In-Situ Soil and Groundwater Decontamination of Site Near Sheffield (Ecclesfield) Using Electric Resistive Heating Technology (Six-Phase Heating)

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This summary describes why Electric Resistive Heating (Six-Phase Heating (SPH)) was selected as the most appropriate technology for remediating the former manufacturing site at Eccelsfield near Sheffield. This first use of SPH in the UK has shown how difficult soil and contaminant conditions should not be a barrier to effective, thorough and rapid in-situ remediation. Included are technical and operational performance details which confirm the SPH technique as one of the most effective and exciting remediation technologies available today.

Background to Site

The five-acre site, located in Sheffield, close to the M1 motorway, was formerly a manufacturing site for over fifty years. The site was acquired by Taylor Wimpey in early 2007.

Analysis of soils revealed two distinct hotspots of chlorinated hydrocarbons, referred to as Plume 1 and Plume 2. Contaminants of concern were identified as trichloroethene (TCE) and vinyl chloride (VC). Minor concentrations of other associated breakdown by-products were also recorded.

The total volume of soils to be treated was approximately 3500m^3 with the core area of each plume extending 4m below groundwater, through the dense mudstone to 7m bgl.

The site is located in a densely populated area surrounded by residential properties with easy access to the M1 and was thus a prime site for redevelopment for residential use.

Development of Six-Phase Heating

SPH was developed by Terra Vac Corp and the Battelle Memorial Institute (BMI) in their Richmond Washington facility under the auspices of the US Department of Energy (DOE). The objective of the research was to develop a technique to address persistent 'source' areas in former military establishments as part of the US Government's Superfund.

SPH consistently outperformed other in-situ technologies and was ultimately voted "best in class" by regulators (Environmental Protection Agency) and consultants alike.

Description of Six-Phase Heating

High voltage electricity is introduced into the impacted soils and groundwater via electrodes. Electric current heats the soils resistively causing groundwater to boil, which is then extracted as steam together with volatilised contaminants.

Electricity flows preferentially through low permeability soils, and their greater resistivity causes these soils to heat more quickly. Each electrode is independently controlled and monitored to ensure the most efficient and balanced operation of the system.

The heated soil causes the interstitial water and 'free' groundwater, to reach boiling point and volatilise. As the internal temperature rises, the contaminant molecules, including non-aqueous phase liquids (NAPLs) that are bound to the soil particles, are liberated. They are then extracted with the steam 'carrier', recovered, and treated above ground.

Technology Evaluation

Several possible remediation techniques were evaluated for the site and compared for technical, practical, and commercial suitability. A significant factor in the process of evaluation was the close proximity of high density residential properties adjacent to the site.

Cost/Benefit Analysis of Six-Phase Heating

As can be seen table 1, SPH was not the cheapest solution offered. However, there were other serious factors to be considered in terms of the final decision.

- Very low level of local disruption; SPH is an in-situ process and operates below the surface of the site. Installation is quick and causes minor disturbance to the site and surrounding area. Given that the site is located in an urban environment with residential properties adjacent, the local population will experience very little disruption. The installation and operation causes little in the way of noise, dust, or any other type of disturbance to the local population.
- Reduced remediation timescale; the use of SPH ensures that multi-phase contaminants are removed from soils and groundwaters simultaneously contributing to the accelerated remedial timeframe. The overall process is extremely rapid, allowing decontamination to be completed within weeks rather than months/years.
  The actual decontamination phase of the project was expected to take in the order of twelve to twenty weeks.
- Low risk of cost escalation; variable heating of electrical elements allows accurate targeting of contaminated layers, ensuring all contaminated areas are treated.
  The ability to accurately target only those contaminated areas means that the electrical current is used efficiently with effective budgetary control.
- Thoroughness of the process; the SPH process is extremely thorough, and a review of previous projects completed in USA and mainland Europe showed that typically, residual contaminants are often below detection levels. This is particularly important in this project as stringent target levels are required to be achieved.

Site Works

Terra Vac (UK) Ltd undertook the site as a turnkey project which included a first phase of demolition of all buildings on site, removal of notifiable material and crushing of concrete slab and relic foundations.

SPH Installation

Based on the findings of various tests and results of laboratory analysis, the SPH system was deployed in April 2007. A total of 48 electrodes were installed in Plume 1 and a further 19 in Plume 2.

System Performance

Subsurface soil and groundwater temperature at varying depths was recorded and monitored continuously on-line from with both Plumes.

Subsoil temperatures increased rapidly over the first few weeks of the project due to the targeted control and distribution of electrical energy. The boiling temperature for TCE in water (73^{o}C as per Daltons Law of Boiling Point Reduction) was achieved within three to five weeks.

The cumulative vapour phase recovery data showed the equivalent of 1662 litres of TCE was recovered from the subsoils over the twenty-week period. This quantity is approximately seventy times the quantity originally calculated, requiring to be removed to achieve the site-specific dissolved phase TCE target concentrations.

Actual groundwater concentrations showed a dramatic net reduction in concentration of in excess of 99% over the project timeframe.

Validation

A rigorous validation regime was undertaken by independent consultants, which included the installation of a total of sixteen validation boreholes, with soil sample collection and analysis at half metre vertical intervals throughout the depth of each borehole.

All validation sample analytical results showed concentrations of TCE below the derived site-specific acceptance criteria for TCE.

In order to achieve this, the SPH system had removed seventy times the quantity of contaminants estimated to be present in the subsoils, based on initial site investigation data.

Separate soil samples were recovered from the treatment zone four weeks after completion to confirm soil moisture etc. had returned to normal and no signs of 'heave' or desiccation were recorded.

Conclusion

After a programme of pre-notification to local residents and through the careful co-ordination of demolition and remediation, the works at the Ecclesfield site were shown to have achieved the requirements of regulators and client with negligible impact on the local environment/neighbourhood.

Continuous close monitoring and optimisation throughout the project allowed considerable programme savings to be made which enabled the client to occupy the site and commence infrastructure building work 12 weeks ahead of schedule.

The quantity of TCE removed was approximately seventy times the quantity originally calculated, and groundwater concentrations showed a dramatic net reduction in concentration of in excess of 99%.

By the end of 2007, main roads, sewers and the sales office were installed at the site with house building starting in January 2008. All remedial equipment was demobilised in December 2007.

Final costs for the project fell within the contract and were demonstrated to be more controllable and not subject to external cost fluctuation due to external factors eg. landfill tax and fuel duty increases, which could have significantly affected alternative options such as excavation and disposal etc.

Technology	Timescale	£/Tonne	Advantages	Disadvantages
Excavation / disposal off site (dig and dump)	16 weeks	£125	Very rapid High degree of confidence	In excess of 700 vehicle movements through urban areas Fugitive vapours to local residents Groundwater and possible NAPL 'lake' at 3m bgl
In-situ Bio	40 weeks	£65	Lower cost	Possible DNAPL to retard reaction Possible extended timeframe unacceptable to client Dispersion difficulty due to soils
Ex-situ Bio	30 weeks	£50	Lower cost	Fugitive vapours during works Reduced confidence due to more cohesive soils
In-situ chemical oxidation	30-35 weeks	£85	Rapid reaction	Possible DNAPL to retard reaction Reduced confidence due to cohesive soils and likely extended programme Possibility of displacing contaminant and spreading plume.
Dual phase extraction	50 weeks	£63	Controlled extraction technique thus progress measureable	Extended programme unacceptable to client Cohesive soils restrict effectiveness
SPH	20 weeks	£78	Most effective in cohesive soils rapid, extremely thorough	Requires high voltage power

Table 1. Technology evaluation