Western Storage Area (Pit No. 18) – Harwell

Excavation-In Situ Thermal – Monitored Natural Attenuation

Site Name: Western Storage Area (Pit No. 18) – Harwell
Site Location: Oxfordshire, United Kingdom
Technology Used:

- Excavation
- In Situ Thermal Treatment (Thermal Conduction Heating)
- Monitored Natural Attenuation (MNA)

Regulatory Program: UK Environment Agency and Department of Energy and Climate Change—Legacy Management Program
Remediation Scale: Full

Site Information: The Western Storage Area (WSA) comprises a series of pits that occupy an area of approximately 1 ha at the Harwell site in Oxfordshire, United Kingdom (Figure 1). The WSA is licensed as a closed landfill by the United Kingdom Environment Agency while the Harwell site is now part of a decommissioning and closure program managed by Research Sites Restoration Ltd.

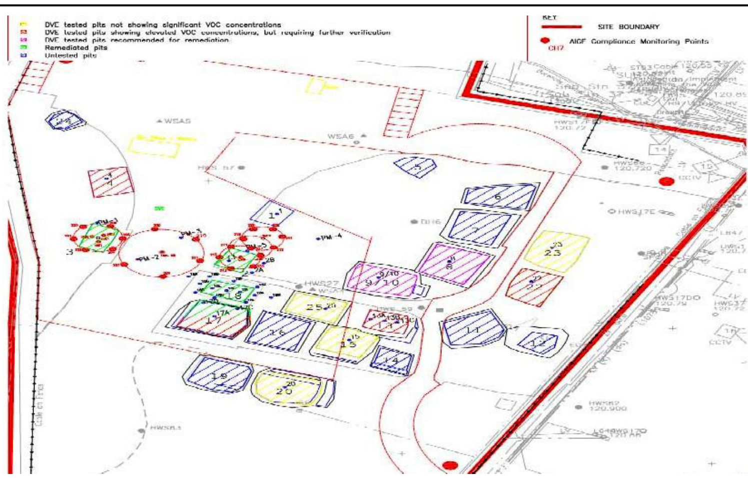

Figure 1: Layout of the WSA. A Series of Pits Characterize the Area (Pit No. 18 Located Toward the Southwestern Portion of the Site).

Courtesy TerraTherm, Inc.

Between 1970 and 1977, 25 unlined pits at the WSA were used for the disposal of various untreated chemical wastes, including chlorinated solvents and organic chemicals. After 1977, chemicals were sent for offsite incineration, but the historic disposal of materials in these pits contaminated groundwater in the chalk aquifer. Non-aqueous phase liquids (NAPL) containing percent levels of chlorinated solvents were also detected as oil films on fissures in the chalk. Light NAPL has been identified periodically in groundwater monitoring wells in the vicinity of the disposal pits.

Following the discovery of groundwater contamination in late 1989, a program was implemented to delineate, contain and remediate the contaminated groundwater and address the source. The primary source materials were excavated and removed from the pits in 2004 to a depth of approximately 150 mm below the original bottom of the pits. The pits were backfilled with granular subsoil and a bentomat layer was installed approximately 1 m below ground surface (bgs) (Kozlowska et al. 2009).

Contaminants: The site had been contaminated with various chemicals including mineral oil, chloroform, trichloroethane (TCA), trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), *cis*-1,2 dichloroethene (*cis*-1,2-DCE), carbon tetrachloride and tetrachloroethene (PCE). The contamination had affected the unsaturated zone, groundwater in the chalk aquifer, and was a continuing source of groundwater contamination below the WSA.

Hydrogeology: The WSA site is underlain by interbedded layers of light grey argillaceous chalk of varying strength and variable clay content. The rock matrix itself has a relatively low effective permeability but high porosity (25%) and retains pore water. A relatively soft weathered chalk is present to a depth of approximately 6 to 8 m bgs. A laterally extensive horizontal layer of chalk marl at 30 m bgs forms the base of the unconfined Chalk aquifer (Kozlowska et al. 2009).

Groundwater elevation data indicate that water levels in fissures vary seasonally. Significant recharge occurs in the winter. Water levels also vary from year to year. Historical water level range is approximately 5 to 23 m bgs. Groundwater flow in chalk fractures is controlled by a series of extraction wells arrayed around the perimeter of the WSA from the southeast to the north.

Project Goals: The primary goals of this project were to decrease contaminant mass in the unsaturated zone at Pit No. 18 to reduce its continuing impact on groundwater at the site. The project also aimed to demonstrate the applicability of thermally enhanced bioremediation as a complementary process to in-situ thermal remediation.

Cleanup Approach: In situ thermal treatment using thermal conduction heating (TCH) and MNA were chosen to remediate the residual contamination within the unsaturated zone at Pit No. 18.

TCH results in uniform heat transfer via thermal conduction and convection in the bulk of the soil volume, which improves contaminant removal efficiency. Reaction kinetics are increased by the utilization of thermal enhancement. This facilitates an increase in the contaminant mass removal rate. Drying of the soil/rock mass during thermal enhancement increases the air permeability and therefore increases the process of transport of contaminant vapors by gas advection as air is drawn through the soil by vacuum extraction.

