Soil Treatability Study

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Natural Attenuation Study FINAL RESULTS

Phase 2: Use of Findings from Bioremediation and Phytoremediation Studies

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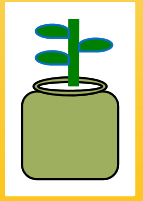
Natural Attenuation Study Phase 2:

Use findings from bioremediation and phytoremediation companion studies for better site-specific analysis

Bioremediation study field results found many known degraders of the contaminants present in SSFL Area IV soils

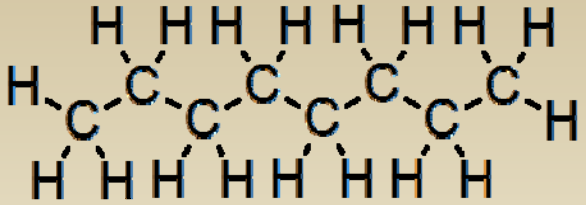
- Cultures isolated on plates
- DNA analyzed by qPCR
- Aerobic conditions prevail in Area IV soils

Bioremediation study results for soil microcosm controls with no additives indicated much slower biodegradation than that predicted from the literature review



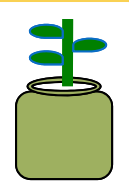
Phytoremediation results also indicate limited contributions of native plants at the site to contaminant degradation

Petroleum Hydrocarbons



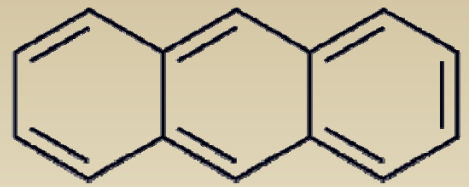
- Field assays identified many species of bacteria and fungi in SSFL soil which have been reported in the literature to biodegrade hydrocarbons

- Rapid biodegradation of extractable fuels hydrocarbons (EFH) by >40% in 126 days was observed for one of the three unamended soil samples
- Little or no biodegradation of petroleum hydrocarbons for the other two soil samples
  - Indicates variability of efficacy of hydrocarbon bioremediation
  - Longer-term microcosm data may be helpful



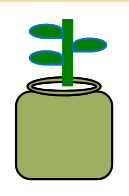
- Phytoremediation microcosms indicated little increase in biodegradation of petroleum hydrocarbons due to plants

Polyaromatic Hydrocarbons (PAHs)



- Analysis of DNA extracted from Area IV soils did not indicate the presence of genes associated with PAH biodegradation

- Microcosm experiments did not show significant PAH biodegradation over a period of 244 days for unamended controls

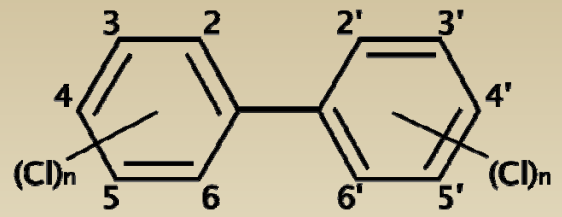


- Phytoremediation study also indicated little or no PAH biodegradation in microcosm soils with plants

➢ Limited PAH biodegradation:

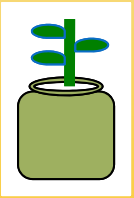
- PAHs remaining in soils at the site have low biodegradability
- PAHs may be sequestered in the soil matrix, limiting their availability to microorganisms (bioavailability)

Polychlorinated Biphenyls (PCBs)



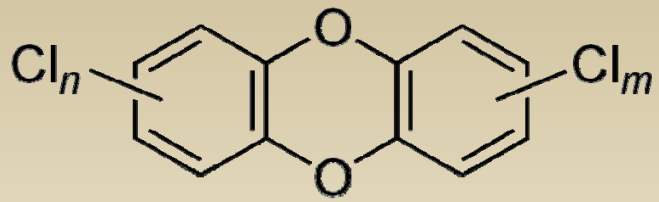
- Bacterial PCB degradation requires anaerobic dechlorination
  - Anaerobic conditions not observed in SSFL Area IV soils
  - Few anaerobic dechlorinating bacteria detected in Area IV soil.
- Fungal biodegradation of PCBs is possible under aerobic conditions
  - Three strains of the white-rot fungi *Phanerochaete chrysosporium* were isolated from SSFL Area IV soils – these fungi reported to biodegrade PCBs

- In bioremediation microcosms, PCB concentrations decreased over the 8 month incubation period, but these decreases were not statistically significant at the 95% confidence level from the sterile controls



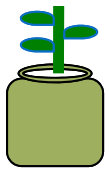
- In the phytoremediation study, soil PCB concentrations also decreased for soil microcosms planted with purple needlegrass and coyote brush.
  - No PCBs were observed in plant tissue, so the mechanism for this reduction appears to be stimulation of microorganisms in the soil

Dioxins (Chlorinated dibenzo-*p*-dioxins and furans)



- Bacterial dioxin degradation requires anaerobic dechlorination
- Fungal biodegradation of chlorinated dioxins is possible under aerobic conditions

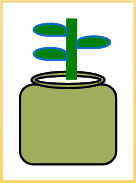
- Only small decreases in dioxin concentrations were observed in the unamended soil microcosms over 244 days of incubation, suggesting slow dioxin biodegradation under natural attenuation conditions
- In bioremediation microcosms microcosms augmented with the fungi *Phanerochaete chrysosporium* chlorinated dioxin concentrations decreased more than in unamended microcosms



- Chlorinated dioxins were detected in plant tissue of purple needlegrass and coyote brush
- Some decreases in soil concentrations of dioxins were observed in planted microcosms

Mercury

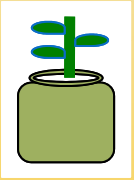
- Mercury does not biodegrade
- Volatilization of elemental mercury and/or methyl mercury is a possible natural attenuation mechanism for mercury removal from SSFL soils
  - Volatilization is likely to be slow
  - Volatilization could create air pollution issues



- Phytoremediation microcosm experiments showed no mercury uptake by the native plants investigated
- Chelation (binding an organic compound to a metal) has been reported to facilitate mercury uptake by plants, but addition of the chelating agent ethylenediaminetetraacetate (EDTA) did not improve mercury uptake by coyote brush

Silver

- Silver does not biodegrade
- Silver does not volatilize from soils



- Some uptake of silver was observed in roots and foliage of one or two species of plants tested in the field and in greenhouse experiments, but the amount of silver accumulated would not warrant use of phytoremediation for silver removal from the soil

Natural Attenuation Phase-2 Conclusions

- Site-specific bioremediation and phytoremediation studies suggest longer estimated times for remediation than originally predicted from published studies.
- Natural attenuation at SSFL is expected to take on the order of decades to reach background concentrations.
- Slow biodegradation rates observed likely the result of weathering:
  - Recalcitrant fractions remain after years of biodegradation
  - COIs may be sequestered in the soil matrix, limiting their bioavailability
- Long predicted remediation times are also the result of the current clean-up goal to reach background levels.
  - Much shorter remediation times would be expected if clean-up goals were set similar to those set for typical past industrial sites.

Phase-2 Conclusions cont'd.

- Natural attenuation should be considered on a case-by-case basis for the different sub-areas in Area IV.
  - Soils with very high contaminant concentrations will likely need to be excavated and hauled off site, but natural attenuation should be considered for soils with lower contaminant concentrations.
  - This could greatly reduce the quantity of soil that needs to be excavated and the many associated environmental impacts of such excavation.
- Although the focus of this investigation was on natural attenuation, the findings suggest that more active bioremediation methods should also be further explored.

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