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**Guaranteed Remediation Certainty
Our Word Is Who We Are**

Project Example – Guaranteed Fixed Price Remediation of Benzene using Electrical Resistance Heating at a Proposed Walgreen’s Store (#10220) located in Bedford, OH

Project Reference: Mr. Jeff Cossel, Visconsi Company, Pepper Pike, IL. (216) 464-3580.

Contracting and Pricing: Guaranteed Fixed Price and Performance Based Remediation

Engineer: Mr. Greg Beyke, Thermal Remediation Services (TRS) Vice President of Engineering, Franklin, TN (615)791-5772, gbeyke@thermalrs.com.

Project Superintendent: Mr. Drew Small, Project Manager, TRS, Charleston, South Carolina. (843) 965-8311, dsmall@thermalrs.com.

Contaminants Treated: Benzene

Technology Applied: Electrical Resistance Heating (ERH).

Lithology: Clay in both the vadose and saturated zones.

Hydrology: Groundwater at 18 - 24 feet bgs.

Treatment Interval: Seven to 32 feet bgs.

Remedial Goals: Remove measurable free product and reduce benzene concentrations in soil to less than five mg/kg (original numerical goal) then 32 mg/kg (revised goal).

Beginning Contaminant Level: Maximum 910 mg/kg benzene in soil. Free product benzene of 1.2 feet thick.

Ending Contaminant Levels: No measurable free product remaining. Maximum 17.6 mg/kg benzene in soil for a 98% reduction. 17 of 21 soil samples were below five mg/kg benzene in soil. All 21 soil samples were well below 32 mg/kg benzene in soil.

Total TRS Price: \$716,000.00.

Period of Performance: 138 days from July-November 2006

Problems Encountered and Corrective Actions Taken:

During the installation of the replacement monitoring wells, free product was found in one location in such abundance that it was extracted as a liquid while drilling the borings. Based on encountering free product during drilling and installation, TRS established additional precautionary measures to ensure that safe drilling operations could continue.

High contaminant concentrations in the subsurface also led to very high VOC concentrations in the vapor recovery stream as the subsurface temperatures increased. These vapor stream conditions required careful management to prevent problems with the catalytic oxidizer that was used for vapor treatment. Power to the subsurface was reduced



Figure 1. ERH Remediation Area

at times to limit temperature increases and control VOC vapor concentrations so the oxidizer was not overwhelmed.

Background

Thermal Remediation Services Inc. (TRS), as a subcontractor to Clayton Group Services, provided Electrical Resistance Heating (ERH) design, construction, operations, and specialty equipment for remediation of this Site. This was a guaranteed fixed price performance based (GFPR) remediation of benzene in soil.

The primary performance goals of this project were to remove all measurable free product and to reduce concentrations of benzene in soil within the treatment volume to less than five mg/kg in 21 confirmatory soil sampling locations.

After an evaluation of the remediation performed and the projected time to complete the project to the initial remediation goal for benzene of five mg/kg, Clayton was requested by the customer to reevaluate the original numerical remediation goal. Clayton considered engineering and institutional controls and evaluated exposure pathways in an effort to establish a site-specific remediation goal for benzene in soil in lieu of the original remedial goal which did not take into account the elimination of pathways using these controls.

Based upon Clayton's findings and assumptions, there were two pathways for which benzene standards exist that had to be considered: 1) soil to outdoor air for nonresidential (32.10 mg/kg); and 2) soil to non-drinking water leaching (21.60 mg/kg). Since the groundwater at the site was discontinuous, already contaminated with petroleum hydrocarbons, and the extent of contamination was assumed to be limited to onsite, Clayton selected the soil to outdoor air action level to be the most applicable soil standard for the Site.

Therefore, Clayton revised the remediation goal for benzene in soil to be less than 32 mg/kg. Based upon the benzene soil sample results from the seven soil borings (total of 21 samples), only four samples (two samples from two borings) did not meet the initial, more conservative, benzene remediation goal of five mg/kg. However, all the confirmatory soil samples were significantly below the revised remediation goal of 32 mg/kg.

