BIOATTENUATION/BIOREMEDIATION

Site Evaluations

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Recent research has revealed that soil microorganisms capable of metabolizing chlorinated compounds like PCE and TCE are widespread in a variety of subsurface environments. These microbes are commonly referred to as dechlorinators, or halorespirors. They utilize chlorinated compounds in a respiratory process similar to the way humans utilize oxygen to drive metabolic functions.

At many sites, the activity of halorespirors and other microorganisms that contribute to contaminant degradation is slow but sufficient to reduce contaminant concentrations to below risk levels before impacting nearby receptors (e.g., wells, rivers, lakes, wetlands, etc.). These sites are often prime candidates for monitored natural attenuation (MNA), risk-based remediation (e.g., contaminant management) strategies.

Conversely, at other sites the activities of halorespirors, and therefore the rates of contaminant degradation, are limited by a lack of available sources of energy, or food. If such energy sources are artificially provided in favorable quantities, degradation rates may be accelerated significantly above those observed under natural conditions. The process of delivering energy sources to the subsurface for the purpose of accelerating bioactivity is referred to as "bioenhancement". Bioenhancement strategies are low cost, and being used with increasing frequency for successful remediation of sites impacted by chlorinated solvents.

The soil microbial communities native to a few sites lack significant populations of halorespirors that are capable of transforming chlorinated compounds completely to harmless end products. By injecting the subsurface with enrichment cultures containing the requisite microbial species and populations, it may be possible to improve the occurrence and rates of dechlorination. The "inoculation" of site sediments and groundwater with dechlorinating enrichment cultures is referred to as "bioaugmentation". Bioaugmentation is a relatively new concept, but one that has proven successful at several sites contaminated with solvents. Very few environmental consulting firms can claim to have the expertise to implement this technology effectively. MD&E is one of the select firms with such expertise.

Since the late 1990s, many sites that have been undergoing active remediation by such means as pump and treat and SVE have been re-examined for *in-situ* bioremediation potential. Numerous cases have been documented in which Record of Decisions (ROD) or Consent Orders have been re-opened to permit the implementation of low-cost, low-maintenance, alternative remedial strategies such as MNA, bioenhancement, or bioaugmentation.

To evaluate a site for bioremediation potential and establish a credible technical case for promoting an *in-situ* microbiology-based remedial strategy for an existing cleanup project requires the participation of professionals knowledgeable and experienced with the science and engineering of these technologies. It also requires practitioners who have intimate knowledge of the regulations applicable to the site, and are familiar with the regulatory community and culture of the region.

Any site currently undergoing remediation should be subject to periodic (e.g., annual, bi-annual) systematic evaluations aimed at optimizing remedial action objectives and technology applications. This establishes a check and balance process that improves treatment and cost efficiency. For sites that have not been scrutinized through an optimization evaluation, or for those for which evaluations did not focus on alternative remediation strategies, the following process may be quickly undertaken to assess the efficacy of bioremediation cleanup alternatives:

1. Examine existing monitoring data for evidence of natural attenuation.

2. Characterize site for bioenhancement/bioaugmentation potential (*see attached table for typical list of analyses and the rationale for their acquisition*).

3. Develop ROD/AOC-amendment strategy.

ANALYTICAL CATEGORIES/PARAMETERS	**MEDIA**	
	Groundwater	***Soil***
Field Measurements		
pH	X	X
Dissolved Oxygen	X	X (soil gasses)
Eh or Oxidation-Reduction Potential	X	
Specific Conductance	X	
Dissolved Hydrogen	X	X (soil gasses)
Carbon Dioxide	X	X (soil gasses)
Methane		
Redox Indicator Parameters		
Nitrate	X	X
Sulfate	X	X
Total Iron	X	X
Ferrous Iron	X	X
Total and Dissolved Manganese	X	X
Ethene	X	X
Ethane	X	X
Methane	X	X
Hydrogen Sulfide	X	X
Volatile Fatty Acids (e.g., lactate, acetate, propionate, etc.)	X	
Nutrient Load Indicators		
Total Organic Carbon	X	X
Total Inorganic Carbon	X	X
Dissolved Inorganic Carbon	X	X
Total Phosphorus	X	X
Total Kjeldahl Nitrogen	X	X
Ammonia	X	X
Total and Specific Cations/Anions (Ca^{+2}, Cl^-, Mg^{+2}, K^+, Na^+)	X	X
Microbiology/Genetics		
Colony Forming Units	X (per mL of groundwater)	X (per gram of dry soil)
SSU rRNA gene probes (RT-PCR)	X	X
Engineering Optimization Parameters		
Alkalinity (bicarbonate)	X	X
Hardness (calcium carbonate)	X	
Total Dissolved Solids	X	
Total Suspended Solids	X	
Oil and Grease	X	
Grain Size Distribution		X
Moist and Dry Densities		X

Red X indicates a critical parameter. All other analyses are recommended, but are not essential.