative clean-up option that would be as simple as growing plants in a field. This technology would reduce the chance of off-site movement of contaminants and reduce the potential for litigation. This system would further protect groundwater systems from the risk of contamination.



Successful application of phytoextration to remediate heavy metal contaminated soils depends on many factors, among which are plant biomass and metal concentration. Plants must be able to produce sufficient biomass while accumulating a high concentration of target metals. In addition, phytotextraction species should be responsive to agricultural practices designed to enhance metal accumulation and to allow repeated planting and harvesting of biomass. Furthermore, it is important to understand the availability and phytotoxicity of metals to the plant themselves. Another potentially significant approach to heavy metals remediation is the use of plants that detoxify metals in situ through plant-based chelation, reduction, and/or other mechanisms.

One area of our environmental research has been focused on the phytoremediation of organic and inorganic wood preservatives in soil and water.

The phytoextraction of different heavy metals by numerous plant species was monitored through remote sensing. A growth restricted brake fern was used to remove arsenic, chromium III, and chromium VI from soil treated with either arsenic or chromium. Brake fern is a patented, well-known hyperaccumuluator of arsenic. The results found a high translocation efficiency for arsenic, but low for chromium. Few structural changes were observed in the arsenic treatment but chromium resulted in significant structural damage in the leaves, stems, and roots of the ferns. In addition, this research evaluated the phytoextraction of cadmium and zinc by barley and Indian mustard and Cr, Cesium (Cs), Strontium (Sn), and As by Indian mustard.

Soil Studies

In a greenhouse study, use of winter (ryegrass) and summer (alfalfa) plants for remediating an organic wood preservative contaminated soil resulted in a significant reduction of contaminant concentration. Both alfalfa and rye grass significantly improved microbial populations, a necessary requirement for remediation of contaminated soil.

Another study determined which species of trees and grasses indigenous to the southeastern region could be used to stimulate degration of the wood preservative pentachlorophenol in contaminated soil. The PCP-contaminated soil came from a wood treating site located in the Southeast. Trees, grasses and winter cover crops were planted in different levels of contaminated and clean soil and monitored for survival, growth, root development and reduction in PCP. In the initial screening study, out of eleven tree species only loblolly pine, water oak, mimosa, bald cypress, and pond cypress survived. Microbial enumerations found no fungi and very few bacteria indicating that this soil was close to sterile. Another screening of winter cover crops including hairy vetch, crimson clover, arrowleaf clover, rape, annual rye, and perennial rye and Switchgrass, gammagrass and Indiangrass determined that only hairy vetch germinated and grew, while annual rye would grow if transplanted, but would not germinate. PCP is a potent plant toxin and the use of phytoremediation for PCP soils appears to be restriced to low PCP concentrations and would likely not be successful on wood treating sites.

Process water study

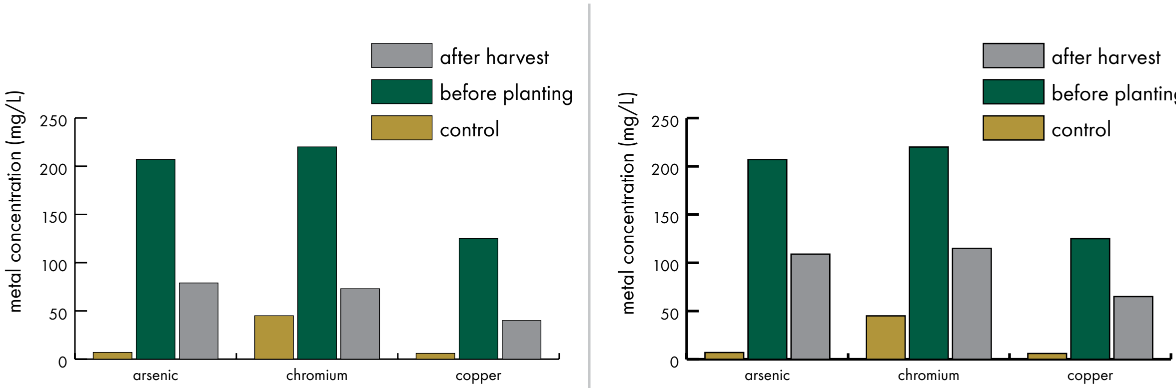
One study evaluated if wetland plants could reduce Biological Oxygen Demand (BOD) levels—an indicator of available oxygen and organic matter content—in Oriented Strand Board (OSB) process waste water. Water hyacinth, Chinese water chestnut, Azolla, Small duckweed, Bulrush, Beak-rush, Soft rush, Bald cypress and Black Willow were screened for survival in high BOD process waste water. Chinese water chestnut, Small duckweed, Soft rush, and Water hyacinth survived the initial screening study and were further evaluated. Two clumps of each plant type were placed in fiberglass tubs containing OSB process waste water or natural lake water. Treatment one consisted of floating plants and treatment two consisted of emergent plants. After 75 days the BOD levels were reduced by 84% in the floating plants compared to 96% in the emergent plants.

