Brownfield Briefing Awards // Best In-Situ Treatment – Project Sunflower, UK

In-situ Remediation at an Operational Research Facility, UK

Introduction

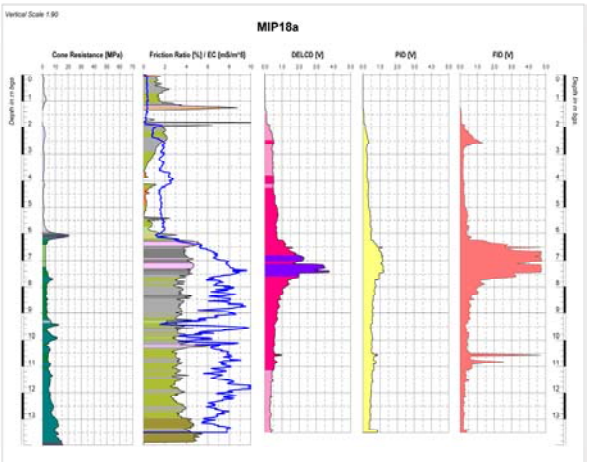
Tamdown Regeneration (Tamdown) and AECOM would like to submit a joint entry for remediation works (termed Project Sunflower) carried out at a research facility in the UK for consideration for the 2011 Brownfield Briefing Awards in the category of '***Best In-Situ Treatment***'. This is due to the innovative use of a combination of in-situ techniques to treat a wide variety of compounds of concern in the most challenging of geological conditions. A total of 17,292 tonnes (8,646m^3) of highly contaminated soil and groundwater have been successfully treated using a combination of **thermal treatment** and **enhanced reductive dechlorination** techniques, to a depth of up to **19.0mbgl** in a complex, multilayered aquifer/aquitard formation to address two separate dissolved phase groundwater plumes.

The works were undertaken on a voluntary basis to meet the client's exemplary Corporate Social Responsibility (CSR) policy and mitigate potential future ongoing liabilities associated with the groundwater plumes. The works were also required to mitigate potential vapour inhalation risks associated with a proposed new research building construction.

Tamdown acted as Principal Contractor for the building decommissioning, demolition and remediation works, and directly managed the installation and operational phases of the in-situ remediation. AECOM acted as the client's consultant, designer and representative during the works. However, due to the highly complex nature of the works with extreme time pressures to implement, a collaborative 'project team' approach was taken to ensure successful delivery rather than a traditional 'contractor – engineer' relationship, since both parties collective strengths were called upon throughout the course of the works.

Background and Project Constraints

Preliminary investigations had indicated that historical storage of waste solvents and herbicide residues in an underground storage tank had resulted in significant contamination within shallow soils and groundwater, primarily BTEX and chlorinated solvents including Chloroform & 1,2 Dichloroethane with concentrations of up to 150,000µg/l total VOC detected. Significantly elevated SVOC concentrations (up to 100,000 µg/l) and List I pesticides / herbicides (total up to 414µg/l) were also detected. Further investigation of the deeper aquifer unit at >14m depth also confirmed significant concentrations of compounds of concern (CoC's) - at similar levels to the overlying shallow aquifer.



It was concluded that the 6m thick sandy clay aquitard had not prevented migration of CoC's into the deeper aquifer. As a result two separate plumes were identified below the site, the shallow plume over 300m length and the deep plume over 200m length. Whilst the CoC's were not recorded at the site boundary in excess of relevant environmental quality standards, the client wished to mitigate potential ongoing liabilities by implementing a robust remediation strategy to significantly diminish the plume within a reasonable timescale. The project presented substantial technical and logistical challenges that the in-situ remediation works had to overcome, including:

- The initial lack of data on the distribution of CoC's both spatially and depth at the onset of the project, due to the restrictions placed by the former building;
- The highly complex and variable nature of the underlying Minor Aquifer units, with very dense to hard slightly clayey, silty sands. The dividing sandy clay aquitard was also highly variable with stratified layers of sandy gravelly clay;
- The highly complex and heterogeneous hydrogeological conditions underlying the site;
- The significant depth of contamination that required active source zone treatment, up to 19.0mbgl, and the greatest proportion of contaminant mass likely within the low permeability aquitard;
- The likely presence of non-aqueous phase (NAPL) contamination given the significant dissolved phase concentrations recorded;
- Extremely tight programme timescales due to the required ongoing construction over the source zone. This necessitated all three strata to be treated simultaneously (effectively three separate thermal treatment projects on a source treatment zone footprint of only 400m^2); and,
- The requirement for minimal settlement tolerances to be met during thermal treatment, due to future construction of shallow pad foundations.