MNA was proposed for the perimeter areas of the heating zones. Microbial degradation rates have an optimum temperature range between 30 and 40 ºC for most organisms, especially those responsible for anaerobic breakdown of chlorinated hydrocarbons. It was proposed that the heat from the target zone would result in accelerated degradation by bacteria as the perimeter zones passed into or dwelt in this temperature range.

Because the success of treating chlorinated solvents by MNA depends on the presence of appropriate strains of bacteria and subsurface geochemical conditions, an assessment of the extent of microbiological activity and changes that occur to the microbiological population prior, during, and post the thermal treatment process was planned prior to remedy implementation. Bacteria and geochemical data would be gathered both within and outside the treatment area.

Thermal conduction heating was completed using vertically installed electrically-powered heaters to heat contaminated soil to target treatment temperatures. Contaminants were removed by applying a vacuum to in situ vapor extraction wells. The target temperature was engineered to be above the boiling points of main CoC and was in the range of 80-100 ºC (see Figure 2 for details on set-up of the thermal treatment system). The collected off gas was treated by granular activated carbon before being discharged to the atmosphere. Heating began in August 2009 and continued into November.

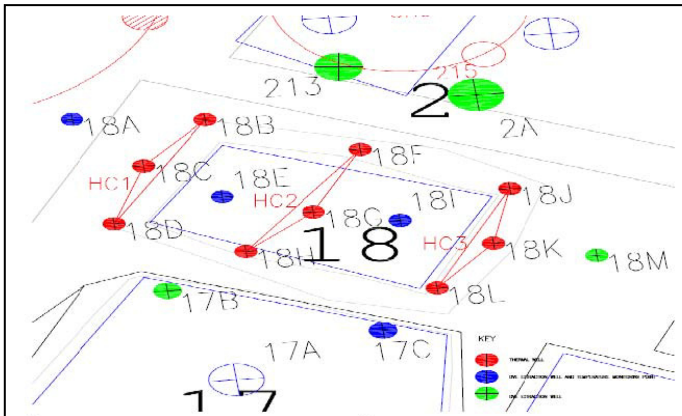

Figure 2: Locations of Thermal Wells (Red), Extraction Wells (Green), and Extraction Wells/ Temperature Monitoring Points (Blue) in the Vicinity of the Target Treatment Area (Pit No. 18)

Courtesy TerraTherm, Inc.

Bacteria enumeration, using the Quantitative Polymerase Chain Reaction (qPCR) method, identified the presence of specific DNA sequences of *Dehalococcoides spp.* and *Dehalobacter spp.* Analysis for methanogens, sulfate and iron-reducing bacteria was additionally conducted in order to investigate the preferential pathways for deriving electron donors for metabolic activities (Kozlowska et al. 2009). Groundwater samples obtained from monitoring wells and a BioTrap® in-situ passive diffusion sampling devices were utilized for DNA extraction and qPCR analysis.

Project Results: A significant reduction of chlorinated solvents in the unsaturated zone was achieved by the full-scale application of thermal treatment. The concentrations of chlorinated ethenes and other CoC were found to be significantly lower adjacent to the thermal treatment area and 1-2 orders of magnitude lower within the thermal treatment zone (Kozlowska et al. 2009). Sequential transfer from PCE to DCE was apparent for all sampling points located within the direct zone of thermal influence and for groundwater samples taken from nearby wells outside the immediate vicinity of the thermally enhanced zone. Dichloroethenes were accumulated as the end product of reductive dechlorination, and no further transformation to VC occurred (Kozlowska et al. 2009). The substantial reduction of PCE and TCE was evident for all sampling locations. The dechlorination reactions within the zone of direct thermal influence was potentially driven by thermal destruction and desorption processes, whereas the driving force for reductive dechlorination was most likely an effect of microbiological activity of reductive dechlorinators (Kozlowska et al. 2009).

It was concluded that because thermal treatment created favorable conditions for growth of dehalogenating bacteria, thermally enhanced bioremediation could be used to provide an inexpensive final polishing step or a complementary process in the perimeter of heated zones and hot spots during the cool-down phase of thermal treatment of a site.

Sources:

Kozlowska, Anna Maria and Stephen R. Langford. Effects of Thermally Enhanced Soil Vapour Extraction (TESVE) on Indigenous Microbial Communities and Continued Biological Reduction of Chlorinated Solvents in Chalk in the United Kingdom. Remediation of Chlorinated and Recalcitrant Compounds. Seventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA; May 2010).

Kozlowska, Anna Maria, et al. Enhanced Bioremediation as a Cost Effective Approach Following Thermally Enhanced Soil Vapour Extraction For Sites Requiring Remediation Of Chlorinated Solvents. Proceedings of the 12th International Conference on Nuclear Environmental Remediation and Radioactive Waste Management/ Nuclear Decommissioning (Liverpool, UK, October 11-15, 2009).

TerraTherm, Inc. Thermal Conduction Heating. 2009. http://www.terratherm.com/thermal/tch/index.htm

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