Phytoremediation of Soil and Sludge Impacted by Petroleum Hydrocarbons And Metals - A Case Study

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Abstract: Phytoremediation is being evaluated at a manufacturing facility in southern New Jersey to address contaminated soil, sludge and lagoon sediment and provide a site-wide remedy that includes a landfill "phyto-capping" system. This approach, which has received preliminary regulatory support under the NJDEP Site Remediation Program, combines the major elements of a conventional landfill cap into a single unit, while simultaneously providing an on-site treatment remedy for impacted media. This paper discusses the results of a four-month laboratory study, in which 35 plant species native to the site were tested for the treatment of soil and sludge impacted by petroleum hydrocarbons and metals. In this extensive study, more than 300 samples of soil/sludge mixtures, plant roots and leaves were analyzed. This paper also describes a phytoremediation field pilot study, which is currently being conducted to examine the "phytotreatability" of 18 plant species including grasses, shrubs and trees. The 10-month field study will evaluate the magnitude and rate of organic degradation and metals uptake and accumulation under field conditions. The results of the study will determine the applicability of the phytoremediation capping system for the entire eight-acre landfill as a means to optimize land use through the use of an innovative technology.

Phytoremediation is an innovative technology that uses vegetation to mitigate contaminated media including soil, sediment, groundwater, surface water and wastewater. The technology is emerging as an effective remedial tool and has been demonstrated to treat or contain the migration of a wide range of organic and inorganic contaminants in both in-situ and ex-situ scenarios. While the advantages are understood, the limitations of phytoremediation must be evaluated before applying the technology at a particular site. This evaluation should incorporate the established remedial goals and performance criteria in determining the feasibility of phytoremediation.

Site remediation is being conducted as part of a voluntary cleanup program in accordance with a Memorandum of Agreement (MOA) executed on 29 August 1996 under the NJDEP Site Remediation Program. The site features active infiltration/percolation lagoons that formerly handled process wastewater, a former sediment area where impacted sludges were deposited, and inactive industrial landfill that received scrap vinyl flooring, an inactive surface impoundment, wetland areas and waterfront boundaries. The results of remedial investigations revealed subsurface soil and sludge containing elevated concentrations of volatile organic compounds (VOCs, primarily benzene and ethylbenzene), semi-volatile organic compounds (SVOCs, including phthalates and naphthalene, petroleum hydrocarbons and metals (mainly mercury, lead and zinc. An evaluation of the remedial options included excavation and disposal, in-situ and ex-situ bioremediation, stabilization and in-situ and ex-situ phytoremediation.

Following discussions with the NJDEP, the inactive industrial landfill (landfill) was voluntarily included in the MOA to be addressed as an area of concern (AOC) under the NJDEP Site Remediation Program. This approach was chosen to allow integrating, to the extent possible, closure activities at the landfill with remedial investigation and remedial action activities at the other AOCs addressed under the MOA, including the active lagoons, the former lagoon sediment placement areas and the inactive surface

impoundment. At this time, Mannington is pursuing an approach to closure, whereby integration of these activities may involve the use of phytoremediation for treatment of soil material from the lagoons and other AOCs at the landfill as part of the landfill closure. Addressing the landfill under the MOA provides a single lead NJDEP point of contact as the MOA Case Manager.

A phytoremediation lab scale treatability study was performed for the site by Applied Remediation Technology, Inc. (ART) of Rutherford, New Jersey and its phytoremediation affiliate, Applied PhytoGenetics, Inc. (APGEN) of Athens, Georgia. The treatability study incorporated an initial laboratory greenhouse growth testing phase performed by APGEN, that started in November 1999 and was completed in March 2000. Based on results of the growth study, the phytoremediation potential of 35 native plant species (local trees, shrubs and grass covers) suited for growth on the site soils was evaluated over the four-month period. Various soil/sludge mixtures were evaluated to determine an appropriate ratio and chelating agents were included to determine their effect on metals uptake. The ability of the plants to degrade the organics and to extract and bioaccumulate metals into leaves for later harvest was examined through periodic measurement of plant growth and contaminant uptake and removal from the test soils.

The treatability study identified a variety of plants capable of extracting and/or degrading the contaminants in the Mannington Mills Site. A large number of the plants were able to degrade what are normally considered toxic levels of phthalates and phenols. In addition, several species were identified that successfully extracted metals. Based on the treatability study, it was concluded that phytoremediation appears to be a viable option for treating the soils and sediments at the site. In order to more accurately determine the phytotreatability of the soil in real world conditions, a field study was implemented at the facility.

The objective of the phytoremediation field study is to further evaluate and determine the viability of phytoremediation as a remedial option under actual field conditions. Using the plant species that demonstrated adequate growth and the affinity to degrade and/or extract contaminants of concern (COCs) in the laboratory treatability study, the field study is examining plant growth, degradability of organics, and extraction/accumulation of metals at the site and evaluating phytoremediation under field conditions.

The field study incorporates a separate treatment cell for soil from the I/P Lagoons and from the Sediment Placement Area. The cells were constructed on the Inactive Industrial Landfill. Approximately 85 cubic yards of soil and sludge was obtained from each area. The material was excavated from areas where impacted material was identified through previous remedial investigation sampling.

The treatment cells in the landfill area were constructed above grade and incorporate a 3-foot high continuous perimeter berm and a 30-millimeter HDPE liner. The liner is buried into the soil surrounding the outside of the berm to prevent migration of leachate into the landfill. Leachate is collected in sumps within the treatment cells and stored in a holding tank, where it is reused as irrigation water in an automated irrigation system. Animal control is achieved by means of fencing enclosing the field cells. Each cell contains 9 to 10 plant species arranged in a grid pattern within the cell, with several grids serving as an unplanted control.

The field cells are routinely inspected to ensure that the irrigation system is operating correctly and to monitor the plant condition. The phyto-treatability of the soil is evaluated by sampling the soil as well as the roots and leaves of the plants. Leachate is also periodically sampled. These samples are analyzed for the following COCs: volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), metals and total petroleum hydrocarbons (TPH). In addition, general soil parameters including pH, alkalinity, nitrogen, phosphorous and percent moisture, are monitored.

The Remedial Concept for the site involves integrating landfill closure with cleanup of impacted media on-site by constructing a phytoremediation cap on the inactive industrial landfill. The cap would consist of an 18" thick lift of impacted soil and sludge excavated from the other on-site Areas of Concern. In the phytoremediation cap concept, a diverse group of plant species would be used to degrade the contaminants in the soil/sludge mixture. The plants would include grasses, shrubs and trees with a proven ability to extract or degrade the contaminants, based on the laboratory and field studies.

Preliminary estimates indicate that the volume of impacted soil and sludge in the active infiltration/percolation lagoons and former sediment placement areas is roughly equivalent to the volume of material required to cap the landfill (approximately 14,000 CY). In addition, the landfill would provide ample space and time for phytoremediation of impacted soil and sludge to take place. Several design issues complicate the implementation of a phytoremediation cap to close the landfill. Leachate from the impacted soil and sludges may adversely affect groundwater on the landfill and as a result will have to be addressed in the final design. Selection of the plant species will be a critical process in establishing a diverse and robust plant system on the landfill. An irrigation system may be necessary to ensure survival of the plants, especially in the first several years. Impacts from local animals and invasive plants will also need to be evaluated and accounted for.