PUDDING MILL LANE - OZONE ENHANCED AIR SPARGING & SVE

Project Background

The Pudding Mill Lane (PML) Crossrail project comprised the construction of a tunnel portal and a new elevated Docklands Light Railway (DLR) station, plus associated structures to bring the subterranean railway into the above ground existing rail network.

The PML site is located adjacent to the former Olympic Park, is 4.3 hectares in size and is generally linear and elongated in shape. The overall site has historically comprised various industrial site uses including a gas works and chemical works. The area of the new DLR station was constructed on a former Waste Yard. Extensive investigation by Crossrail had identified a groundwater hydrocarbon plume beneath the area of the new DLR station requiring remediation. Contaminants of concern included benzene and naphthalene.

Ecologia were appointed by Morgan Sindall (the Contractor) to design, construct and operate a groundwater remediation system beneath the newly constructed and operational DLR Station.

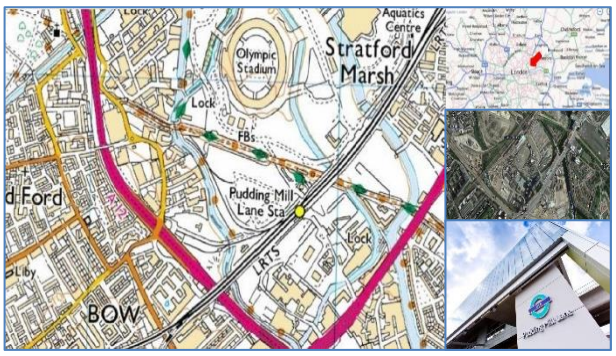

Figure 1. Site Location (*Source: Google, Crossrail*)

The following key outcomes of the project are summarised:

Represents best rather than good or average practice

- Detailed options appraisal incorporating a sustainability assessment in accordance with SuRF-UK has ensured that the Best Available Technique has been selected for the treatment works.
- All Ecologia's operations operate under a combined Safety, Health and Environmental management system accredited to ISO 9001, OHSAS 18001 and ISO14001 ensuring the highest standards are maintained.

Cost effectiveness and durability over the period of operation

- Cost effectiveness has been a key requirement of Crossrail which is required to be publicly accountable and commercially transparent. Ecologia have proven the cost effectiveness of the groundwater remediation works by the preparation of a single source paper providing demonstrable evidence of design and engineering value.
- Durability of the works i.e. no hydraulic rebound, has been proven by rebound monitoring in combination with ex-situ bench scale laboratory trials.
- The groundwater remediation approach (including ex situ laboratory trials) was designed to deliver the remediation works within compressed timescales. The remediation works were ultimately completed some 6-months quicker than originally planned to support early hand back of the site to various land owners.

Significant reduction of the pollution burden rather than transferring it

- Betterment of the groundwater concentrations has been significant and no further work is required.

Community and stakeholder acceptance

- Regulatory acceptance is required as part of the Crossrail Environmental Minimum Requirements. As such all the design documents and the verification reports have been sent to the Environment Agency and London Borough of Newham for their acceptance.
- Extensive community liaison was undertaken by Morgan Sindall throughout the works.

Compliance with health and safety

- The constraints of an operational DLR station with members of the public was significant. A continuous ozone monitoring and shut-down system was put in place as a safeguard to site construction workers and public users of the DLR.
- The breakdown of the contaminants of concern required close monitoring of the groundwater to ensure the protection of below ground concrete structures / foundations from sulphate reducing conditions.
- Compliance with the requirements of the mobile plant treatment licence, as well as Crossrail and Morgan Sindall procedures ensured the strictest standards of health and safety were maintained, and no environmental and safety incidents were reported.

Key Design Considerations

Technical Objectives

Key to the process of completing groundwater treatment works was the close liaison between Ecologia and the Environment Agency in agreeing the remedial objectives as betterment. This was predicated on the basis of poor regional background water quality and the significant site constraints, in addition to the extensive source removal of shallow soils.

Cost

The groundwater remediation works were procured by Crossrail via Morgan Sindall. As a result, to demonstrate the best possible value to the tax payer, Ecologia prepared a single source paper providing demonstrable evidence of design and engineering value for scrutiny by Crossrail.

