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PREPARED BED REACTOR FOR FULL SCALE REMEDIATION OF SOIL CONTAMINATED WITH WOOD PRESERVING WASTES: FIELD BIOREMEDIATION EVALUATION

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INTRODUCTION

The Champion International Superfund Site, a former wood perserving site in Libby, Montana, was nominated by the Robert S. Kerr Environmental Research Laboratory (RSKERL), Ada, OK, as a candidate site for bioremediation performance evaluation under the Bioremediation Field Initiative (BFI) sponsored by the U.S. Environmental Protection Agency (U.S. EPA). The Initiative was designed to address the need for additional field experience concerning the implementation of bioremediation techniques, including the collection and dissemination of performance data from field experiences.Target chemicals for bioremediation at the Libby Site included the polycyclic aromatic hydrocarbons (PAH) naphthalene, phenanthrene, and pyrene

The field performance evaluation was designed and conducted by Utah State University (USU) with support from the U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, to provide information on the effectiveness of bioremediation in addition to the information generated by Champion International personnel as part of regulatory monitoring requirements. Champion International, agreed to cooperate with the RSKERL and USU in conducting the proposed bioremediation performance evaluation studies for biological treatment processes in operation at the Libby Site.

The Libby Site uses three distinct biological processes in the site remediation scenario: (1) surface soil biological treatment in a prepared bed system,consisting of two lined land treatment units, liners, and leachate collection; (2) extraction of ground water, followed by aqueous phase treatment in an above-grade, fixed-film bioreactor; and (3) *in situ* bioremediation of the Upper Aquifer . Results of the evaluation of bioremediation in the prepared bed system are presented in this paper.

Contaminated soils were located in three primary source areas at the Libby Site: a former tank farm, an unlined butt dip area, and an unlined waste pit. In 1989, contaminated soils from these three areas (approximately 75,000 cubic yards of materials) were excavated down to the water table. Before the tank farm and butt dip areas were filled with clean soil, samples were collected and analyzed to verify that contamination had been removed.

Since the major contaminants of concern were expected to be associated with finer-grained materials, the soils excavated from the tank farm and butt dip areas and any previously excavated contaminated materials from the waste pit area were physically screened to remove rocks larger than one inch in diameter (referred as de-rocking). The screened soils from all three areas (approximately 45,000 cubic yards) were placed in the excavated waste pit area. The separated rocks were placed upgradient to the waste pit area to construct sub-grade infiltration galleries. This rock percolation bed is used for biological treatment of the contaminated rocks using effluents from the above grade, fixed-film bioreactor.

After a lift of contaminated soil is treated to target remediation levels in the prepared bed system, another lift of contaminated soil is added and treated until target remediation levels are obtained. Target chemicals for bioremediation at the Libby Site include three polycyclic aromatic hydrocarbon (PAH) compounds, naphthalene, phenanthrene, and pyrene, total carcinogenic PAH compounds (TCPAH), and pentachlorophenol (PCP). Target remediation levels for soil treated in the two LTU cells at the site are: naphthalene, 8.0 mg/kg; phenanthrene, 8.0 mg/kg; pyrene, 7.3 mg/kg, total carcinogenic PAH compounds, 88 mg/kg; and PCP, 37 mg/kg as specified in the Record of Decision (ROD).

Objectives of the evaluation of bioremediation in the prepared bed system were to: (1) describe and summarize previous and current remediation activities; (2) develop an approach to the evaluation of the prepared bed; (3) conduct a comprehensive field evaluation to assess performance of the unit in terms of treatment effectiveness, treatment rate, and detoxification of contaminated soil; and (4) perform a laboratory evaluation using field samples to determine indigenous soil microbial potential to accomplish bioremediation of target chemicals in the soil matrix under site conditions of temperature and soil moisture.

METHODOLOGY

Three-dimensional sampling of the two full-scale LTU cells was conducted over a two-year period. Analyses of over 300 soil samples were conducted, from which greater than 4,000 individual chemical concentrations were determined for 16 U.S. EPA priority pollutant PAH compounds using gas chromatography/mass spectrometry (GC/MS) and for PCP using gas chromatography/electron capture detector (GC/ECD). The field performance evaluation was based upon results obtained with regard to: (1) soil chemical concentrations compared with target remediation levels for target chemicals; (2) evaluation of downward migration of target chemicals as a result of the application of additional lifts; (3) detoxification of contaminated soil using bioassays; and (4) a laboratory evaluation for confirmation of indigenous soil microbial metabolic potential to biodegrade the target chemicals.

A chemical mass balance approach (1) was used to focus the evaluation of bioremediation at the Libby Site. Field-scale sampling and analysis were used in conjunction with a laboratory evaluation to provide complementary information for assessing the extent and rate of bioremediation and therefore, the effectiveness of bioremediation at the site. Specifically, a field-scale mass balance evaluation approach was used to develop information that could be used to eliminate the possibility of escape of target chemicals in air, water, and soil phases as a cause of disappearance of PAH compounds and PCP from the LTU cells. This was accomplished by evaluating the tendency of target chemicals to be associated with each phase and by identifying the containment of each phase within an LTU. The laboratory-scale mass balance approach was used to provide direct information concerning the biological degradation (mineralization) of target chemicals in the site soil, and the influence of site environmental and management factors on the extent and rate of bioremediation.

The field-scale methodology used for data collection and evaluation of soil remediation consisted of four activities (1): (1) site characterization, (2) assessment of the problem, (3) evaluation of the treatment (train) selected, and (4) monitoring treatment performance.

