BROWNFIELD BRIEFING AWARDS 2017

Arcadis Entry

In Situ Thermal Remediation Enhancement of a Dual Phase Extraction System

Category 2 – Best In Situ Treatment

Overview

Our submission demonstrates the positive outcomes which have be achieved through continuous adaption of remediation technologies, with the goal of achieving the greatest impact balanced against the cost effectiveness and sustainability of the solution. The success of the remediation of this site starts back with the detailed characterisation undertaken some years ago, which itself was awarded the Brownfield Briefing Award for Best Scoping or Operation of a Site Investigation in 2012. Since that time a remediation system was then operated at the site, comprising Soil Vapour Extraction (SVE) and Dual Phase Extraction (DPE) technologies.

Following a review of the remediation performance in 2016 the decision was made to enhance the system via an In Situ Thermal Remediation (ISTR) approach.

Through implementation of traditional remediation techniques, including SVE and DPE, Arcadis successfully removed over **8,500kg** of Trichloroethene (TCE) contaminant mass from beneath the site over a period of 36 months. With declining mass recovery rates the DPE system at the site was enhanced with ISTR enabling the recovery of a further **1,520kg** of contaminant mass within 10 months, **which would otherwise not been recovered.**

The Site

The site occupies an area of approximately 8,200 m^2 and was previously used for the manufacture of electronic control units and sensors. It is planned for redevelopment as a commercial property and bound by sensitive receptors, including a school premises, community hall and residential properties. Following closure of the site in 2010, Arcadis was appointed to support with the site investigation activities in support of the site's divestment. The investigation activities focused on developing a detailed conceptual site model through a combination of investigation methods, the outcome of which included a 3D geological model. This helped conceptualise the likely pathway for DNAPL migration in sand lenses, followed by sorption to the adjacent clay deposits, and supported the design of the remediation strategy for the site.

Remediation Strategy and Implementation

The remediation strategy for the site initially comprised the operation of an SVE and DPE system, designed to both mitigate against off-site migration of contaminated groundwater and soil vapours, but also to target the reduction of the contaminant mass in the identified source areas. The system was originally commissioned in 2013 and operated for a period of 36 months until the middle of 2016.

During 2016 it was observed that contaminant recovery rates were beginning to plateau (Figure 1), and were forecast to become asymptotic during late 2016/early 2017. Recovery rates had dropped year on year from an average of 589kg per month in 2013, to 87kg per month in the first half of 2016 (Table 1).

Table 1 – Average DPE/SVE Recovery Rates

Year	Average monthly mass recovery / kilograms
2013 (6 months)	589
2014 (12 months)	264
2015 (12 months)	207
2016 (6 months)	87

Based on this a decision was made between all stakeholders, and with agreement from the regulators, that rather than go into a lengthy monitoring period we would enhance the operation of the DPE system with ISTR. ISTR had originally been considered at the start of the project, but, due to the significant extent of the original source and plume area (Figure 2) it was identified to be grossly cost prohibitive.

However, once the source and plume areas had reduced following the success of the DPE and SVE operation, it was clear to see where the use of ISTR would have the greatest impact (Figure 2) in supporting closing out remediation activities at the site.

Figure 1 - Total Contaminant Mass Recovery – 2013 to 2017 (kg)