Programme

Of key importance to the approach was the requirement to complete all the treatment works within the Crossrail programme, and to enable the handover of sites back to the landowners without long term residual liabilities. This required a 12-month maximum allowable duration on site. This meant that any rebound monitoring period needed to be completed within the 12-month programme, which had the potential to reduce the treatment duration (limiting the betterment that may be achieved). Therefore demonstration of the rebound mechanism by Ecologia as pore-water recharge rather than hydraulic recovery, minimised the requirements for long term post works rebound monitoring, this was undertaken by a combination of:

- A mini rebound period during the works where the treatment plant required relocation to allow the construction works to progress unhindered. This demonstrated no significant recharge of groundwater and rebound of contamination concentrations.
- Ex-situ bench scale laboratory trials which demonstrated the nature of the preferential treatment of large pore voids and subsequent micro pore recharge from adsorbed contamination.

Operational Requirements

Remediation works were required to be undertaken during the construction works on site cognisant of:

i. Restricted space and utility and services easements.
ii. Managing several contractor interfaces including working practices as well as limited accessibility during parts of the construction programme.

The system was constructed with regard to the above site constraints. To this end the treatment wells were installed in phases prior to construction of the new station and the treatment plant was designed as fully mobile and able to be reconfigured in layout and / or relocated around the site whenever required.

Health and Safety

The constraints of an operational DLR station with members of the public was significant. A continuous ozone monitoring system was put in place as a safeguard to site construction workers and public users of the DLR. Remote sensors were installed across areas of the treatment area and within the operational station with an automated shut-down programmed into the ozone generator should safe exposure levels be exceeded.

Sustainability Requirements

Crossrail required that remediation works be undertaken using the UK Sustainable Remediation Forum (SuRF-UK) framework which defines the process of assessing sustainable remediation.

The works were also required to contribute to the overall sites Excellent CEEQUAL (Civil Engineering Environmental Quality scheme) award.

Treatment System

Selected Treatment Technique

An Ozone Enhanced Air Sparging system was chosen as the most appropriate approach to treat hydrocarbon contamination (dissolved phase benzene and naphthalene) cognisant of the key design considerations. Air sparging would oxygenate groundwater and / or volatilise the dissolved phase contaminants. The addition of ozone to the airflow added a chemical oxidative effect to the process providing the following key functions:

- A low intensity oxidative effect to oxidise the contaminants of concern in-situ while minimising contaminant migration or damage to the geotechnical properties of the ground that may have resulted from the injection of large volumes of chemically aggressive liquid oxidants. The use of ozone also avoided the significant health and safety issues associated with handling large volumes of powerful liquid oxidants on site.

- The ozone sparging also provided significant quantities of oxygen to the saturated zone to improve the rate of aerobic in-situ biodegradation.
- The treatment technology also treats larger void spaces and adsorbed contamination preferentially. Subsequent recharge from the micro pore space allows the treatment system to continue to treat contaminant concentrations and increase its effectiveness.

A soil vapour extraction system (SVE) was designed to capture fugitive emissions from the sparging. The SVE system provided the added benefit of removal of any residual vapours in the unsaturated zone by:

- Reduction of the pressure in the unsaturated zone and destabilisation of the thermodynamic system leading to increased volatilisation of contaminants.
- Sub-surface mass transfer of gases, enabling the volatile hydrocarbons to be removed from the sub-surface system and the introduction of oxygen.

System Design

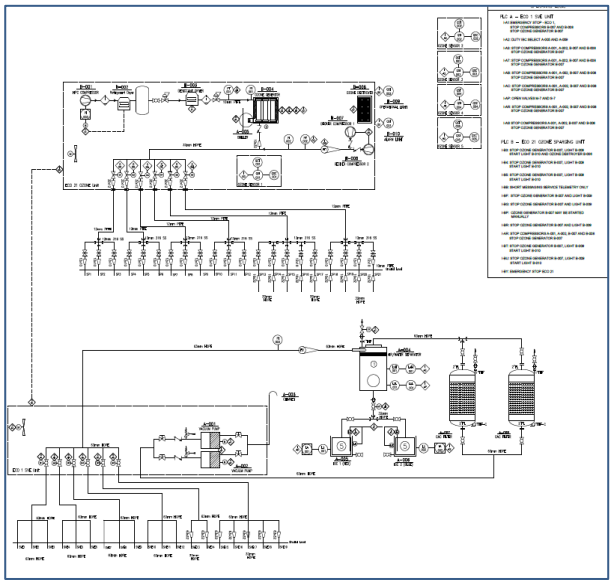

Figure 2. Process Flow Diagram of Treatment System

The system was prefabricated at Ecologia's workshops. To be as flexible as possible the treatment system was designed as modular and housed in 20ft shipping containers which supported easy reconfiguration of the set up and fast relocation.

