Geoelectrical Stratigraphy and Analysis of a Hydrocarbon Impacted Aquifer

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ABSTRACT

A recently proposed geoelectrical model for hydrocarbon impacted sites predicts anomalously high conductivities coincident with aged contaminated zones. These high conductivities are attributed to an enhancement of mineral weathering resulting from byproducts of microbial redox processes. To evaluate this model, high resolution in situ vertical bulk conductivity measurements were acquired from a mature light non-aqueous phase liquid (LNAPL) contaminated site. The geoelectrical stratigraphy showed conductivity maxima coincident with the free phase LNAPL zone, and occurring within the water table fluctuation zone. This zone is inferred as an active zone of biodegradation suggesting significant microbial degradation under partially saturated conditions. A simple Archie's Law analysis reveals that large pore water saturation and/or large pore water conductivity enhancements are necessary to produce the bulk conductivity observed at the contaminated locations. These results support the conductive model and demonstrate the potential of geoelectrical investigations for assessing microbial degradation of mature LNAPL impacted soils.

Notice: The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development (ORD), approved this abstract as a basis for an oral presentation. The actual presentation has not been peer reviewed by EPA.

INTRODUCTION

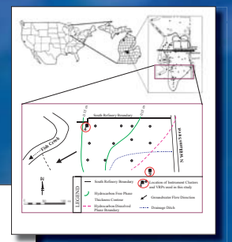
- An electrically resistive response has been the geophysical model for hydrocarbon contamination [e.g., Lien and Enfield, 1998].
- Hydrocarbon impacted sites have shown high conductivities [e.g., Atekwana et al., 2000]
- Conductive layer model links this conductive response to the effects of biodegradation processes [Sauck, 2000].

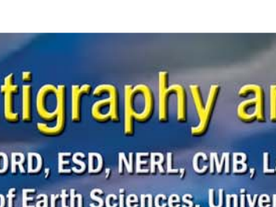
OBJECTIVES

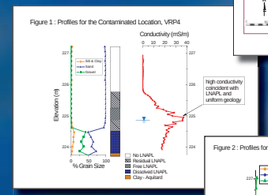
- To evaluate the conductive and insulating layer models and the nature of the geoelectrical response at a site impacted with light non-aqueous phase liquid (LNAPL) contamination.

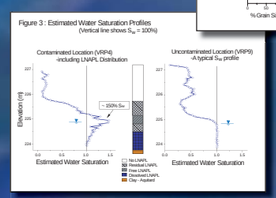
STUDY SITE

- City park adjacent to the former Crystal Refinery in Carson City, Michigan, leaked hydrocarbon since 1945.
- Glacially derived unconsolidated fine to medium grained sands with some gravel overlie a clay aquitard.
- Intrinsic biodegradation is occurring.
- Alkane degrading microorganisms occur in the hydrocarbon impacted zones.
- Methanogenesis occurs within the core of the contamination
- Sulfate, iron, and manganese reduction occur at the fringes of contamination.
- Volatile organic acids and biosurfactants have been detected within contaminated locations.







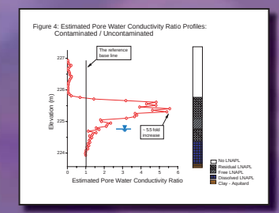


DISCUSSION

- Variations in S_w could not account for the conductivity profiles.
- The conductive layer model required a minimum 5.5 fold increase in pore water conductivity (Figure 4). Is this reasonable?
  1. Cassidy et al., [2001] showed a 6 fold increase during biodegradation of diesel in lab experiments.
  2. Preliminary aqueous geochemistry data show σ_w^c of ~1.4 times greater than uncontaminated [Legall, 2002].
  3. Figure 4 shows a 1.5 fold increase below the water table.
  4. Elevated concentrations of Si, Ca, Mg, Na, $HCO3^-$ at the contaminated locations are consistent with enhanced dissolution of the aquifer minerals [Legall 2002].
  5. McMahon et al. [1995] showed dissolved organic acids from microbial degradation of hydrocarbons positively correlated with dissolved silica.
  6. Elevated populations of oil degrading bacteria have been documented at this site coincident with the zone of elevated conductivity [Werkema et al., 2000].

CONCLUSIONS

- These findings corroborate the conductive layer model and provide an indication into the biologically driven mechanism.
- The vertical position of the high conductivity anomaly occurs in partially water saturated conditions above the water table.
- The fluctuating water table likely smears the LNAPL potentially making it more readily available for microbial activity.
- If the conductivity anomaly is an indirect measure of biological activity through changes in pore water geochemistry, then our geophysical data suggests that the zone of most active biodegradation occurs above the water table and not below as is conventionally studied.



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