TAMDOWN

AECOM

Brownfield Briefing Awards // Best In-Situ Treatment – Project Sunflower, UK

Best Practice

A remedial options study was undertaken by Tamdown in close consultation with AECOM during initial development of the Remedial Strategy. It was agreed by all stakeholders that conventional remediation techniques would not achieve the required objectives, and traditional ex-situ methods (source excavation & off-site disposal/treatment in conjunction with pump & treat) were not the best practicable environmental option (BPEO) and carried high risk of CoC 'rebound'. Certain in-situ methods considered would have effectively treated the shallow and deep sand aquifers, however would not have addressed the significant proportion of contaminant mass assumed to be present in the middle clay aquitard. AECOM thereafter developed a Detailed Remediation Strategy adopting a staged 'Treatment Train' approach to the remediation works with risk-based targets derived for the source zone and 100m down-gradient. This commenced with sheet piling and ex-situ removal of the solvent UST and surrounding VOC contaminated soils to a depth of 6.2mbgl. Thereafter, the following combinations of technically advanced in-situ techniques were applied, adopting industry best practice:

- In-situ delineation of the source zone was achieved in real time using Membrane Interface Probing (MIP) technology calibrated with core sample testing, once the former research building had been fully demolished. This approach enabled the required extent of thermal treatment to be rapidly determined and design calculations/well spacings for the systems to be finalised;
- Shallow and Deep sand aquifer source zones treated by steam/air injection combined with dual-phase recovery of liberated dissolved and vapour phase CoC's, using remediation wells installed to depths of up to 20.0mbgl. Due to the variability between each strata, split steam injection systems were operated at differing injection pressures to ensure effective heat propagation;
- Middle sandy clay aquitard treated using electro-thermal conductive heating combined with high-vacuum (multi-phase) recovery of liberated dissolved, free and vapour phase CoC's. Multi-phase extraction achieved at two depths (top & bottom) within the sandy clay layer;
- In-situ monitoring of soil temperatures at all depths throughout the three treatment strata using profiles of 149 thermocouples, relayed via telemetry link for both field and remote data collation / interpretation on a daily basis for process optimisation;
- Continual determination of VOC mass recovery from all treatment strata using field gas-chromatographs and airflow monitoring, relayed via telemetry to derive regular mass flux and cumulate mass recovery profiles from each of the treatment strata;

- Steam injection and vapour/water extraction and treatment achieved using a highly complex above ground treatment process combining high and low vacuum extraction systems with full ATEX compliance, heat exchangers and liquid/vapour phase activated carbon media to absorb liberated CoC's. The system had automated monitoring systems with full safety interlocks and SMS telemetry link to provide the plant operators with warning of 'out of hours' shutdown;
- Residual dissolved phase plume treatment in the shallow and deep aquifers through injection of controlled release organic substrates (3D Micro-emulsion (3DME) and a hydrogen release compound (HRC) primer), to promote enhanced reductive dechlorination (ERD) following active source zone treatment. These substrates were demonstrated to be most effective during in-situ field trials, where three separate products (also including emulsified vegetable oil and cheese whey/fructose) were assessed; and,
- Enhancement of the residual in-situ treatment was achieved through continued high-vacuum extraction and groundwater

TAMDOWN

AECOM

recovery/treatment after cessation of thermal treatment, using the pre-treated (warm) groundwaters as the feedstock for diluting the ERD substrate rather than cold, sterile mains water supply.

The combined operation of steam/air injection in the sand aquifers and electro-thermal conductive heating in the clay aquitard is understood to be the first such application of its kind in the UK or Europe, and one of the most technically complex thermal treatment projects undertaken.

