Soil Treatability Study

Energy Technology Engineering Center • U.S. Department of Energy

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Natural Attenuation Study FINAL RESULTS

Phase 1: Literature Review

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Natural Attenuation

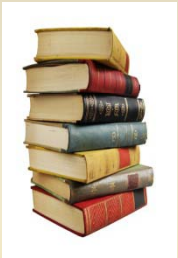
- **Defined as the reduction of contaminant mass through natural biological and abiotic processes**

- **Verified through identification of the mechanisms of these processes and field monitoring**

The purpose of this study was to determine what natural processes may be operative at Area IV to reduce contaminant soil concentrations and to estimate what rates of biodegradation could be expected in the field under natural attenuation conditions.

Natural Attenuation Study Phases

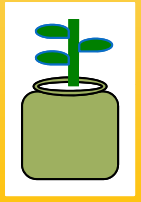
Phase 1: Literature review of natural attenuation processes



- Determine which contaminants in Area IV are amenable to biodegradation
- Estimate time required for natural attenuation of contaminants in SSFL Area IV soils based on published field and laboratory studies
- Use recent historical data to estimate natural attenuation on site

Phase 2: Use findings from bioremediation and phytoremediation companion studies for better site-specific analysis

- Use bioremediation field results to determine if known degraders of the contaminants are present in SSFL Area IV soils
- Use bioremediation microcosm results (for controls with no additives) to more accurately predict biodegradation rates under natural attenuation site conditions



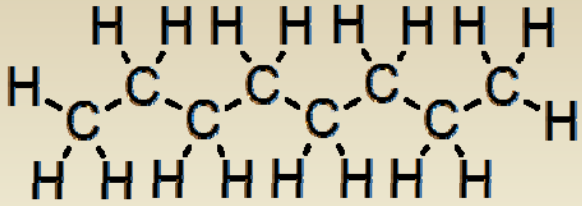
- Use phytoremediation results to examine potential contributions of native plants at the site to reduce contaminant concentrations

Results of Natural Attenuation Literature Review

- Petroleum hydrocarbons biodegrade readily
- Chlorinated chemicals (PCBs, chlorinated dioxins) are not as easily biodegraded
- Possibility to increase biodegradation rates of certain chemicals using *in-situ* biostimulation and/or bioaugmentation
  - Biostimulation: Adding nutrients, surfactants, etc. to enhance biodegradation by indigenous microorganisms
  - Bioaugmentation: Adding microorganisms with known chemical-degrading capability

Natural Attenuation Literature Review

Petroleum Hydrocarbons

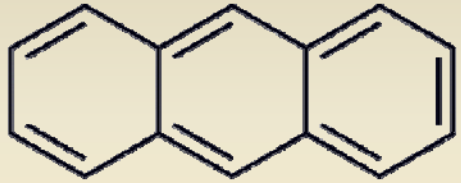


(e.g. octane)

- Biodegradation times (rough estimate from literature):
  - C7 – C9: 2 years
  - C10 – C14: 5 years
  - C15 – C36: 10 years
- Biostimulation through adding chemicals, nutrients, or soil bulking material (e.g., straw, rice hulls) may speed up/shorten biodegradation times
- Bioaugmentation through adding bacteria and/or fungi can speed up biodegradation times

Natural Attenuation Literature Review

Polyaromatic Hydrocarbons (PAHs)

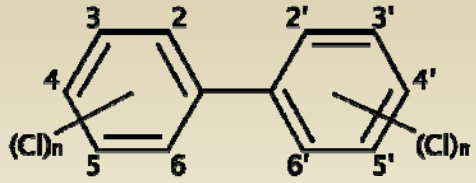


(Anthracene)

- Biodegradation times (rough estimate from literature):
  - 2 rings: 1-10 years
  - 3 rings: 10-25 years
  - 4-6 rings: 50-200+ years
- Biodegradation is complex because different soil microbes are typically required for degradation depending on PAH ring structure
- Soil fungi may be more adept at biodegrading larger PAH molecules
- Biostimulation/Bioagumentation is an important consideration

Natural Attenuation Literature Review

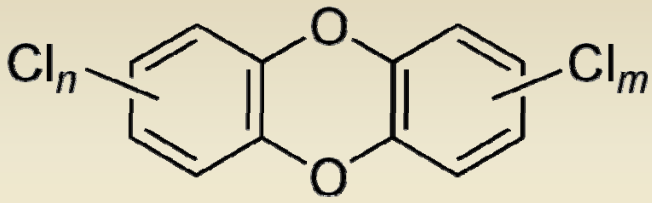
Polychlorinated Biphenyls (PCBs)



- Reported rates of PCB biodegradation are extremely low, even under ideal conditions.
- Bacterial dechlorination can only occur in an anaerobic environment
  - Once dechlorinated the remaining biphenyl can be degraded aerobically
  - Biostimulation and bioagumentation using dechlorinating bacteria has some promise, but such bioaugmentation would only be effective under anaerobic conditions
- Soil fungi have been shown to be effective at biodegrading PCBs under aerobic conditions

Natural Attenuation Literature Review

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



- Biological degradation of dioxins has similar considerations as for PCBs (anaerobic/aerobic bacteria)
- Biodegradation by fungi has been demonstrated
- Biostimulation/bioagumentation has some promise

Natural Attenuation Study:

Analysis of historical soil concentrations of petroleum hydrocarbons and PAHs

Preliminary observations in the comparison of recent soil data with historical data (2006-2013):

- Petroleum Hydrocarbons
  - 54% decrease in soil concentration over 5 to 10 years
  - Average biodegradation rate 0.29 mg/kg/day
- Polyaromatic hydrocarbons
  - PAH concentrations increased at more locations than they decreased
- More data needed for adequate statistical analysis

Natural Attenuation Conclusions from Phase 1:

- Literature review suggests all chemical compounds in Area IV soils will eventually biodegrade, but some compounds will degrade very slowly.
- Predicted natural attenuation rates at SSFL Area IV:
  - Petroleum hydrocarbons: 0.42 to 69 years
  - PAHs: 5 to 15 years
  - PCBs: Undetermined (half-life = 40 years)
  - Chlorinated dioxin/furans: 1 to 50 years
  - Wide ranges due to wide range of initial concentrations and wide range of biodegradation rates reported in the literature
- Measurement of historical chemical concentrations in soils will require more sampling to provide meaningful statistics. Analysis of changes in composition could be useful.
- Biostimulation and/or bioaugmentation may accelerate biodegradation.