

## LESSONS LEARNED FROM BIOREMEDIATION AND THEIR IMPLICATIONS FOR MICROBIAL ENHANCED OIL RECOVERY

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Over the past three decades, bioremediation has evolved as a viable technique for the transformation and degradation of organic compounds in the subsurface. Bioremediation strategies for the surface and shallow surface have exploited the complete range of microbial respiratory potential from aerobic metabolism through methanogenesis. Bioremediation depends on the initial stimulation or introduction and subsequent establishment of selected microbial populations in a community of microorganisms. Strategies for the management of microbial ecology have progressed from simple, gross stimulation of the microbial community by applications of inorganic nutrients and electron acceptors to the targeted applications of specific growth limiting compounds, electron acceptors or specially selected microbes. Emphasis has advanced from merely monitoring shifts in the microbial community to managing and directing populations' shifts to achieve the desired results. One approach to microbial community management involves injection of high populations of microbes 1) isolated in the laboratory, 2) isolated from other sites or 3) isolated from the target site and increased in the laboratory for reintroduction. Factors used to manage either indigenous or introduced microbial populations in nature include nutrients, electron acceptors, antibiotics, phages, metabolic inhibitors, redox potential, and pH. One interesting nutrient-based strategy employed a nitrogen source available only to special, introduced organisms. This gave the new organisms the competitive advantage needed to occupy the niche and deliver the desired transformations. Electron acceptors can also be used to manipulate microbial ecology. Nitrate for example, is a preferred electron acceptor compared to lower-energy electron acceptors, like ferric iron, sulfate, chlorinated hydrocarbons and carbon dioxide. When nitrate is present, Sulfur Reducing Bacteria (SBR) become less competitive and are then relegated to the lower oxidation-reduction-state micropores of the formation. Likewise, growth conditions such as nutrient concentrations and incubation conditions have been manipulated to foster the production of important microbial products like surfactants, emulsifiers, wetting agents and enzymes that degrade paraffins, reduce viscosity or produced acids and gasses. For example in some microbes, nitrogen limiting conditions induce important lignolytic and peroxidase enzymes for biodegradation. In contrast, deep subsurface applications of these surface and shallow subsurface bioremediation strategies to enhance oil recovery have produced mixed or disappointing results. The recent discovery and characterization of extremophiles from volcanic formations, subsea vents, geothermal outcrops and deeper oil wells has increased our understanding of the deep subsurface environment, the capabilities of their extremophile residents and their potential role in Microbial Enhanced Oil Recovery (MEOR). Management of extremophile communities for MEOR presents unique challenges. This presentation reviews and evaluates successful surface and shallow subsurface bioremediation strategies and discusses their potential applications to MEOR.