A COST EFFECTIVE APPROACH FOR LARGE SCALE REMEDIATION OF TPH IMPACTED SOIL

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ABSTRACT

A field remediation program involving excavation, monitoring and soil segregation was implemented for remediation of 500,000 cubic yards of soil impacted by total petroleum hydrocarbons (TPH). The impacted soil was encountered during the decommissioning and abandonment of various facilities formerly associated with the production of crude oil and natural gas at a 320-acre site. The remedial activities were performed under the oversight of multiple interest regulatory agencies in anticipation of the planned re-development of the site as commercial/manufacturing property. Soil impacted by volatile organic compounds (VOCs) was segregated from non-VOC (crude oil) impacted soil during excavation and transported to a designated area for remediation using vapor extraction. Crude oil impacted soil was transported to one of several land treatment areas for bioremediation. Clean overburden was stockpiled adjacent to the excavations. Careful monitoring and segregation at the time of excavation minimized soil handling, thus resulting in significant cost savings for remediation. All of the soil remediated on site and clean overburden was utilized as backfill or placed in areas requiring additional fill for the planned re-development.

Introduction

Soil impacted by petroleum hydrocarbons was encountered during the removal of abandoned well cellars, small lease flowlines, gathering lines and water injection lines, formerly associated with the production of crude oil and natural gas on a 320-acre site located in Southern California. In general, soil beneath the site consists of clay and silty clays from the surface to depths ranging from approximately 20 to 30 feet bgs. The clay and silty clay are underlain by fine-grained sand and silty sand to a depth of approximately 100 feet bgs. There is no evidence that oilfield operations have impacted any regional aquifers beneath the site. The depth to groundwater in two monitoring wells located on the site was reported to be between 243.82 feet and 237.50 feet below ground surface (bgs).

Site cleanup values for total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene and xylenes (collectively referred to as BTEX) were specified by the Regional Water Quality Control Board (RWQCB), the lead regulatory agency with oversight for the site. Cleanup values for TPH impacted soil were established as follows: 1,000 milligrams per kilogram (mg/kg) for TPH as gasoline (C4-C12), 10,000 mg/kg for TPH as diesel (C13-C22) and 50,000 mg/kg for TPH compounds with hydrocarbon chain length up to C23-C32. BTEX cleanup values were established as follows: 0.30 mg/kg, 1.18 mg/kg, 0.81 mg/kg and 0.48 mg/kg, respectively.

Prior to the initiation of field activities, an application for a site specific permit for the excavation and handling of soil impacted by VOCs and subject to South Coast Air Quality Management District (SCAQMD) Rule 1166(c) was submitted to the SCAQMD for review (1). Subsequently, a contaminated soil mitigation plan permitting the excavation and handling of soil impacted by VOCs was received.

The mitigation plan was intended to minimize VOC emissions during excavation and subsequent handling of VOC-impacted soil (1). The mitigation plan issued for the site included, but was not limited to, the following requirements: 1) A stringent VOC monitoring program utilizing organic vapor analyzers (OVAs) be implemented and all applicable records maintained; 2) All VOC impacted soil be stockpiled separately from non-VOC impacted soil and each stockpile shall not exceed 500 cubic yards; and, 3) During excavation, the only exposed VOC impacted soil shall be restricted to the immediate working area of the stockpile only. All other VOC impacted soil on the site must not be exposed to the atmosphere.

Excavation and Segregation

Excavation of a total of approximately 670,000 cubic yards of soil was initiated during March 1999. During excavation activities, soil impacted by condensate (i.e., VOC impacted soil; C_4-C_{12}) was segregated from crude oil impacted soil based on field observations and monitoring of VOC concentrations. VOC impacted soil, as defined by the SCAQMD Rule 1166, is a soil which registers a concentration of 50 parts per million by volume (ppmv) or greater of VOCs when measured at a distance of no more than three inches from the surface of the soil with an organic vapor analyzer.

