

PTAC ABSTRACT:
**USING OILFIELD TECHNOLOGY AND IN-SITU BIOREMEDIATION FOR
ACCELERATED SITE REMEDIATION**

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Traditional approaches to site remediation at oil and gas sites include soil excavation and landfill disposal, attempts on site at ex-situ treatment (“bio-piles”), or landspreading and treatment (“landfarming”). These options are often very costly, have limited effectiveness in Canadian climates, or merely transfer contamination to a different location instead of treating contaminants. Natural Attenuation has recently been identified as another option with potential applicability as a remediation strategy at some upstream oil and gas facilities (CAPP, 2002). However, natural contaminant biodegradation rates generally tend to be lower in Alberta than reported for sites in the U.S., and biodegradation capacity is not always sufficient to significantly degrade hydrocarbon concentrations. Natural attenuation of organic contaminants, unless enhanced, is often impractical because it is a slow process.

In the 1990’s, hydraulic fracturing, an oilfield technology used to increase production rates in oil and gas wells, and *in situ* bioremediation were identified as promising techniques (Walden, 1997) to enhance remediation in low permeability soils (i.e. < 100 millidarcys or 10^{-6} m/s equivalent hydraulic conductivity). Motivating factors for the increasing use of *in situ* bioremediation include its non-intrusiveness, cost-effectiveness, and potential for speedy conversion of contaminants to innocuous end products. However, the growing use of *in situ* bioremediation (particularly in the U.S.), has led to the realization that its effectiveness in low permeability soils, such as those that cover much of Western Canada, is limited. This is due primarily to geologic constraints posed by fine grained soils (Lu and Zheng, 2003) that inhibit adequate delivery of substrates and nutrients required for sustained microbial metabolism in the subsurface environment. Specifically, the major limitation for the effectiveness of *in situ* bioremediation is achieving adequate distribution of treatment amendments, electron acceptors/donors, enzymes, etc. beyond the injection point and into the contaminated soil mass (Nyer, 2004). An additional limitation is the inability to accurately map the final placement of injected treatment amendments relative to the distribution of subsurface contaminants.

Hydraulic *Soil* Fracturing (HSF) technology and fracture mapping technology were developed in the 1990’s by modifying conventional oilfield fracturing technology for environmental remediation applications in contaminated, low permeability soils. HSF has been successfully applied to accelerate site clean-ups with conventional remediation technologies. Examples include soil vapor extraction, multi-phase extraction, and pump and treat. Recently, HSF has been identified as a tool not only for permeability enhancement, but also for the delivery of chemical and biological treatment amendments into contaminated soils and groundwater (Sorenson et al, 2002).

The combination of HSF and *in situ* bioremediation is a relatively new remedial approach for commercial applications, as very few sites have undergone fracture-enhanced bioremediation. Hydraulic soil fracturing with simultaneous *in situ* emplacement of bio-amendment, or “Bio-Fracturing”, has been shown to be a powerful remediation tool for soil and groundwater contaminants present in difficult to remediate, low permeability soils such as clays and silts. Bio-Fracturing can be used to enhance the remediation of virtually any organic contaminant (e.g. hydrocarbons, chlorinated solvents) because of the ability to incorporate and deliver a variety of treatment amendments in the fracture slurry .

Bio-Fracturing was evaluated on a pilot scale and subsequently on a full scale application at a U.S. EPA Superfund site near Louisville, Kentucky from 2001 through 2003. The project was sponsored by the U.S. National Science Foundation. Fracturing and simultaneous injection of “chitin”, a slow release solid electron donor, was carried out in contaminated low permeability silts and clays. The primary objectives of the work were to determine if soil fracturing would enhance the geologic formation permeability, and assess the long-term performance of chitin for anaerobically reducing dissolved chlorinated solvents. The distribution and impact of chitin- and sand-filled fractures to saturated, low permeability sediments was evaluated using hydrogeologic, geophysical, and geochemical parameters.

The results indicated that, where distributed, chitin favorably impacted redox conditions and supported enhanced anaerobic reductive dechlorination (ARD) of chlorinated solvents. Soil fracturing also increased the hydraulic conductivity in contaminated sediments by at least an order of magnitude (Martin et al, 2002). Results to the end of 2003 fracturing continue to show redox conditions at the site becoming methanogenic due to chitin-fracturing and therefore more favorable for ARD. Groundwater sampling data show Trichloroethylene and cis- 1,2 Dichloroethene concentrations that have decreased to near or below U.S. EPA maximum concentration limits in all of the original pilot test wells since full scale chitin fracturing at the site in May, 2003. Bio-fracturing was determined to be a viable approach for remediation of chlorinated hydrocarbon contamination in low permeability, variably saturated hydrogeologic systems. Bio-fracturing of petroleum hydrocarbon contaminated soil and groundwater is a much simpler application because most petroleum hydrocarbons are easily degraded under aerobic conditions, provided that the limiting substrates can be effectively delivered. The typical cost of soil hydraulic fracturing per cubic metre equivalent compared to soil excavation and disposal costs is approximately one-fifth or less at most sites fractured to date.

The combination of hydraulic fracturing oilfield technology and innovative *in situ* bioremediation techniques provides site managers with a cost-competitive remedial alternative to conventional remediation approaches. “Bio-fracturing” is an effective approach to significantly accelerate natural attenuation of petroleum contaminants and expedite clean-ups to achieve site closure within reasonable time frames at oil and gas sites in Western Canada.

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