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*Using **in situ** bioremediation to destroy pesticides in impacted soil is a cheaper, more permanent alternative to "dig-and-dump" treatment methods*

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As urban centers grow in size, substantial areas of agricultural and industrial land are being converted to residential use. One of the issues frequently encountered when such a change in land use is implemented is the presence of elevated concentrations of chlorinated pesticides and herbicides historically used in agricultural crop production.

Understanding the Problem

Where possible, pesticide-contaminated soil is often excavated and transported to an off-site landfill for disposal ("dig and dump"). Given the large amount of soil generally involved (commonly between 1,000 and 2,000 tons per acre), however, the cost of removing it is substantial, and in some cases, prohibitive. For example, the total cost for excavation, transportation, disposal, and backfilling is generally between $125 and $250 per ton of soil. This equates to a cost of $125,000 to $500,000 per acre.

Even if such a cost were borne by the developer, other problems with the dig and dump approach must be considered. For example, assuming a 25-acre housing development, a total of over 3,000 truckloads of soil would likely need to be hauled out — often through residential areas. Furthermore, an additional 3,000 loads of clean soil would need to be hauled back into the site for backfill. This amount of truck traffic can do a lot to irritate residents of neighboring communities. Finally, the potential for industrial and other types of accidents must be considered a significant downside to this approach.

When stepping back from the financial and technical aspects of such a task, one may also question whether the dig-and-dump approach is responsible in this world of limited resources, increased focus on sustainable development, and concern about greenhouse gas emissions. After all, once the contaminated soil has been dug, hauled, and dumped, it is still contaminated and the potential risk it poses to the environment and human health has just been relocated, not eliminated.

One main reason that lower-cost treatment approaches, such as *in situ* soil bioremediation, have not been more commonly applied to these settings relates to the general recalcitrance of most chlorinated pesticides and herbicides. These types of contaminants can be very challenging to remediate. Common examples include DDT, toxaphene, dieldrin, lindane, and 2,4,5-T. These agricultural chemicals were quite effective as insecticides and herbicides; however, they are persistent under typical surficial environmental conditions. The half-lives for most chlorinated pesticides in agricultural soils are in the range of many months to many years[1]. Hence, natural processes can require several generations to reduce the pesticide's concentration to levels acceptable for residential land use. Use of simple soil remediation methods, such as nutrient supplementation, composting, or microbial inoculation, have not been widely effective in removing these residuals from soil. In fact, many in the site remediation industry remain under the impression that soil contaminated with chlorinated pesticides can only be physically removed (e.g. dig and dump) or effectively treated using very expensive thermal technologies. As a result, some form of effective *in situ* active remediation is needed to allow sites to be developed in a timely manner.

Some Historical Background on Bioremediation

Bioremediation, in some form, has been applied to contaminated soils and other wastes for at least 35 years. During the 1970s, the primary focus was on treatment of materials contaminated with petroleum hydrocarbons. In the 1980s, much energy was devoted, albeit with relatively little success, to bioengineering specialized bacteria capable of increasing decomposition rates and extending application to more resistant compounds such as pesticides and PCBs. During the 1990s, the focus again shifted to understanding and modifying physical and chemical conditions to maximize the activity of native microbial populations. Most recently, the emphasis has been on development of methods and materials for *in situ* generation of strong reducing conditions, which can simultaneously promote both biological and chemical reductive dechlorination processes.

The Advent of *in situ* Chemical Reduction

Bioremediation methods that combine chemical and microbiological processes have been termed *in situ* chemical reduction (ISCR)[2] and have now been successfully applied to surface soils containing chlorinated pesticides and herbicides as well as a wide variety of groundwater environments contaminated with chlorinated solvents, and even most heavy metals (*via* mineral precipitation reactions). One of the most effective variations of the new ISCR approach to bioremediation involves the combination of a metallic reducing agent, such as powdered zero valent iron (ZVI), with a fermentable organic carbon substrate (e.g., processed plant material). The combined approach yields both chemical reducing power, generated as the ZVI corrodes, and biological reducing power, generated as native bacteria grow on the carbon substrate. The fact that two independent contaminant degradation mechanisms are simultaneously stimulated provides a more powerful and reliable treatment approach than that attained when either of the two mechanisms is operative on its own. This approach has proven to be effective and has enabled attainment of drinking water standards in groundwater contaminated with a range of chlorinated solvents. It has also been used to treat surface soils contaminated with chlorinated pesticides, with achievement of residential land use remedial standards.

Application of ISCR to Pesticide-impacted Surface Soils

For application to surface soils, the treatment materials (ZVI and processed plant material) are generally spread onto the surface of the contaminated soil and blended to the desired depth. Once this has been completed, water is added to bring the soil moisture content up to the desired level. At this point, iron corrosion will proceed, resulting in generation of free hydrogen and ferrous iron, which also reduces the redox potential (Eh) in the soil matrix. Simultaneously, native microorganisms will begin to ferment the plant material and convert it to a number of volatile fatty acids (VFAs). At the same time, they consume oxygen and thereby reduce the soil's Eh even further. Under these ISCR conditions, the dechlorination of pesticides proceeds much more rapidly and completely than under natural soil conditions.

A number of large-scale applications of ISCR to pesticide-impacted surface soils have recently been completed in the United States and Canada (*Figure 1*). Representative data from one such application, conducted at a former agricultural site in the southeastern United States, are presented in *Table 1*. Similar results have been attained at other sites and relatively rapid attainment of residential land use criteria has been repeatedly demonstrated. The treatment cost is somewhat variable, based on project size and the degree of pesticide removal required, however most applications can be completed at a cost of between $15 and $30/ton of soil. This equates to a cost of between $15,000 and $60,000 per acre.

Conclusions

While it is tempting to deal with chlorinated pesticide and herbicide-impacted soil with the traditional dig-and-dump approach, it may be worth considering an ISCR bioremediation approach. The typical costs of the ISCR method are roughly 10 percent to 20 percent of the cost of dig and dump. In addition to the substantial cost savings, the contaminants are being destroyed, not just relocated, and the remediation is being

Table 1.

Parameter	Remedial Objective	Initial	Mid-Treatment	Post-Treatment	Final Treatment Efficiency (%)
Diedrin	25	48	34	12	75.0

Influence of in situ chemical reduction bioremediation on dieldrin concentrations in soil. Concentrations shown in parts per billion.

accomplished in a more community and environmentally friendly manner.

References

[1] *Handbook of Environmental Degradation Rates.* Lewis Publishers, Boca Raton FL. Howard, P.; Boethling, R.; Jarvis, W.; Meylan, W.; and Michalenko, E. (Eds.) 1991.

[2] *The Technical Basis for In Situ Chemical Reduction (ISCR). Proceedings of the Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds.* Monterey, Calif. May, 2006. Battelle Press, Columbus OH. Brown, R.A.; Lewis, R.L.; Fiacco, R.J.; and Leahy, M.C. 2006.

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Figure 1

Photograph of soil at a site near Montgomery, Ala. after completion of in situ chemical reduction bioremediation.

e-Sources

U.S. Environmental Protection Agency's Pesticides Home Page
www.epa.gov/pesticides

U.S. Environmental Protection Agency's Technology Innovations Program that provides information about characterization and treatment technologies for hazardous waste remediation professionals
www.epa.gov/tio