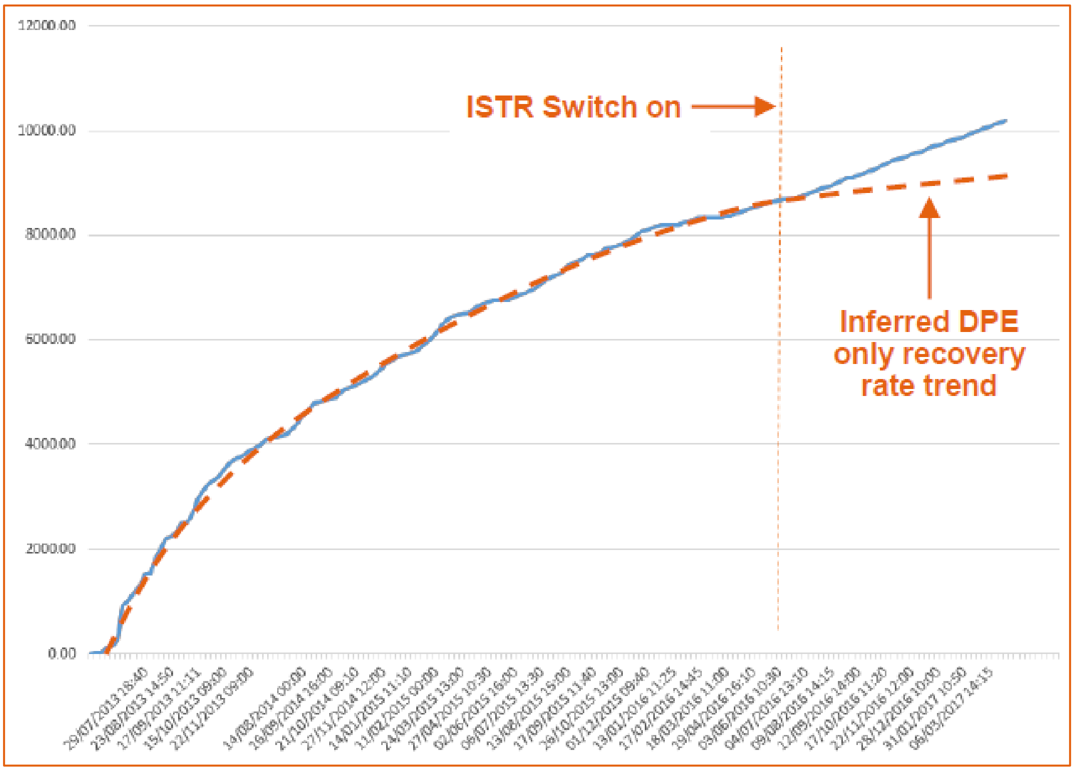
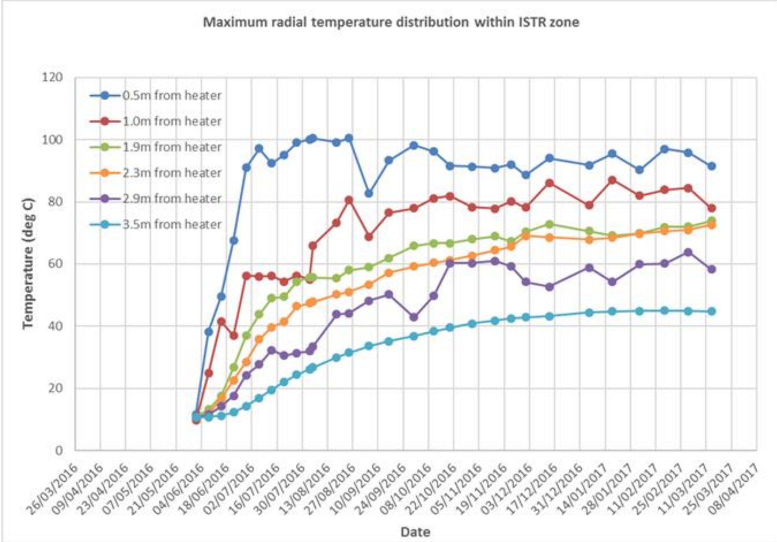


Figure 2 - Groundwater TCE extent pre-remediation and prior to ISTR implementation highlighting the target areas.

The ISTR system was then designed, commissioned and installed by Arcadis in June 2016. The system was then operational between June 2016 and March 2017 for 10 months. The ISTR system involved the following:

- Connection of additional vapour extraction points in areas where high levels of residual contaminant mass was observed to continue to reside, to the existing SVE and DPE system retained on-site to control vapour recovery.
- Selection of 25 heating locations across the site, within the four main target zones (see Figure 2) where concentrations of TCE were measured in excess of 100 mg/l. Electrical conductive heating elements were installed between 4 and 8m below ground level.

- The heating elements were then raised to a temperature of 500ºC, providing an increase in ground temperatures in excess of 60ºC within 3m laterally of each heating location, and up to 100ºC within 0.5m, across the soil profile.
- Extracted soil vapours were then passed through a heat exchanger prior to treatment via a bank of vapour phase activated carbon vessels. All vapour discharges were treated to a concentration of <1ppm bearing in mind the sensitivities of the neighbouring receptors, with starting vapour concentration in excess of 2,000ppm in some locations at the point of extraction.