Site Information

The Site is located on a busy street within a commercial/residential area. The Site was an open, asphalt paved area. Overhead power lines ran along the sidewalk in front of the Site. The treatment area was approximately 5,800 square feet with a remediation depth interval from seven to 32 feet below ground surface (bgs) and a treatment volume of 5,400 cubic yards. Figure 1 is a site picture showing a portion of the treatment area.



The site lithology in the remediation area consisted of silty clay with thin interbedded gravel seams. Although the original design was based on groundwater elevations of 8 feet bgs, the actual groundwater elevations ranged from approximately 18 to 24.4 feet bgs as measured early in the ERH operations phase.

Construction

Construction of the ERH system began the week of May 15, 2006 with the placement of the surface equipment, including one 950 kilowatt (kW) Power Control Unit (PCU), one steam condenser with cooling tower, one 15 horsepower vapor recovery blower and one electric catalytic oxidizer. In addition, a site security fence was installed to ensure personnel and equipment safety through the project.

The ERH system included 30 electrodes, each with a co-located vapor recovery (VR) well. Subsurface temperatures were measured at 42 thermocouples placed at set depth intervals within seven TMPs, with an average of six thermocouples spaced vertically at set five-foot intervals. Temperature data was collected at least once per day from the seven TMPs installed at the confirmatory boring locations. Four TMPs were co-located with the new/replacement Monitoring Wells (MWs) and three TMPs were in independent borings. Each TMP was constructed using 3/4-inch chlorinated polyvinyl chloride (CPVC) pipe, and each TMP included a TRS-installed string of temperature sensors that monitored temperatures at six separate depth intervals. Figure 2 Site Layout shows the locations of the ERH system components.

In an effort to reduce costs, four of the TMPs were co-located with monitoring wells during the replacement of plastic groundwater monitoring wells prior to the start of ERH. The remaining three TMPs were installed in independent borings.

The ERH system was deemed fully operational on July 12, 2006 when the project moved from the Startup phase to the Operations phase.

Operations

ERH operations lasted 138 days and a total of 839,281 kilowatt-hours (kW-hrs) of energy were applied to the subsurface. The maximum subsurface temperature achieved was 110 degrees Celsius (°C). During the course of the ERH project, it was estimated that 3,390 pounds of total aromatic hydrocarbons were removed from the subsurface as recovered vapors.

The subsurface temperatures within the treatment volume were measured using 42 thermocouples distributed among the seven TMP's. The PCU system control program was utilized to automatically read each thermocouple daily. Figure 3 depicts the average temperatures at each TMP location over time from the initial baseline reading taken on July 12, 2006 through the last day of ERH operations on November 13, 2006.