Monitoring for VOCs was performed by Komex personnel using Photovac photoionization detectors (PIDs) calibrated with 100 ppmv isobutylene. When PID readings exceeded 50 ppmv (correlated to, and expressed as hexane), the excavated VOC impacted soil was transported to one of 7 on-site VOC treatment areas for remediation utilizing vapor extraction. Crude oil impacted soil was transported to one of 7 on-site land treatment areas for bioremediation. Clean overburden was stockpiled adjacent to the excavated areas. Samples from the stockpiled clean overburden were subsequently collected to document that this soil met the site cleanup values.

The average TPH concentration reported in the impacted soils was 16,200 mg/kg and ranged from 1,200 mg/kg to 120,000 mg/kg. A graph indicating the average concentration of TPH compounds and their distribution is shown in Figure 1. Excavation of TPH impacted soil within each area continued until elevated PID readings were not recorded and stained soil with hydrocarbon odors was no longer apparent. Confirmatory samples were then collected from the sidewalls and bottom of each excavation to evaluate whether the TPH impacted soil had been removed. When the confirmatory sample results were within the cleanup values the excavations were backfilled.

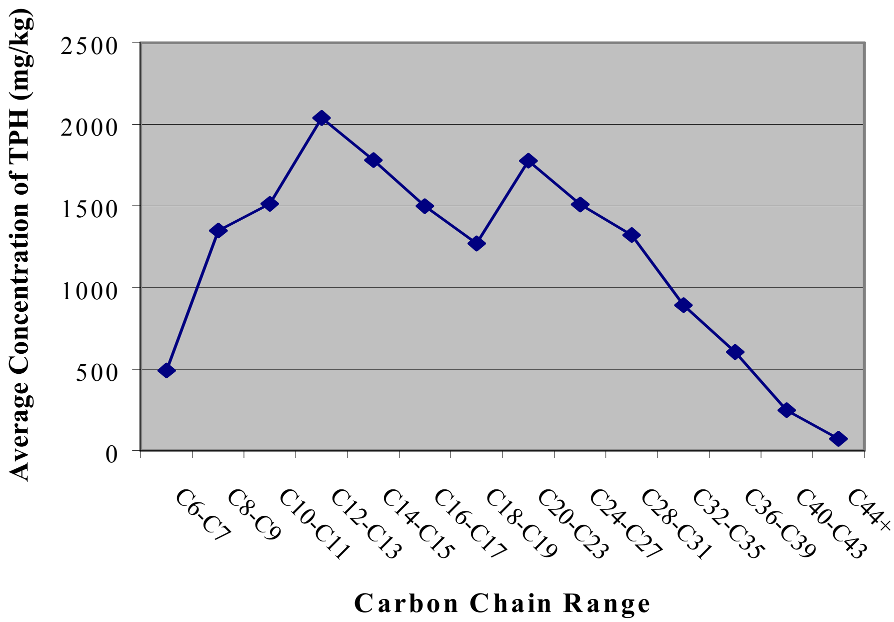

Figure 1. Average Concentration of TPH in impacted soil vs. Carbon Chain Range.

Treatment of VOC Impacted Soil

Seven VOC treatment areas were located on the site to minimize transport distance from impacted areas. Approximately 200,500 cubic yards of VOC impacted soil, generated during excavation activities was transported to the different treatment areas and placed into approximately 650 separate Remediation Stockpiles (RSPs) to undergo vapor extraction. RSPs were underlain and covered with visqueen plastic, and treated using mobile soil vapor extraction (SVE) units. Each RSP measured approximately 100 feet long by 25 feet wide and contained approximately 300 cubic yards of soil. Two 2-inch slotted PVC pipes were placed in the center of each of the RSPs and subsequently, connected to mobile SVE units. A PVC end cap was placed on the end of the piping opposite the SVE unit. An isometric of the RSP construction is shown in Figure 2. SVE units were connected to between two and ten RSPs, depending on the capabilities of the individual SVE unit and the extent of VOC impact in the soil being treated. The SVE units were checked daily and general operating parameters including fuel flow rate, well flow rate and well vacuum were recorded.