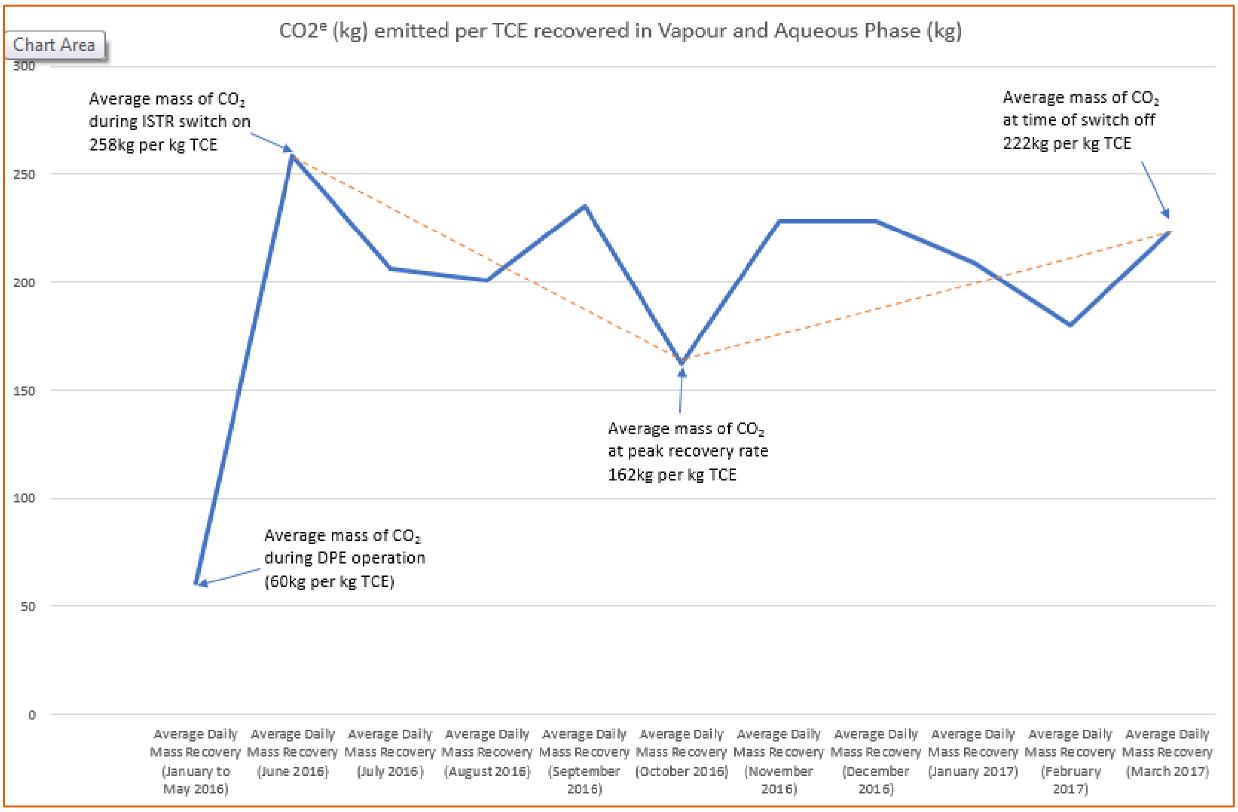
Demonstration of Best Practice

Optimisation and combination of remediation technologies
Through regular weekly monitoring of the system performance during the project the remediation process has been continually optimised to ensure the system has been focussed on achieving the greatest impact on reducing the contaminant mass beneath the site. This has included the adjustment of groundwater pumping rates and pumping locations, the adjustment of vacuum levels at individual extraction locations and, installation of additional groundwater and soil gas extraction points to support additional mass recovery. This process has also been supported by continuous remote monitoring of the system enabling any system faults, drop in temperatures, or power outages to be picked up and dealt with immediately.

Remediation system enhancement rather than monitoring
The ISTR enhancement of the remediation system on-site at a time when contaminant recovery rates were becoming asymptotic, as opposed to switching the system off and moving into a prolonged period of monitoring, has supported the recovery of a significant proportion of additional contaminant mass. Based on a review of the data collected as part of the remediation process it was clear that residual contaminant mass was residing within the more cohesive zones beneath the site, which had the potential to ‘bleed’ back out into the aquifer in the future. ISTR was identified as the best technology to support further remediation efforts at the site, directing the heat from the conductive heating probes into these cohesive zones.