The systems were fully automated, controlled by a programmable logic controller (PLC) with a telemetry system, including SMS alarms to mobile phones of engineers / technicians.

The SVE unit was connected to an air water separator used to capture any water extracted by the unit with an IBC located in a bund underneath. Two GAC filters were setup between the separator and the blower allowing the system to run continuously during a carbon change.

The sparging system used a low maintenance oil less compressor which was able to run continuously. An ozone generator and associated safety systems were installed within the unit.

System Installation, Commissioning & Optimisation

Treatment wells were installed by Ecologia prior to construction of the operational DLR station. The SVE wells were advanced to approximately 2.5m depth i.e. just above the groundwater table. The sparging wells were installed within the saturated zone at between 6 - 9m depth.

Figure 3. Installed and Commissioned System

Ex-situ bench scale laboratory trials were undertaken at Ecologia's laboratories by ozone sparging of drill core samples obtained during the treatment well installation works. The trials were intended to assist in system optimisation but also to:

- Estimate the total contaminant load associated with the source area.
- Estimate a contaminant removal rate.
- Demonstrate the mechanism of rebound through pore-scale recharge.

The results showed the rapid breakdown of hydrocarbons within the soil column and importantly demonstrated the nature of the preferential treatment of large pore voids and subsequent micro pore recharge from adsorbed contamination. A time-lapse video can be seen here: https://youtu.be/JWRPCM-yAeQ.

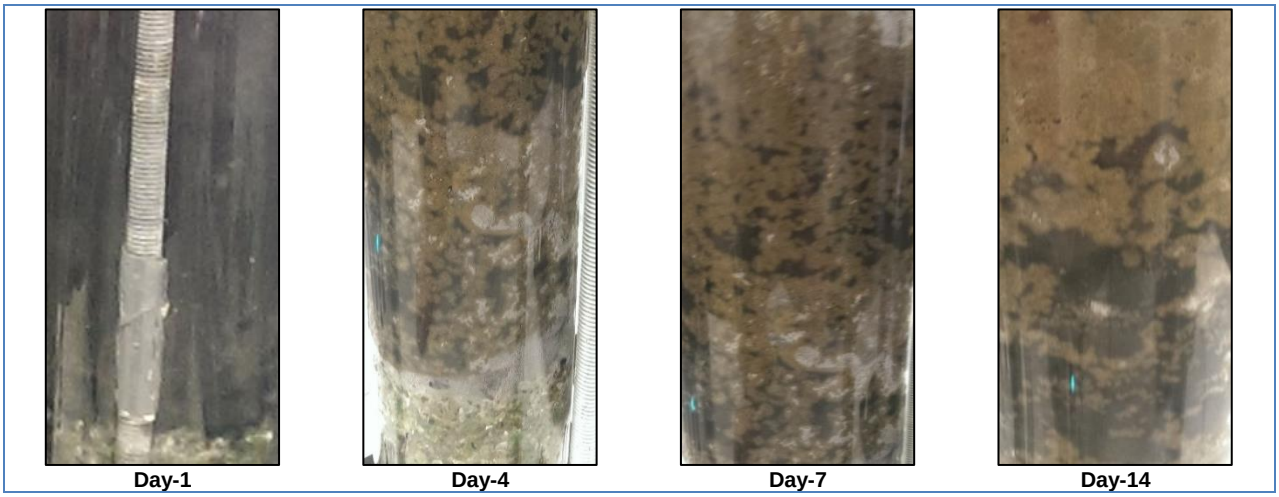

Figure 4. Soil Column from Laboratory Bench Scale Trials

The modular prefabricated units were delivered to site, once the DLR station had been constructed and was operational. The system was then connected to the existing treatment well network and commissioned.

Optimisation was undertaken by:

- Adjustment of the SVE flow rate to avoid excessive mounding of the groundwater table.
- Gradual adjustment of the ozone flow rate to avoid excessive emissions and reach optimal environmental conditions for microbial degradation, whilst maximising the destructive efficiency of the ozonation.

System Operation

Total treatment period comprised 302-days, with 275-days of operational time, and a temporary shutdown period of 27-days observed during road surfacing works. Post treatment, a 43-day rebound monitoring period was undertaken.

During the operation of the system, the 'ozone sparging' was cycled among selected groups of injection wells in a programmed manner to achieve: a more even spread of ozone concentrations across the treatment area. This maximised treatment efficiency; and, allow areas of higher contamination concentrations to be targeted.