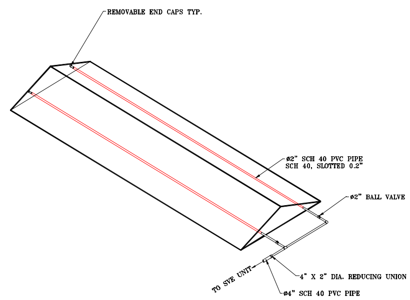

Figure 2. Isometric of above-ground remediation stockpile.

Soil samples were generally collected from the RSPs on a weekly basis to monitor the progress of remediation. The number of samples collected was approximately one sample for every 35 cubic yards of soil. Samples were collected from approximately three feet into the RSP at six to eight locations around the perimeter of the RSP. A hand-auger borehole was advanced to the desired depth prior to sample collection. Soil samples were then collected from the RSPs using a 6-inch drive sampler lined with 2-inch inside diameter stainless steel tubes. The soil samples were sealed with Teflon sheets and PVC end caps, labeled, placed on ice, and transported to the on-site mobile laboratory for analyses. Samples were analyzed for TPH in accordance with Modified EPA Method 8015 (simulated distillation extended range) and BTEX in accordance with EPA Method 8020.

Vapor extraction continued for an average of 11.03 days before soil samples collected from the stockpiles met the site cleanup values. Treatment times for vapor extraction ranged from 1 day to 42 days with a standard deviation of 9.06 days. The analytical results indicate that a 77% reduction in VOC concentrations (C_6-C_{12}) and a 62.4% reduction in TPH concentrations (C_6-C_{32}) occurred over an average of 8 days. When the analytical results of the collected samples met the site cleanup values, the RSPs were decommissioned. If site cleanup values were not met following additional treatment due to the presence of long chain hydrocarbons, the soil was subsequently transported to one of the LTAs located on-site for bioremediation.

Nearly 25% of the total remediation costs or approximately \$3.00/yd^3, can be directly related to the implementation and enforcement of AQMD Rule 1166. In other regulatory environments, eliminating exposure of VOC impacted soil to the atmosphere is not pertinent and therefore, there is potential for additional cost saving measures. However, controls utilized to eliminate exposure of VOC impacted soil may have assisted in meeting remediation objectives. Although only limited data was collected, it is suspected that black plastic sheeting used to cover the RSPs increased the average temperature of the piles and may have also

