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Editor's Note Advancement of Phytoremediation

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EDITORIAL

ADVANCEMENT OF PHYTOREMEDIATION

Phytoremediation has been considered as a technology for cleansing contaminated soil and water for only a little more than a decade. The earliest work focused upon metals accumulation in plants, in particular, the search for hyperaccumulators. From that work the concept of using plants in remedial efforts grew and new approaches that looked at other plant interactions with contaminants including organic pollutants were investigated. A number of studies followed that investigated other plant/contaminant interactions including uptake of organic compounds, plant metabolism of organics, resistance to metal-toxicity, enhanced rhizosphere degradation, and others. Through these endeavors and evaluating related research in the area of plant/herbicide interactions for agrochemicals, a better understanding of how plants interact with their environment and contaminants in that environment was achieved among researchers working in the infant field of phytoremediation. The progression of research and the findings gathered led to a number of full-scale phytoremediation applications to address various contaminated sites. These initial sites have provided more information regarding the use of plants for remediating contaminated soils and waters.

While the initial search for information regarding plant/contaminant interactions in various combinations and settings continues, a new series of experimental undertakings are being or have been conducted with the goal of engineering and enhancing the mechanisms involved in phytoremediation. The enhancement of the natural mechanisms is undertaken in hope of speeding the rate of remediation, changing contaminant fate, and making phytoremediation more widely applicable in terms of locations where it can be used and the contaminants that can be treated. These studies have included microbial inoculations, plant and microbial genetic engineering, soil amendments with the vegetation, and varied planting methods. For example, the search for hyperaccumulators found a variety of plants that could accumulate different metals; the availability of the metals and the limited biomass production of most hyperaccumulators have limited the effective use of hyperaccumulators for metals-contaminated sites, however. Some studies have focused on increasing metals availability so that uptake can be increased, but then toxicity can be an issue. Utilizing molecular genetics and plant breeding, endeavors are under way to generate high-biomass plants that can accumulate and withstand high levels of metals. Other studies have the objective of using genetically engineered plants that can uptake, degrade, store, or simply survive higher levels of contaminants than the ‘‘unengineered’’ species. A series of studies have achieved the incorporation of microbial enzymes into the plant genome that can alter the form of mercury to a volatile, less toxic form following uptake by the plants (specifically, tobacco plants in the initial work). Other research endeavors have looked at increasing the expression of existing plant enzymes such as cytochrome P450 that are involved in metabolism of anthropogenic organic compounds. Other research has looked at engineering the rhizosphere by inoculating plant roots with contaminant-degrading organisms or by engineering existing root-colonizing bacteria to express enzymes that can degrade compounds of interest. Through these combinations of understanding the natural system and then approaching the system and enhancing it through modern science and engineering tools, the potential applications of phytoremediation is not yet measurable for this still juvenile technology.

This issue of the *Practice Periodical* includes some of the peer-reviewed papers presented at the 2000 ASCE Environmental Engineering Conference held in Kansas City, Missouri, July 23–26. The papers represent the advancing comprehension of plant/contaminant interactions, and include papers that look at the phytoremediation of metals and organics including (MTBE). MTBE has proven to be difficult to treat by more conventional methods, and a treatment technology has not been identified to treat MTBE in situ. The paper presented here shows that phytoremediation of MTBE-contaminated groundwater has potential and deserves more consideration for research and potentially field-scale testing. In controlled laboratory studies, MTBE is shown to be translocated from the contaminated soil and groundwater profile. The fate of MTBE following uptake is discussed and the transfer to the atmosphere is proposed as its major fate. Other papers considering organic compounds, benzene, and glycol-based deicers look at field-scale considerations such as toxicity and fate. One paper shows that secondary effects of the plants such as lower soil-moisture levels and increased redox conditions can greatly impact contaminant degradation. Rhizosphere effects are also shown to be plant-specific as different plants were able to increase degradation of deicing agents, and the impacts of nutrient additions were also delineated. Another paper looks at enhancing the ‘‘natural’’ use of phytoremediation using chelating compounds as chemical amendments to increase the rate of uranium uptake in a phytoremediation setting. This research was also performed with the objective of using natural, biodegradable chelators to maintain the natural treatment aspects of phytoremediation. Through use of appropriate chelators the availability of the uranium can be selectively controlled, maximizing plant uptake and limiting long-term mobility.

In addition to the direct plant/contaminant interaction, plants can be used in water-management applications. Water-management aspects of using vegetation are highlighted in the article on landfill capping. While this application of vegetative systems falls outside the usual phytoremediation applications, it brings about a new branch of phytotechnologies. While divergent from phy-

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toremediation systems, this approach still relies on the plants' inherent properties in an engineered system—in this case to prevent or minimize groundwater contamination rather than treat existing contamination.

Overall the modest sampling of research endeavors represented in this issue shows the diverse nature of current research into phytoremediation and phytotechnologies. The articles herein address a range of topics including organic compounds, inorganic compounds, and water management. These articles also range from precise, controlled laboratory studies investigating plant/contaminant interactions to investigating secondary plant mediated environmental changes to full-scale studies that span multiple acres and look at integrated, engineered systems reliant on plants. Although phytoremediation is a juvenile technology, the understanding and subsequent engineering of the complex plant/microbe/environment interactions is rapidly progressing and being applied to an increasing number of contaminants in a variety of settings.

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