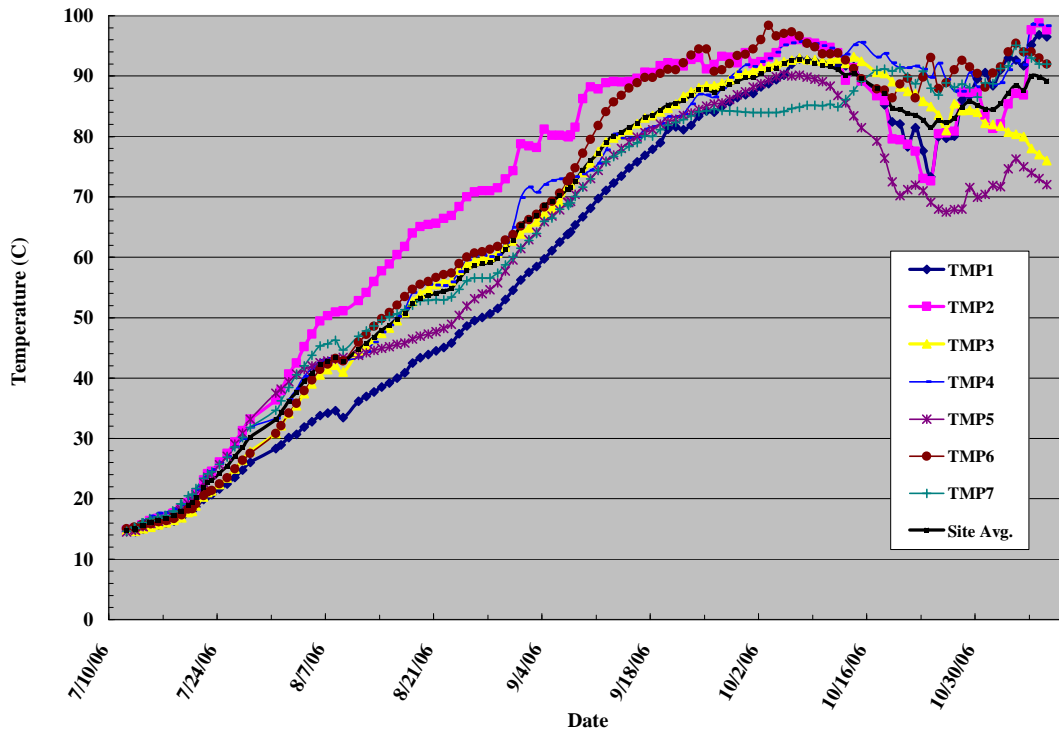


Figure 3. Average Subsurface Temperatures versus Time

Results

Soil sampling was conducted during ERH operations to measure the amount of contamination remaining in the treatment area and to guide operational changes intended to focus remediation efforts towards the most impacted portions of the site. Of the 21 post ERH soil samples collected from three separate depth intervals at each of the seven TMP locations, 17 had achieved the original cleanup goal of less than five mg/kg for benzene

in soil. All of the confirmatory soil samples (21 total) were well below the revised numerical remedial goal of 32 mg/kg for benzene in soil.

The laboratory results for benzene from each sampling event are presented in Table 1. Prior to application of the ERH technology, the maximum concentration of benzene in soil reported at the site was 910 mg/kg and free product thickness was determined to be as much as 1.2 feet in monitoring well RW-1. Achieving the remediation goal for benzene concentrations in soil effectively reduced contaminant mass in the source area by an estimated 99.5%.

Table 1. Benzene Concentrations during ERH Application

Sample Identification	9/20/06	10/9/06	10/24/06	11/06/06	11/13/06	11/13/06 dup
	Benzene Concentrations in mg/kg					
CS-1 Shallow	13.8	3.47	2.68	0.172	1.26	
CS-1 Intermediate	25.06	13	13.55	23.4	17.6	
CS-1 Deep	12.27	14.25	41.65	25.8	10.7	
CS-2 Shallow	15.101	0.0519	1.96	0.109		
CS-2 Intermediate	27.04	21.2	47.66	1.8		
CS-2 Deep	4.174	12.1	75.5	1.5		
CS-3 Shallow	9.76	0.24				
CS-3 Intermediate	4.09	0.162				
CS-3 Deep	9.58	0.057				
CS-4 Shallow	68.8	121.8	13.1	21.6	3.24	11.7
CS-4 Intermediate	10.99	100.9	13.41	6.5	0.52	0.64
CS-4 Deep	119.3	84.1	144.9	122	4.76	17.6
CS-5 Shallow	18.6	3.7				
CS-5 Intermediate	22.9	3.67				
CS-5 Deep	5.07	2				
CS-6 Shallow	8.85	0.007	1.6			
CS-6 Intermediate	8.12	0.9	0.01			
CS-6 Deep	0.406	6.5	0.051			
CS-7 Shallow	14.89	1.32	3.71			
CS-7 Intermediate	3.83	12.7	0.068			
CS-7 Deep	6.69	0.005	0.135			

*Note: Values shown in **bold** exceed the original cleanup criteria of 5 mg/kg. A revised goal of 32 mg/kg was developed later into the project. All confirmatory soil samples were below the revised goal.

Based upon results obtained from vapor sampling, approximately 3,390 pounds of total aromatic hydrocarbons were removed during the ERH project. Recovered soil vapors were treated using the catalytic oxidizer, while recovered steam was condensed and either evaporated in the condenser cooling tower or returned to the subsurface through the electrodes.