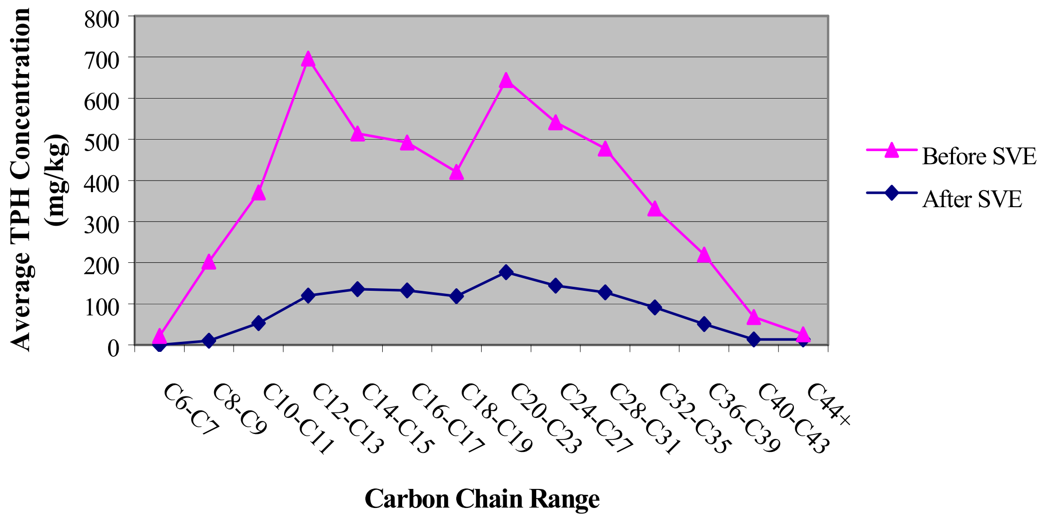

Figure 4. Average TPH Concentrations vs. Carbon Chain Range Before and After SVE

increased the vacuum within the system. The temperature recorded under black plastic sheeting was approximately 9 degrees C higher than the temperature recorded under clear plastic sheeting and substantially higher than the ambient site temperature. Thus, it is suspected that utilizing black plastic sheeting to cover the RSPs enhances the effectiveness of the SVE treatment process. Black plastic sheeting was used for the duration of the project.

Treatment of Crude Oil Impacted Soil

Non-VOC (crude oil) impacted soil generated during excavation activities was transported to one of 7 land treatment areas (LTAs) located on site. Heavier (non-volatile) petroleum products do not evaporate during aeration; the dominant mechanism that breaks down these hydrocarbons is biodegradation (3). Therefore, the requirements of the contaminated soil mitigation plan were met because these heavier hydrocarbons are not highly volatile and did not exceed the 50 ppmv OVA reading.

Soil within each treatment area was underlain by plastic sheeting to prevent soil beneath the active land treatment area from becoming impacted by TPH compounds. Berms were constructed around the perimeters to prevent storm water runon or runoff and the subsequent saturation of the treatment area and/or washout of the soils.

Soil undergoing bioremediation within LTAs was generally disked to a depth of approximately 12 inches once a week and watered and fertilized periodically, to optimize soil conditions for microbial degradation of petroleum hydrocarbons. Each treatment area was divided into grids for sampling purposes. Based on a treatment depth of 1-foot, sampling events within the grids were generally performed at a rate of one sample for each 450 cubic yards of soil. A 1-foot lift of soil was removed from the treatment area when samples collected from the LTA were in conformance with the site cleanup values established by the RWQB. The remediated soil was utilized as backfill at various locations on the site.

The cost of land treatment of impacted soils is significantly lower than the cost of SVE. The industry average, calculated using the RS Mean Environmental Remediation Estimating Methods Handbook for Environmental Remediation Cost Estimates for land treatment and vapor extraction is $\$19.10/yd^3$ and $\$85.10/yd^3$, respectively (4). Therefore, careful segregation and utilization of the land treatment option helped to significantly reduce overall costs.

Summary and Conclusions

Site conditions were favorable for the selected remediation strategies because large open areas were available to perform ex-situ treatment. In addition, TPH and BTEX concentrations did not require reduction to less than 1000 mg/kg which can be difficult to achieve using the methods described above. Incremental costs associated with achieving reductions in TPH concentrations increases substantially when target cleanup levels are lowered. Costs are generally more significant when reducing TPH concentrations from 1,000 mg/kg to 100 mg/kg vs. 10,000 mg/kg to 1,000 mg/kg.

The careful segregation of VOC impacted soil, non-VOC impacted soil, in addition to salvaging all clean overburden, resulted in minimal remediation costs. The overall cost for excavation, handling and treatment of the soil was approximately $12.00/cubic yard of soil (2). I`1n addition, utilizing the remediated soil as fill at various locations on the site eliminated the costs associated with purchase, transport and placement of foreign fill material.

In comparison, other biopile projects have reported costs of approximately $28.17/yd^3 and disposal costs for landfilling have been reported at $57.50/yd^3 of impacted soil depending on the nature and concentrations of the hydrocarbons present(5). The remediation approach described herein is an appropriate and economically feasible treatment option where regulatory constraints restrict exposure of VOC impacted soil to the atmosphere.

Figure 4. Remediation Stockpiles (RSPs)

References

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