The first step involved characterizing the chemical/soil/site interactions to address the question "Where is the contamination and in what form(s) does it exist?" The target contaminants, PAH compounds and PCP, originally contaminated the soil as part of an oily matrix currently present in a residual saturation phase. The target chemicals are strongly associated with the soil (sorbed residual saturation of total petroleum hydrocarbons and soil solid phase), with the exception of naphthalene. Naphthalene was present in low concentrations in contaminated soil applied to the LTU cells, generally below the target remediation level (8.0 mg/kg), and therefore did not present a problem with regard to volatilization. The remaining target PAH compounds and PCP are only slightly soluble in water, are non-volatile, and are strongly associated with the soil/oil matrix (log K_{ow} and log K_d values greater than 4.0). Therefore, the focus of this investigation was on the soil solid/oil sorbed phase.

The second step addressed the question "Where is the contamination going under the influence of natural processes?" The target PAH compounds and PCP will remain associated with the residual oily saturation in the soil and with the soil solid phases within each LTU cell. Each lift of contaminated soil was applied on the top of each LTU cell, thus providing potential for downward migration of PAH compounds in an oily/water phase (leachate) within the LTU cells. This downward migration was identified as a potential escape process from the top lift that could be misinterpreted as bioremediation. Therefore, to determine if downward migration of target chemicals was occurring, the soil was sampled through depth at each sampling event in order to determine if the concentration of PAH compounds within previously treated and buried soil increased with time.

The third step was the evaluation of the treatment train used for remediation of the contaminated soil at the Libby Site. This treatment train consists of containment of contaminated soil in the lined LTU cells, with provisions for leachate collection, and followed by long-term bioremediation of sorbed contaminants. Berms provide effective containment of the soil phase, and the leachate collection system provides effective containment of the water phase within the LTU cells. Therefore, changes in concentrations of target chemicals within the LTU could be attributed to changes occurring within the LTU cells and the possibility of escape of target chemicals from the system through phase transport, including air, water, and soil phases, could be eliminated.

Finally, a monitoring strategy for determining the extent and rate of degradation was developed for the soil solid phase that consisted of taking discrete samples through depth and through time. With regard to interpretation of results in the context of bioremediation, this monitoring strategy was supported with a laboratory mass balance evaluation using site soil spiked with radiolabeled PCP and phenanthrene. Results of three-dimensional field sampling for determination of the decrease in target chemical concentration within each LTU cell and laboratory determination of biological mineralization were used to evaluate the effectiveness of bioremediation.

The objective of the methodology for the location of sample site collection points was to develop a random systematic sampling technique to minimize statistical bias and increase coverage of the contaminated area. To gain confidence that target remediation levels have been reached, the amount of data is increased by collecting and analyzing discrete samples rather than composited samples so that the variance of the concentration of contaminant(s) across the treatment site is accurately estimated (i.e., the information available is maximized). Since the goal of treatment is to protect public health and the environment, extremes in concentrations and not their central tendency (i.e., mean concentration) are of concern. Compositing of samples, in effect, averages the concentration in the composited samples, which only tends to indicate the central tendency of the concentrations. No estimate of the variance of the mean and thus the precision with which the mean is estimated can be obtained from a composite of samples. In addition, compositing does not provide information about the likelihood of the existence of relatively high concentrations (i.e., above the target remediation levels) within the soil being treated. Concentrations of compounds in soils, both natural and contaminant-related, are typically highly variable over small distances, both horizontally and vertically).

The boundaries of the LTU beds at the Libby Site are well-defined, which allowed the design of a systematic sampling protocol that maximized coverage of the soil materials, provided sufficient samples to indicate the variance of the contaminants of concern, and increased the probability that more highly contaminated soils were sampled. The systematic approach used a sample selection grid to assure that sample locations were not close to one another, which resulted in the distribution of samples over essentially all of the treatment bed. Samples taken at locations that are close together tend to result in redundant information.

RESULTS

The field performance evaluation of a prepared bed bioremediation system at the Libby, Montana Superfund Site indicated that biodegradation of wood preservative chemicals in a prepared bed system was effective and resulted in the treated soil meeting target remediation levels for target contaminants, as specified in the Record of Decision (ROD). Downward migration of target chemicals as a result of the application of additional lifts was not observed. The contaminated soil was detoxified to background levels as a result of the treatment, based upon results of toxicity and mutagenicity assays.

Design of the performance evaluation was based on analysis of discrete soil samples collected using a random systematic sampling technique to minimize statistical bias and increase coverage of the contaminated area. This design allowed identification of areas within the LTU cells where individual soil samples exceeded the target remediation level, even though the mean value for a sampling event was less than the target remediation level. In addition, statistical analysis of the results provided information concerning variation in chemical concentrations both horizontally and vertically and with time.

Based on the results of the field evaluation, a possible management tool may be to place a new lift on top of a lift after some significant treatment has been accomplished, but before the lower lift reaches target remediation levels for individual chemicals. This conclusion is based on limited field results that demonstrated that concentrations of pyrene and PCP appeared to continue to decrease with time after subsequent lifts had been placed on the first lift in the LTU cells. Follow-up field-scale measurements at the Libby Site are continuing to evaluate this management tool for accelerating prepared bed bioremediation.

Results of the field performance of the land treatment units at the Champion International Superfund Site in Libby, Montana, indicated that bioremediation using indigenous microorganisms was the process that accomplished soil treatment. Soil treatment included degradation of target PAH compounds and PCP in contaminated soil to target remediation levels and detoxification of contaminated soil.

CONCLUSION

Information obtained through field evaluation, and supporting laboratory evaluations not reported here, based upon a chemical mass balance approach provided the necessary confidence that results observed through analysis of field samples were due to bioremediation and not due to interphase transfer or escape pathways for the target chemicals including PAHs and PCP.

REFERENCES

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