At the start of the project, it was estimated that 1,092,000 kW-hr of energy would be required to reach the original project goal of 99.5% removal of benzene from soil. Only



839,291 kW-hr of energy was applied during the project, 252,000 kW-hr less than calculated to reach the cleanup goals.

Upon review of the analytical results from the final interim sampling event, the Visconsi Company determined that since there was no more measurable free product, the majority of the soil samples were below the original goal and all of the soil samples were below the revised goal, site remediation was complete. Figure 4 illustrates the benzene concentration reduction at each location with the highest concentration of each of the three depth intervals displayed.

Following the successful ERH remediation, The Visconsi Company redeveloped the Site into a Walgreen's Store.

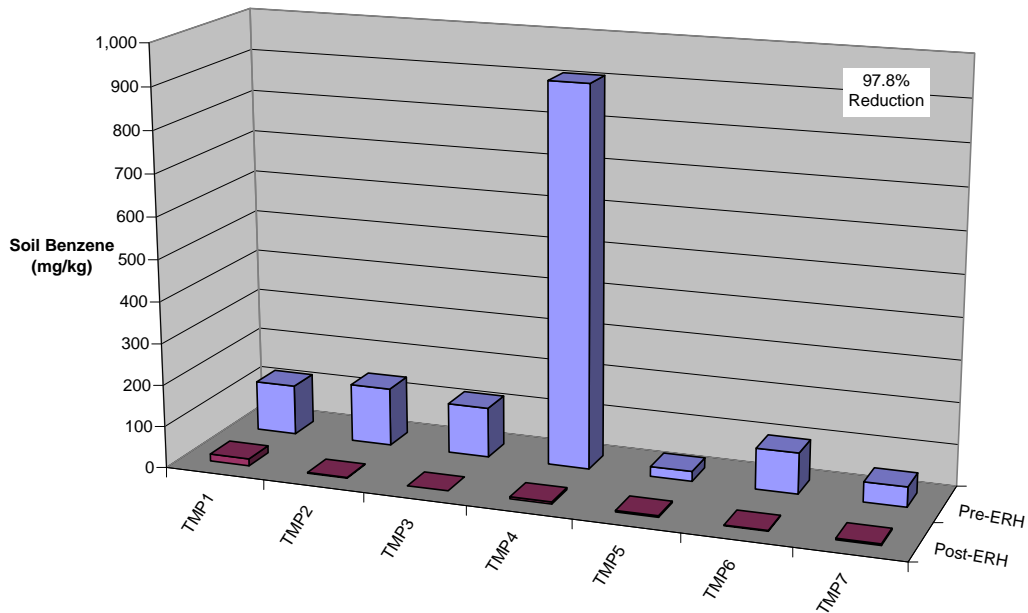


Figure 4. Benzene Concentrations in Soil Before and After ERH

Conclusions

Based upon the data collected before and during the project the following conclusions were drawn:

1. Based upon sampling at the four groundwater monitoring wells within the treatment area, the ERH project successfully accomplished the performance goal of removing all free product from the site.
2. Soil samples from three depths at seven sampling locations showed that the original numerical performance goal of reducing benzene concentrations in soil to five mg/kg (a 99.5% reduction) had been achieved in all but four of 21 samples.
3. All confirmatory soil samples were well below the revised numerical cleanup goal of 32 mg/kg of benzene in soil.
4. During the course of the ERH project, it was estimated that 3,390 pounds of total aromatic hydrocarbons were removed from the subsurface as recovered vapors.
5. At the start of the project, it was estimated that 1,092,000 kW-hr of energy would be required to reach the original goal of 99.5% removal of benzene from soil. Only 839,291 kW-hr of energy was applied during the project, 252,000 kW-hr less than calculated to reach the cleanup goals. There can be little doubt that had the full design energy been applied to the site, the original remediation goal for all 21-soil samples would have been easily reached.
6. The maximum subsurface temperature achieved was 106°C within the ERH treatment volume.