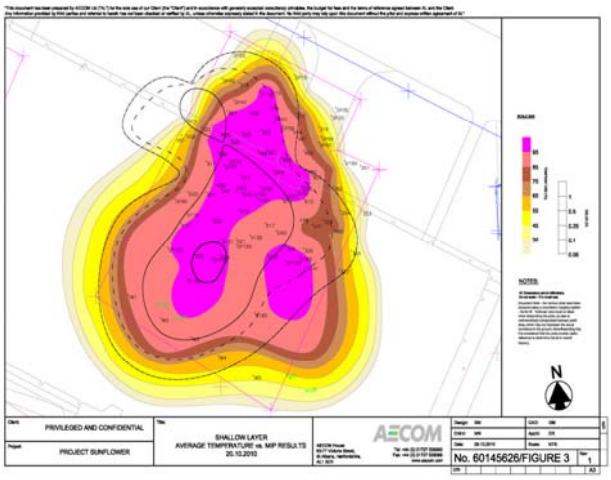
All remediation works were installed, operated, maintained and monitored by **Tamdown,** with **AECOM** fulfilling an overseeing/liaison role. During in-situ treatment, process equipment, field pipework, telemetry systems and ongoing operational & maintenance (O&M) support was provided by **Cornelsen Limited** as Tamdown's specialist sub-contractor. Thermal conductive heating equipment, remote mass recovery and temperature monitoring equipment, as well as specialist thermal treatment design and ongoing technical support was provided by German specialists **Reconsite GmbH**. Drilling and substrate injection services were provided by **Tor Drilling**, and substrates supplied by **Regenesis**.

Installation of remediation and thermal treatment wells, system setup, testing and commissioning was undertaken between May and June 2010, and full-scale thermal treatment works undertaken for an 18 week period from July until November 2010 when all parties agreed there was no further benefit to continuing active thermal treatment as asymptotic mass recovery conditions had been achieved in all layers. Residual in-situ treatment (residual vapour/water extraction and substrate injection) was undertaken during November and December 2010.

Cost Effectiveness and Durability

Based on a total of 8,133 tonnes of soil/groundwater being treated in the source zone, the cost of the active thermal treatment was £67.60/tonne (£106.50/m^3) inclusive of energy costs and all operational monitoring costs, resulting in an overall saving of **£277,000 (35%)** compared to a *far less robust*, higher risk ex-situ approach that would only achieve remediation to a practical limit of 9.0mbgl). Moreover, the proposed building would have required piled/ground beam foundations that would also have significantly increased construction costs that are not accounted for in this saving.

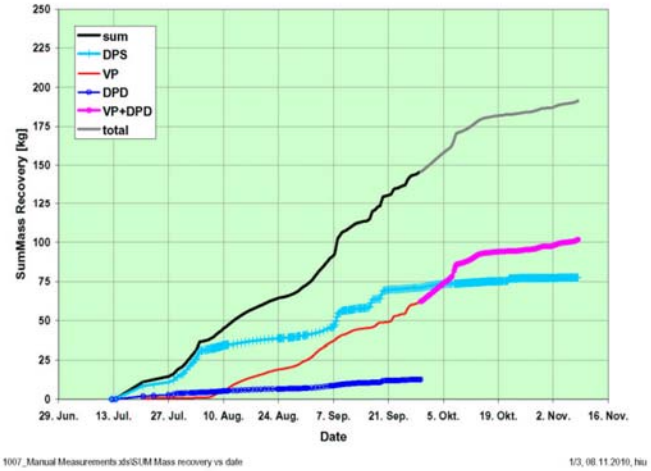
The total cost to treat 3,600m^3 of shallow/deep aquifer saturated zones through ERD treatment equates to a maximum of **£45.86/m^3** of saturated soil (includes contingency for top-up injection). Long term residual groundwater pump & treat is estimated to have cost at least **£89.68/m^3** of saturated zone, with greater risk of contaminant rebound – presenting a saving of at least **51%.**



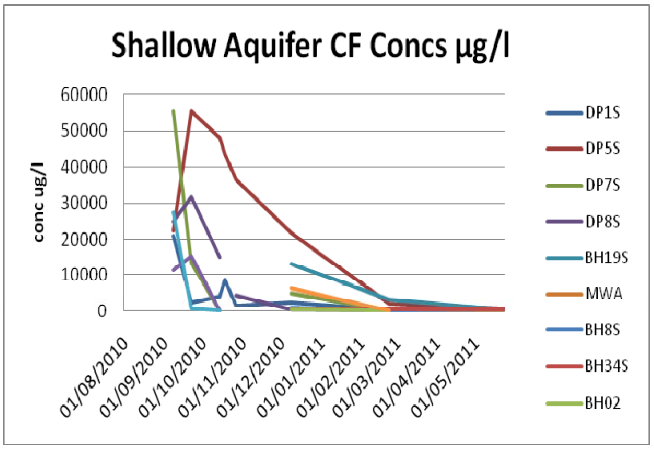
There are several aspects that demonstrate the durability of the in-situ treatment techniques adopted: a) complete vaporisation of target CoC's as well as a wide variety of CoC's was achieved in each layer, minimising risk of 'rebound' and significant betterment of contaminant concentrations in the aquifers including several List I compounds; b) significant mass removal achieved over a short timescale; c) accelerated betterment of the wider groundwater plumes through rapid mass reduction; and, d) the significant biodegradation of residual dissolved phase compounds occurring due to latent warmth within the source zone and the downstream 'halo' of the plumes. For example, 9 months after cessation of thermal treatment, groundwater temperatures are still 26-30°C within the source treatment zone and groundwater temperatures are 2-3°C above ambient up to 30m downstream.

