

## Microbial Responses to Long-Term Restoration and Sustainability of Sub-Surface Contaminants

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### Editorial

The BP 200-million gallon oil spill at the Gulf of Mexico and many others in the past made headlines because of their magnitude and cost to the environment and brought to limelight why microbes matters in these clean-up efforts. In these man-made disasters, we recognized the role microbes could play in long-term restoration of contaminated sites and sustainability of the environment. With a focus on Light Non-Aqueous Phase Liquids (LNAPLs), which also include crude oils, this editorial comment highlights these microbial advantages and how best to maximize their benefits.

LNAPL contamination has historically been perceived as a significant environmental threat by the general public and the regulatory community. New assessments that provide the critical information necessary to evaluate and define clean-up goals for LNAPL are needed. A major obstacle is the recovery of the residual and free phase fractions that are trapped due to capillary and interfacial forces. This implies that conventional pump and treat methods will require excessive energy and costs to for extraction of excessive pore volumes of the groundwater to recover the trapped phases due to mass transfer limitations (ACS symposium series).

Treatment options such as those utilizing natural processes have been found to be efficient and cost-effective. For example, other well-known natural processes such as in: nutrient cycling of nitrogen, phosphorus, sulfur, carbon dioxide, and water; flow of energy through the various trophic levels of the ecosystems; and natural attenuation of pollutants have served as the underlying template in the sustainability of the ecosystems around the world. By understanding and enhancing these important natural processes, the need for cost efficiency and sustainability has now emerged as the underlying factors for measuring remediation processes and assessment of environmental quality.

The inherent ability of microbes to biodegrade organic contaminants such as LNAPLs can be enhanced through processes that combine the use of surfactants, enhanced mobilization, biostimulation, mineralization, and bioaugmentation indicating the growing importance for a better understanding and use of these emerging biotechnologies. For example, the combined use of surfactants can significantly enhance the rate of extraction of LNAPLs from groundwater due to increased solubility of the aqueous phase that result from the presence of surfactant micelles.

### Limiting Factors

A number of limiting factors have been recognized to affect the biodegradation of LNAPLs, many of which have been extensively described in literatures. The composition and inherent biodegradability of the LNAPL hydrocarbon pollutant is the first and

foremost important consideration when the suitability of a microbial-system approach is to be assessed.

Among physical factors, temperature plays an important role by directly affecting the chemistry of the pollutants as well as affecting the physiology and diversity of the microbial flora. There is abundant evidence that at low temperatures, the viscosity of the LNAPLs increased, while the volatility of the toxic low molecular weight hydrocarbons were reduced, delaying the onset of biodegradation. Temperature also affects the solubility of hydrocarbons. Although hydrocarbon biodegradation can occur over a wide range of temperatures, the rate of biodegradation generally decreases with the decreasing temperature. A consensus of opinions from literature show that highest degradation rates occur in the range 30-40°C in soil environments, 20-30°C in some freshwater environments and 15-20°C in marine environments.

Nutrients are key to ensuring a robust sustained microbial growth for successful biodegradation of LNAPL contaminants especially nitrogen, phosphorus, potassium (NPK), and in some cases iron. Some of these nutrients could become limiting factor thus affecting the biodegradation processes. The role of nutrients in biodegradation is closely tied to the soil type. Natural soils consist of particles of different sizes, which imply that the pores in the soil matrix are of different sizes. Some of the pores in soil materials are smaller than the indigenous bacteria and therefore inaccessible for them. In the pores that are accessible for bacteria, bacterial growth can be limited by slow mass transfer of nutrients and organic substrate. This means that the organic content of a soil determines to a large extend how much of the LNAPL will adsorb to the soil particles.

Soil moisture content also plays a critical role in microbial degradation of hydrocarbons. Due to the bacterial metabolism, which utilizes water, soil moisture content has a significant effect on biodegradation rates. The implication is that aerobic degradation may be most active in the capillary fringe of a soil, though it can be limited by several local conditions.

### Is Biological Remediation Right for Your Site?

Microbial remediation is not a viable option for every site. An initial site characterization is highly recommended to determine whether microbial remediation will be an effective treatment of choice. Among others tests, a typical site characterization should include the following: analysis of nutrient availability to ensure that the site has the necessary nutrient sources (such as nitrates, phosphates, carbon source, and minerals) to support the microbial species; sequential extraction processes to determine the bioavailability of the pollutant for effective treatment; analysis of soil acidity/alkalinity to determine if the addition

of fertilizers and aeration will be necessary to support the growth of microbes; determination of the chemical form of the LNAPL species; and identification of which microbial species are best suited to the LNAPL contaminated site.

## Resources

Additional information on microbial degradation of hydrocarbons and bioremediation technologies can be found at the following web sites:

- <http://www.nal.usda.gov/bic/Bioremed/bioremed.htm>

- EPA Office of Research and Development (ORD) Bioremediation Documents
- <http://www.epa.gov/ord/WebPubs/bioremed/index.html>
- <http://www.epa.gov/tio/download/citizens/bioremediation.pdf> (*A Citizen's Guide to Bioremediation*)
- <http://www.epa.gov/tio/pubitech.htm>
- DOE Natural and Accelerated Bioremediation Research (NABIR)
- <http://www.lbl.gov/NABIR>
- U.S. Geological Survey, <http://www.usgs.gov>