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Department of Horticultural Science
University of Minnesota, St.Paul, MN

Overview of Vol.5, No.2 - Biophysical Techniques for Decontamination

Edward M. Quinn

Soil is a critical component controlling early stages of ecosystem development and is also a key element directing ecosystem maturation. Since ecosystem degradation is nearly always accompanied by poor soil quality, one of the first problems to be addressed in a restoration project is how to restore the soil. Degraded soils can inhibit natural succession or ecological restoration through physical hostility, such as severely compacted soils, deficiency or occasionally, an excess of nutrients and through toxins, which inhibit plant growth (Bradshaw 1997). This section of Volume 5 deals primarily with decontamination of soils that have been degraded by toxins.

There are two main strategies for accomplishing soil decontamination: physical decontamination and bioremediation. Physical decontamination is conducted using techniques such as soil washing and soil vapor extraction. Physical decontamination strategies can be used on a variety of both organic and inorganic toxins, the techniques are readily available commercially, and their efficacy rate is relatively high. However, some drawbacks of physical decontamination techniques are that they are generally conducted ex-situ, resulting in greater site disturbance, costs are high and these methods usually require de-toxification or immobilization of contaminants that were in the soil and after decontamination are present in solvents or other soil cleansing materials.

Bioremediation is the productive use of biodegradative processes to remove or de-toxify contaminants that have found their way into the environment (Crawford 1996). Although intentional biodegradation of wastes has been going on for centuries, it is only recently that serious attempts have been made to manipulate nature's biodegradative capabilities with the intent of developing large-scale applications for cost-effective and efficient environmental restorations. Bioremediation is attractive because it is lower cost than conventional approaches, it often can be conducted in-situ and eliminates the need to de-toxify or dispose of contaminated solvents or other cleaning materials. In spite of these advantages, there are drawbacks to bioremediation as well. Currently, bioremediation strategies have limited application for sites contaminated with metals or other inorganics and overall have not been developed commercially to the extent that physical decontamination strategies have been. Bioremediation also usually requires significantly longer time to decontaminate a site than physical methods and by itself can only remove 70%-90% of the pollutants in a site.

Both physical decontamination strategies and bioremediation techniques are described and evaluated in this section of Volume 5. Scott Boulden describes soil washing strategies and their effectiveness in removing organic and inorganic pollutants. Remediation methods for volatile organic compounds (VOC), which are present at over two-thirds of Superfund sites, are covered by Becki Tlusty with an emphasis on in-situ bioremediation.

The chemical and thermal stability of polychlorinated biphenyls (PCB) made them ideal for use as a fire retardant liquid in hydraulic and compressor fluids, in electrical equipment and heat exchangers in the middle of the twentieth century. Unfortunately, the properties that made PCB's such a boon to industry have also allowed them to persist and accumulate in the environment. Techniques to physically detoxify PCB contaminated sites are known to be effective. Neal Hines explores the developing arena of bioremediation for these recalcitrant chemicals which is showing significant promise in field studies.

During this century, the nearly exponential demand for petroleum as an energy source and as raw material for the chemical industry have caused petrochemicals to become some of the most ubiquitous pollutants. Correspondingly, detoxification of sites contaminated by hydrocarbon compounds was addressed by more authors (3), than any other subject in this section. Kathleen Bennett summarizes two techniques for in-situ treatment of benzene contaminated sites: soil vapor extraction, and biodegradation enhancement using aerobic and anaerobic pathways. Diane Hellekson addresses the current uses, equipment designs and potential future applications of bioventing, an in-situ bioremediation technique. David Heiser explores the efficacy of three bioremediation strategies in Arctic and Antarctic environments where the extraction, transport or use of petroleum products has resulted in spills and leaks that have contaminated terrestrial and marine environments. These areas are particularly challenging because extremely low temperatures can hamper soil detoxification efforts.

Although a variety of decontamination strategies and pollutants were covered in this section, a number of common themes were evident. For example, all of the authors noted the importance of conducting a careful site assessment to provide the information necessary to select the strategies that have the highest probability of success while ensuring that other negative ecological impacts are not incurred in the clean-up process. Some of the factors to be considered in the assessment are the distribution, levels and types of contaminants, the composition and texture of the soil, the location and depth of groundwater and the presence or absence of indigenous microbe populations.

In-situ bioremediation is currently receiving a great deal of attention in the research community and that elevated interest was clearly mirrored in the number of papers that emphasized this technology as a means to decontaminate soils. As noted earlier, bioremediation has some distinct advantages over more traditional methods, such as significantly lower costs, little site disturbance and the elimination of the need for secondary decontamination of soil cleansing materials. However, there are certainly instances where the types of pollutants present, or the need to detoxify the site in a relatively short period of time make physical decontamination methods the preferred alternative. In fact, because all current remediation techniques are less than 100% effective, several authors noted that a combination of strategies is likely the most effective means for removing the greatest amount of pollutants from a site.

The efficacy and rate of site decontamination varies significantly among the strategies described in these papers. Although no direct comparison of all the techniques presented was made, several papers evaluated two or more methods. The efficiency and speed with which a particular technique can detoxify pollutants will be especially critical to consider when selecting appropriate options for a specific site.

Although several types of toxins were addressed in this collection of papers, only one discussed decontamination of sites polluted with metals (see Boulden's paper on soil washing). Toxic metals are a unique group of environmental pollutants. Unlike carbon-based compounds, metals cannot be degraded but only changed from one form (oxidation state) to another. Therefore, unless they are completely removed from a system, they will persist indefinitely. This means that bioremediation strategies for metal contaminated sites focus on isolating the metals from the biological components of the ecosystem or mobilizing them so that they can be "flushed" from the system using hyperaccumulating plants for consolidation and removal (Crawford 1996, Roane et al. 1996). Some of these strategies can be found in the papers in Section 5.4 Phytoremediation Applications and in Section 5.5 Case Studies of Terrestrial Decontamination of this volume of Restoration and Reclamation Review. Detoxification of metal contaminated sites is probably the greatest challenge currently facing both physical decontamination and bioremediation technologies.

Decades of manufacturing and industrial development in both urban and rural areas of the United States have left some lands ecologically degraded and contaminated with a vast array of organic and inorganic chemicals. These sites, called brownfields are abandoned, idle or under-utilized lands that are not being restored or redeveloped because of perceived or real environmental contamination. Environmental consequences of brownfields include continued new development into natural areas or uncontaminated disturbed sites as well as inhibited natural succession or restoration of the brownfield sites themselves. The papers in this section describe and evaluate strategies for decontaminating soils on these areas which is the first step toward redevelopment of the site for commercial purposes or to initiate ecological restoration. A number of brownfield reclamation projects have already been completed which have allowed economic redevelopment of sites, thus saving other more natural areas from impact by new development and some sites have also been redeveloped into open space areas for outdoor recreation, such as golf courses (Goodwin 1999). Current and future physical decontamination and bioremediation technologies will continue to play significant roles in reclaiming brownfields for economic redevelopment and natural area restoration.

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