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Recent Trends Toward In-Situ Remediation Technologies – Focus on Microbial Processes

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Geoprobe injection of HRC® at a Connecticut site.

In the last 10 years, groundwater remediation technologies have undergone a gradual yet fundamental shift as a result of technological advances and cost-conscious market forces. The typical groundwater treatment regime of 10 years ago typically entailed a highly engineered, expensive, mechanical pumping system offering the ability to pump contaminated groundwater to the surface for ex-situ treatment. These systems often required significant capital investment, engineering, operations and maintenance (O&M). With advances in environmental biotechnology and environmental chemistry, the groundwater remediation industry is becoming more attuned to naturally occurring biological processes and their ability to degrade a wide range of groundwater contaminants in place (in-situ).

The utilization of natural processes and organisms for bioremediation was born in the wastewater treatment industry. Application of these technologies to remediate groundwater in-situ has been shown to be a cost-effective and proven approach. As a result, many government agencies and private parties are actively seeking to optimize existing remediation systems to shorten remedial timeframes and save money. A recent review of 20 Superfund-financed pump and treat projects (EPA 2003) indicates that the average O&M costs per year are $570,000.

Furthermore, the EPA suggests that 85 percent of the pump and treat sites need to be optimized and that 65 percent of the sites should consider alternate technologies. According to the Environmental Business International: Annual Surveys of U.S. Remediation Contractors, trends in groundwater remediation technologies reveal a decrease in overall ex-situ, pump and treat applications, which went from 35.2 percent of remediation systems in 1992 to 12.9 percent in 2002. Conversely, biological treatment (bioremediation) increased during the same time period from 7.9 percent in 1998 to 14.2 percent in 2002. These market indicators convey a message of success for bioremediation which has emerged as a significant part of the groundwater and to some degree soil remediation market.

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Fuss & O'Neill, Inc. has employed numerous remedial technologies at a variety of sites and geologic settings. In recent years, Fuss & O'Neill has initiated in-situ remediation projects at numerous sites in the northeast. These in-situ remedial approaches typically were selected through remedial alternatives evaluations conducted as part of on-going response actions and with regulatory approval. At these sites, in-situ technologies have provided cost-effective, innovative approaches to both contaminant source and plume remediation, by utilizing existing microbial populations and enhancing naturally occurring processes. In-situ technologies also have been utilized in conjunction with other remedial technologies (e.g., pump and treat, excavation). In all cases, proper site characterization and conceptual site model development have been critical to the proper design and success of the remedial approach.

Bioremediation alone is defined as the use of naturally occurring and/or cultured microorganisms to degrade and remove contaminants in groundwater and soil. Enhanced bioremediation is an approach that increases the rate of bioremediation through the addition of performance enhancing ingredients such as oxygen, hydrogen, nutrients, etc. These ingredients, upon addition, are then utilized by the naturally occurring microorganisms to acquire energy, increase populations, and degrade groundwater contaminants. Examples of in-situ bioremediation approaches are provided below.

Enhanced Aerobic Degradation

It is generally accepted that biodegradation of petroleum hydrocarbons occurs most favorably under aerobic conditions and that these processes typically are limited by oxygen deficiencies in the aquifer. In recent years, Fuss & O'Neill has approached in-situ enhanced aerobic degradation of petroleum-contaminated aquifers through the application of Oxygen Release Compound (ORC®). ORC® is a magnesium peroxide solid manufactured by Regenesis of San Clemente, California, that slowly releases oxygen when hydrated. ORC® is applied in the field via Geoprobe® slurry injection and as a component of backfill to excavated areas. Addition of ORC® to backfilled excavations has proven to be an effective means of remediating petroleum hydrocarbons.

Fuss & O'Neill has used ORC® at a number of sites in Massachusetts and Connecticut within the past five to six years. Sites include commercial heating oil storage facilities, state and commercial underground gasoline storage facilities, and a residential heating oil release. Site closure has been achieved at half of the sites, including the residential heating oil release site. At remaining sites, ORC® is one component of a multi-phase approach to site clean-up and remedial actions are ongoing.

Enhanced Reductive Dechlorination

Recently, much research has focused on the role that microbes play in the process of reductive dechlorination under anaerobic conditions in chlorinated VOC contaminated aquifers. Reductive dechlorination is the process by which anaerobic microbes replace chlorine on chlorinated contaminants with hydrogen, thereby systematically reducing contaminants (e.g., chlorinated solvents) to benign end products such as ethane and ethene. This approach has been implemented to solvent contamination at several sites in Connecticut and Massachusetts where primary contaminants include tetrachloroethene (PCE) and trichloroethene (TCE).

Enhanced rates of reductive dechlorination have been achieved through the application of Hydrogen Release Compound (HRC®), which is a polylactate ester manufactured by Regenesis that slowly releases lactic acid to groundwater. The microbial breakdown of lactic acid releases hydrogen to groundwater and facilitates increased rates of reductive dechlorination. In most cases, HRC® was applied to VOC-impacted unconsolidated aquifers via Geoprobe® injection. However, at one site HRC® was applied to backfill material following excavation of a source area.

Most commonly, HRC® is applied to VOC contaminant plumes within unconsolidated aquifers; however, recent data at one of the sites has shown evidence of enhanced reductive dechlorination occurring within the contaminated bedrock aquifer underlying the unconsolidated aquifer treatment zone. Fuss & O'Neill's first full-scale application of HRC® was completed at a Connecticut site in 2002. At this site, significant reductions in VOC concentrations have been achieved in a dense till aquifer where pump and treat or other active, mechanical system would be expensive and difficult to design, install, and operate.

Metals Immobilization/Enhanced Reductive Dechlorination
Fuss & O'Neill is in the process of conducting pilot scale testing of Metals Remediation Compound (MRCTM) at two sites in the northeast – one in eastern Massachusetts and one in upstate New York. Both sites include source areas were chlorinated VOCs are co-mingled with dissolved metals contamination. The eastern Massachusetts site is a former plating facility where the primary metal of concern is nickel and prominent VOCs include 1,1,1-TCA, TCE, and PCE. The New York site is a former manufacturing facility and remediation is being carried out as part of the New York State brownfield program. Constituents of concern include dissolved metals such as copper, nickel, chromium, zinc and lead as well as chlorinated solvents TCE and 1,1,1-TCA.

MRCTM is a non-toxic formulation designed to release a polylactate polymer and a benign organosulfur compound to groundwater thereby facilitating enhanced reductive dechlorination of chlorinated VOCs and the formation of insoluble metal-sulfide solids to immobilize dissolved metals. In essence, this product utilizes the properties of HRC® to stimulate microbial activity and establish reducing conditions in the aquifer favorable to both the degradation of chlorinated contaminants and the formation of organosulfide solids that complex and immobilize dissolved metals. Pilot-scale results will determine whether a site-specific MRCTM treatment program could be designed to cost effectively address co-mingled VOC and metals plumes at these sites.

In Conclusion
In-situ technologies such as those discussed in this article can provide effective means of reducing, destroying, and/or detoxifying contaminants. Given proper site characterization, remedial design, and performance monitoring, these approaches have the potential to meet remedial objectives in a cost-effective manner with little site disturbance and minimal infrastructure requirements. Furthermore, effective in-situ remediation can eliminate the need for and potential liabilities associated with abovegrade management/off-site disposal of contaminated media.

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