SOIL PARTITIONING STUDY

The purpose of the soil partitioning study was to determine if the volume of soils requiring treatment or disposal could be reduced by separating out those soil sizes that had contaminant of interest (COI) concentrations exceeding LUT Values. The COIs for this study included metals, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), petroleum hydrocarbons, and dioxins/furans. The study evaluated the distribution of the COIs within the soil in terms of depth and the following soil size fractions – coarse material (>2.0 mm), medium sands (0.425 to 2.0 mm), fine sands (0.075 to 0.425 mm), and silts and clays (<0.075 mm).

A total of six soil samples from selected locations and depths across Area IV were obtained and separated into the four size fractions. Each size fraction was then analyzed for the COIs. Although results vary depending on soil sample location, the following general observations were noted:

- Area IV soils are dominated by sands and coarse material; less than 7% of the soil are silts/clays.
- Contaminant concentrations are substantially higher at the surface compared to soils two to three feet below ground surface.
- Contaminant concentrations generally increase with decreasing soil particle size.
- Although soil size partitioning may not yield any appreciable additional volume reduction for ex situ treatment/disposal, treatment using soil washing of the sand fractions may be an alternative to offsite hauling. Additional study could be considered to assess this potential.

MERCURY CONTAMINATION STUDY

The purpose of the mercury contamination study was to determine the different types of mercury found in Area IV soils to understand how mobile/available for uptake by plants the various mercury types are. Four locations across Area IV were sampled for total mercury, volatile elemental mercury, methyl mercury and different forms of ionic mercury. At the majority of the sampling locations, mercury concentrations were highest in surface soils and decreased with soil depth.

Methyl mercury was detected in trace amounts at a few sites and ionic mercury was widely observed in surface soils. A considerable fraction of mercury in chemical forms that are mobile or potentially bioavailable exists in surface soils. This suggests that soil washing, bioremediation, or phytoremediation could be treatment options to remove the mobile fractions of mercury in surface soils. In soils with depths below 3 ft, a majority of mercury exists in an immobile form that is tightly bound to soil particles. Disposal or alternative cleanup approaches would need to be evaluated for these soils.

BIOREMEDIATION STUDY

The purpose of the bioremediation study was to determine the potential for biodegradation to reduce the soil COI concentrations. The COIs for this study included PAHs, PCBs, petroleum hydrocarbons, and dioxins/furans. This effort included both (1) a field study to determine if COI-degrading bacteria and fungi are present in site soil and (2) a laboratory microcosm study using site soils to examine biodegradation rates under controlled conditions. The microcosm experiments also investigated the use of fertilizers and other amendments ("biostimulation"), and adding additional microorganisms ("bioaugmentation"), to increase biodegradation rates

The field study indicated the presence of bacterial and fungal species in Area IV soils that are known to biodegrade the COIs. However, the laboratory microcosm experiments indicated that the biodegradation rates are slow, even with biostimulation and bioaugmentation. These low biodegradation rates are likely due to the fact that the easily degradable COIs at the site have already been degraded over the past few decades. Petroleum hydrocarbon concentrations appeared to decrease slightly for two of three soils tested after four months of incubation, but after 8 months they appeared to increase dramatically. This unexpected increase may have been an anomaly caused by using a different analytical laboratory for the 8-month samples compared to the initial and 4-month samples. Further study of petroleum hydrocarbon levels in the microcosm soils is being conducted.

PHYTOREMEDIATION STUDY

The purpose of the phytoremediation study was to determine which plants already growing at Area IV would be the best candidates for phytoremediation (i.e., "Phytoremediation Phase 1") and to determine phytoremediation rates and possible mechanisms of COI removal and/or biodegradation by these plants (i.e., "Phytoremediation Phase 2"). The COIs for this study included metals, PAHs, PCBs, petroleum hydrocarbons, and dioxins/furans. In Phase 1, native and naturalized plants were collected from Area IV and analyzed for COI uptake as a screening tool to identify the best candidate species for Phase 2 of the phytoremediation study. In Phase 2, the best candidate plants identified in Phase 1 were grown in controlled greenhouse experiments.

In Phase 1, nine plant species were screened. Three samples of each species growing in contaminated soil and one of each species growing in uncontaminated soil were selected for harvesting and analysis. The roots, above ground plant tissue, and soil around the roots were sampled separately and analyzed for the COIs. For the Phase 2 greenhouse experiments, three plant species with a wide variety of observed contaminant uptake in the field were selected: Coyote Brush, Mule Fat, and Purple Needlegrass. These species were grown in soil collected from Area IV and analyzed after seven months of growth to quantify the removal or remediation of COIs from the soil.

The findings suggests that phytoremediation of the organic COIs at the site will proceed slowly, at best. However, the greenhouse experiments also indicated that there may be some potential for phytoremediation of PCBs and chlorinated dioxins/furans. Metal uptake by the plants was not substantial enough to lower metal concentrations in the soils.

NATURAL ATTENUATION STUDY

The purpose of Phase 1 of the natural attenuation study was to determine, from a literature review, (1) which COIs in Area IV are amenable to biodegradation and other natural attenuation processes (see above discussion of the bioremediation study COIs), (2) what biodegradation and natural attenuation pathways are known for these COIs, and (3) what rates of natural attenuation of these COIs have been observed in published field and laboratory studies. The purpose of Phase 2 of this study was to make site-specific predictions of natural attenuation rates at Area IV using the findings of the companion bioremediation and phytoremediation treatability studies.

The Phase 1 literature review suggests that all of the bioremediation study COIs in Area IV soils are amenable to natural attenuation processes. These processes include biodegradation by bacteria and fungi, volatilization, leaching, and phytoremediation (by existing vegetation at the site). However, the rates of natural attenuation may be slow because of the long time the COIs have been aging and weathering in the soil. The literature review also found that bacterial and fungal biodegradation appear to be the most likely processes to contribute to further reductions in bioremediation study COI concentrations.

Literature predictions of the times required to reach proposed clean-up levels via natural attenuation varied widely, from under one year to over fifty years, depending on the COI. However, site-specific information reviewed during Phase 2 of the natural attenuation study (i.e., the results of the companion phytoremediation and bioremediation treatability studies) suggests that natural attenuation may already be occurring at Area IV, but the estimated times to reach proposed clean-up levels would be at the long end of the time ranges predicted by literature. These long attenuation times are likely due to the fact that the easily degradable COIs at the site have already been degraded over the past few decades

Natural attenuation could be considered on a case-by-case basis for different sub-areas in Area IV, particularly those areas with lower contaminant concentrations. Natural attenuation could reduce the quantity of soil that needs to be excavated and the many associated environmental impacts of such excavations. Although the focus of this particular study was on natural attenuation, the findings suggest that more active bioremediation methods could also be a potential remediation option.