Sustainability in design
It was recognised that the implementation of an ISTR approach at the site would significantly increase the carbon burden associated with the remediation system, with a 4 to 5 fold increase in energy consumption rates. As such, the effectiveness of the ISTR system was monitored closely each week, allowing for clear decision making each month over whether to extend the lifetime of the ISTR system or switch it off. The decision was made to switch it off after 10 months when it was clear that recovered soil gas concentrations has returned to pre-ISTR levels, but also that the mass of CO_2 (kg) per kilogram of TCE (total) recovered was no longer demonstrating the system was providing a significant benefit to the environment. This is highlighted on Figure 3, which demonstrates prior to installation of the ISTR the system was ‘emitting’ 60kg of CO_2 per kilogram of TCE recovered. On switch on of the ISTR system this peaked to 258kg of CO_2 during the heating phase, reducing to 162kg of CO_2 at the point of maximum TCE recovery, and later increasing to in excess of 220kg of CO_2 at the point of switch-off.

Figure 3 – Carbon Dioxide emissions associated with the operation of the ISTR system



Cost Effectiveness and Durability

The ISTR enhancement of the existing remediation techniques implemented at the site has led to the robust treatment of the contamination present beneath the site, building on the success of the investigations and subsequent DPE/SVE remediation approach. This is evidenced by the significant mass of TCE recovered during the relatively short operation of the system (10 months) and improvement in conditions beneath the site.

The ISTR upgrade to the system supported the removal of an additional 1,520kg of contaminant mass in the 10 months of operation, averaging at 155 kg/month with a peak of nearly 200kg comparable 2015 levels, before reducing back to levels comparable with the DPE/SVE system prior to the switch-on of the ISTR system. Vapour phase recovery rates were observed to increase by up to 210% at the peak of the ISTR systems operation. Continuous monitoring of recovery rates and system performance has ensured that the cost effectiveness and sustainability of the remediation process has been continually optimised.

Reduction in Pollution Burden

The remediation process is considered to have had a huge impact on reducing the pollution burden beneath the site, and a large part of this was grasping the opportunity to proactively install and operate the ISTR system to recover contaminant mass which could otherwise be have been left in place and likely further delayed the redevelopment of the site back into beneficial use. A summary of the key performance metrics are highlighted below.

SYSTEM PERFORMANCE

In excess of **10 tonnes** of TCE contaminant mass recovered, with **over 1.5 tonnes** of this total recovered using ISTR enhanced DPE which would otherwise not have been recovered

Over **50,000,000 litres** of groundwater treated, through the lifetime of the project, with nearly **14,000,000 litres** treated during the ISTR phase – enough to fill over 20 Olympic Swimming pools

Reduction in groundwater TCE concentrations beneath the site by **>90%**

Reduction in the contaminant source are by **>95%,** and the plume area by **>85%.**

Community and Stakeholder Acceptance

Liaison with the regulators and local stakeholders including the neighbouring school, church warden and neighbouring residents has been ongoing throughout the remediation process. Regular contact has been had with the neighbouring land owners to facilitate ongoing access off-site to permit groundwater and soil gas monitoring on a quarterly basis – this has included regularly returning footballs back to the school playing field accidently kicked over the site boundary. Following the cessation of the ISTR activities in March this year it has now been agreed with the regulators that following the ISTR cool down phase planned for completion in July 2017, the remediation system can then be removed from site allowing plans then to be made to support the site's redevelopment.

Compliance with Health and Safety

Throughout the remediation programme there has been a continuous focus on the Health and Safety of those performing the work, but also on stakeholders surrounding the site which had the potential to be impacted by the changing vapour conditions beneath the site. Some of the key initiatives taken during the project include:

- Weekly site visits to check treated vapour discharge conditions and boundary site conditions.
- Fortnightly site audits to confirm the system is operating in accordance with the requirements of the site's Environmental Permit and all critical safety devices are operational.
- Quarterly off-site soil gas monitoring and testing around the sensitive neighbouring receptors including the residential properties and school.
- Full time remote monitoring of the system operation, to allow for immediate identification and rectification of potential faults.
- Installation of a bank of eight lead and lag vapour phase activated carbon vessels, allowing carbon changes to be arranged immediately on breakthrough of the lead vessels, whilst the lag vessels continue to treat the contaminated vapours to <1ppm. During the ISTR phase of the project a further bank of 4 vessels was maintained on-site to allow for immediate swaps of spent vessels, hence allowing for the continuous operation of 8 treatment vessels at all times.
- Installation of a back-up generator to maintain the operation of the vapour extraction system during the ISTR phase of the project and in the event of a power cut to the site. This was proven to be a valuable critical safety device when power was lost to the site due to a local power cut, ensuring that contaminant vapours continued to be controlled beneath the site.