Enhanced biodegradation will occur over a prolonged period of time due in the source zone 'halo' and downstream plumes, with an estimated 3-5 year substrate release profile. The combination of active and passive in-situ treatment processes will significantly reduce the timescales required for ongoing completion monitoring to demonstrate acceptable groundwater conditions, which has proven to be the case during the first 9 months post-completion monitoring.

Finally, settlement monitoring undertaken during thermal treatment works confirmed that the soil heating processes had minimal impact on the geotechnical characteristics of underlying soils, with all settlements recorded below the agreed tolerance of <20mm.



Reduction in Pollution Burden



The use of a combination of thermal treatment approaches achieved soil temperatures of up to **103°C** in the shallow/deep sand aquifers and **104°C** in the sandy clay aquitard. During this active source zone treatment phase a total mass removal of **326kgs of VOC's**, **2kgs of SVOC's** and **1kg of pesticides/herbicides**. Concentrations of the most prevalent COC's have been reduced from peak recorded levels during treatment by more than 99%, as demonstrated by ongoing groundwater monitoring and soils analysis in each layer pre/post works. The subsequent reduction in pollution burden for all compounds to be achieved by the residual ERD treatment in the down-gradient plume is more difficult to estimate, however is considered to be at least **35kgs** of chlorinated VOC's over the course of residual treatment.

In order to ensure that the pollution burden is not simply transferred to another environmental media, the spent activated carbon utilised for vapour/liquid phase removal was subjected to a regeneration process that destroys the compounds and recycles the carbon media.

Community and Stakeholder Acceptance

Numerous stakeholders were involved in the assessment and remediation stages of the project, the client and its Global Environmental Risk Management team, the project consultants (AECOM), the Environment Agency (EA) and operational site staff.

Numerous stages of consultation were held between all parties to develop a robust remediation strategy that exceeded normal risk-based 'suitable for use' approaches due the client's high CSR standards. Ongoing liaison was maintained with the client's project team, and key site operation staff and the EA throughout the project to ensure that any perceived or actual risks associated with the site remediation works were minimised.

Health & Safety Compliance

Tamdown acted as Principal Contractor in line with CDM Regulations, and completed all works fully in accordance with stringent health & safety procedures set out by its own ISO 18001 accredited management system. Tamdown's use of the **WiSE (WorkSmart Engagement) system** helped ensure that all the potential hazards were noted and discussed by all operatives, from time to time problems were discussed and solutions to these were found by the operatives themselves thus ensuring that the measures were practical, workable and adhered to. In doing so, the Health & Safety record of the project was exemplary throughout the duration of in-situ works.

To meet the requirements of its Environmental Permit and the client's stringent OHS standards, Tamdown implemented a rigorous environmental monitoring regime including noise, dust, odour and VOC's at various locations surrounding the thermal treatment area, treatment plant and site boundary. No exceedences of environmental quality standards were recorded during the works, and no complaints associated with noise or odour emissions were received by any of the client's operational staff throughout the works.

Conclusion

The innovative use of a combination of in-situ treatment techniques ensured that hazardous soils & groundwater could be rapidly and effectively treated without significant surface exposure on a restricted available footprint to meet the clients overall tight construction programme. In doing so Tamdown met the client's remediation budget whilst preventing >300 loads of hazardous waste being removed off-site to landfill.

The client's Project Manager, said "*The in-situ treatment systems adopted by Tamdown and AECOM for Project Sunflower were at the cutting edge of remedial technology, in the most challenging of environmental settings, restricted programme and treatment footprint. This was achieved without compromise to the high standards of Health, Safety & Environmental controls we require at all our facilities, and the treatment systems achieved zero complaints from our staff*".

TAMDOWN

AECOM