Removal of heavy metals from drinking water is also a major concern. A study evaluated several aquatic plant species for removal of copper, chromium and arsenic in hydroponics studies. Results from these on-going studies have indicated excellent arsenic, chromium, and copper removal by duck weed. Parrot feather also removed these metals. Water hyacinth could only remove chromium and showed a poor removal efficiency for As and Cu.

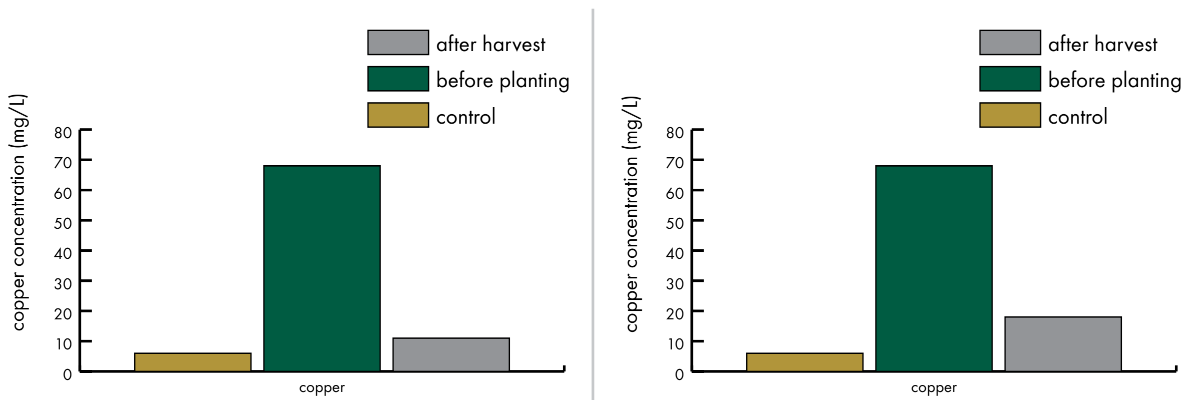
Ryegrass roots in clean soil (left) versus those in creosote contaminated soil (right) after 90 days.

Table 1. A comparison of soil PCP concentrations of water oak (Quercus nigra L.) trees planted on Day 0 and Day 148.

Soil Description	PCP Concentration (ppm) Day 148	PCP Concentration (ppm) Day 0
	Clean Soil	Clean Soil
Control (Clean Soil + Horse Manure/Sand)	Average 0.16	Average 1.11
	Contaminated Soil	100% Contaminated Soil
2,500 ppm + Clean Soil/Horse Manure/Sand	Average 2,778.3	Average 4,500



Average metal concentration of arsenic, chromium, and copper in CCA contaminated water before planting and after the harvest of duckweed (left) and parrotfeather (right).



Average concentration of copper in copper contaminated water before planting and after the harvest of duckweed (left) and parrotfeather (right).

Future Research

Root exudates seem to play an important role in phytoremediation of organic and inorganic chemicals in making chemicals of interest more phyto-available. Identification of some of these beneficial exudates could be of great value to researchers looking for suitable substitutes for chelators that are currently being used.

A new technology, TimTek, utilizes fast-growing, low-value logs to produce engineered-wood products. During the production cycle, some process water from crushing logs and condensate from the press cycle are generated. Scientists are researching phytoremediation as a potential remedy for treatment of this type of wastewater.

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