Continual monitoring of VOC's was undertaken using an in-line PID. This was undertaken at the well heads to estimate the mass of vapour recovered and at the exhaust point to ensure compliance with emission targets. The exhaust monitoring also allowed maximum efficiency GAC filters to be maintained. In total three GAC filters (3,000kg) were spent over the treatment duration and transferred to a regeneration facility.

Figure 5. SVE & Sparging Unit Interiors

System Effectiveness

Groundwater monitoring completed during the treatment works demonstrated an overall reduction of benzene and naphthalene concentrations in groundwater. A significant reduction was noted corresponding to the ozone sparging operations and the data was shown to gradually stabilise as a declining source. The following groundwater betterment was achieved:

- Benzene, 99.8% reduction.
- Naphthalene, 98% reduction.

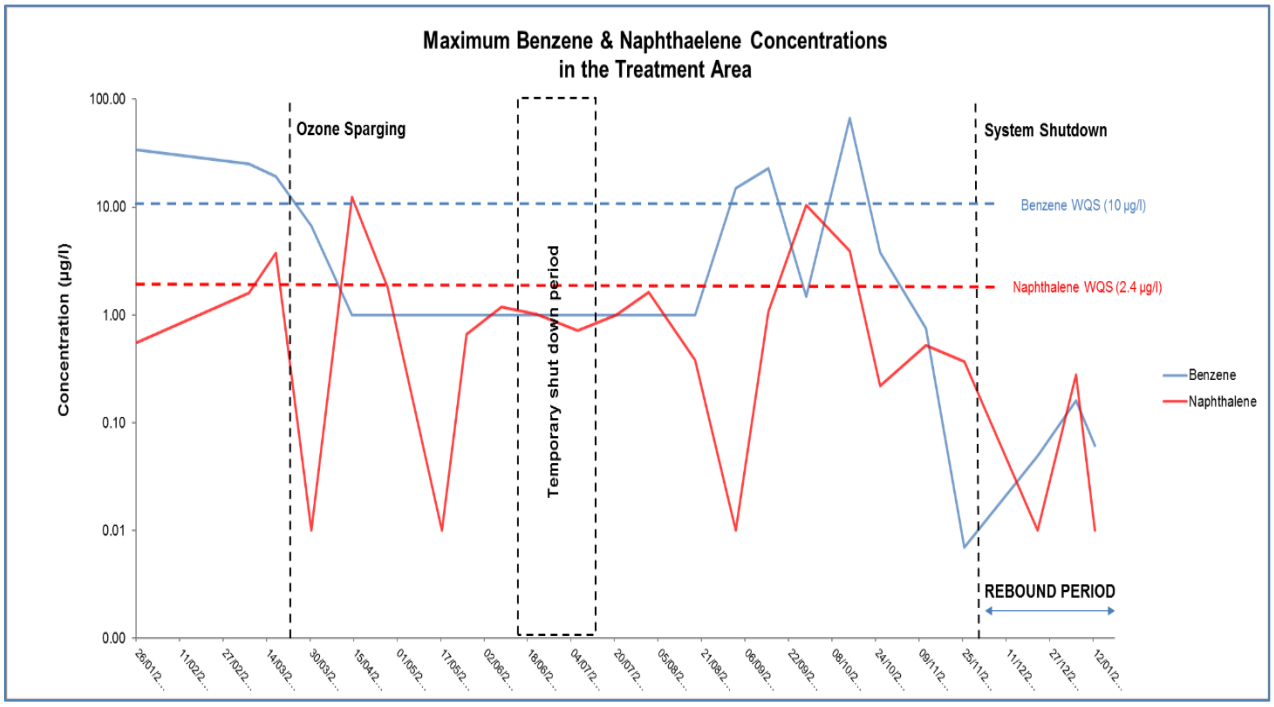

Figure 6. Groundwater Concentrations in Treatment Area

The secondary lines of evidence gathered comprised physical data (e.g. redox, pH, dissolved oxygen, dissolved ozone etc). This demonstrated the mechanism by which groundwater concentrations were reducing, thus providing further confidence to the treatment effectiveness.

The tertiary lines of evidence further corroborated the mechanism of reducing groundwater concentrations from volatilisation. The total estimated amount of VOC mass recovered as part of the off-gas venting was calculated as 214kg.

Closure

Ecologia were able to design a bespoke system for the works based on our knowledge of the site and Morgan Sindalls works due to extensive previous involvement in the project.

The works were consequently completed in a short timescale whilst achieving the remedial objectives on a challenging and constrained site, and removing any future groundwater liability / risks in the area remediated to the eventual landowners once handed back by Crossrail.