INSTALLATION OF A DUAL PHASE EXTRACTION SYSTEM IN A RESIDENTIAL NEIGHBOURHOOD
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INTRODUCTION

This paper is intended to provide our experience on the activities involved with implementation of an extensive in-situ remediation system in an urban setting. The first half of the paper provides background on the subsurface conditions, remediation objectives, design considerations, process equipment and infrastructure involved. The latter half of the paper focuses on the construction process.

BACKGROUND

Refined petroleum hydrocarbons at a retail service station that operated between the 1950’s and 1990’s in Western Canada, caused impacts to the subsurface soils and groundwater in an adjacent residential neighbourhood. The refined petroleum hydrocarbons consisted of gasoline that entered the subsurface through leaking infrastructure (pump islands, piping and underground storage tanks) and from a historical spill. Through assessment of soil and groundwater conditions, benzene concentrations above the applicable regulatory criteria was identified on-site and across half a city block off-site. The plume extended approximately 150 m off-site beneath public and private utilities, municipal roadways and approximately 3 m to 4 m beneath the basements of numerous residential homes and a few small commercial businesses.

SEACOR completed the assessment of the environmental impacts in 2001 to 2003 and installed more than 90 monitor wells across the site and across a city block. The stratigraphy consisted of silty clay in the upper 3 m followed by silty sand from 3 m to approximately 12 m below ground surface (bgs). The shallow groundwater on and off the site was approximately 6.5 m to 7.5 m bgs and flowed unconfined with a relatively flat gradient. The measured hydraulic conductivity was $3 \times 10^{-6}$ m/sec. It has been estimated that there may be the equivalent of 50,000 L to 100,000 L of petroleum hydrocarbons in the subsurface in the forms of residual, dissolved and light non-aqueous phase liquid (LNAPL). Soil vapour extraction (SVE) was conducted on-site in 2002 and 2003 and effectively reduced the apparent LNAPL thickness to less than measurable detection limits. LNAPL has never been identified off-site.
OBJECTIVE

Although assessment determined that the vapour inhalation risks for the off-site plume could be considered low, our client wished to conduct remediation to reduce the potential risks even further, with the objective of achieving the numerical regulatory limits. The regulatory criteria are quite stringent as it is governed by the predominantly coarse-grained characteristics of the soil and the surrounding residential land use receptors. Although the ultimate objective is to remediate to this risk based regulatory level, our client was aware that achieving such low concentrations of benzene could be difficult. At the least, it was expected that an assertive remediation effort would reduce benzene concentrations and could accommodate a future risk assessment for any remaining residual impact if present above regulatory limits.

DESIGN

Remediation through conventional methods such as excavation was impractical because of the existing roadway and utility infrastructure as well as the residential homes and commercial businesses. In order to actively mitigate any potential risks from the petroleum hydrocarbon impacts, an in-situ remediation strategy was identified to be the most appropriate approach. A dual phase extraction (DPE) system was selected as the in-situ technology of choice as the subsurface conditions were amenable to this technology and it would involve significantly less disruption to the local community. DPE technology involves the removal of groundwater and lowering the groundwater table surface while simultaneously conducting soil vapour extraction.

Pilot testing was conducted in order to design appropriate process equipment and infrastructure that could sufficiently control and recover the petroleum hydrocarbon plume. Data collected during the pilot test that was useful in the design of the DPE system included:

- formation air flow rates;
- applied negative pressures (vacuum);
- Pneumatic radius of influence;
- Hydraulic radius of influence;
- Groundwater production rates;
- Hydraulic conductivity;
- Groundwater chemistry; and
- Air emission chemistry

A team of SEACOR engineers, hydrogeologists and technologists with education, training and experience in civil construction, earth science, contaminant hydrogeology, air quality and emissions modeling, mechanical engineering/design and equipment operations was assembled for the project. The team used the information obtained during the assessment and pilot test to design and develop the specifications for the infrastructure required to facilitate a DPE system.
In order to meet the objective of remediating the soil and groundwater concentrations to an acceptable regulatory level, the design of the DPE system would require attention to the following factors:

- Target remediation timeline of 5 to 10 years;
- Continual year-round operation of groundwater pumping would be necessary to achieve and maintain groundwater depression and desaturation of the capillary fringe;
- Emissions were not to cause a nuisance odour or adverse effect to the public or neighbouring land owners/residents;
- The infrastructure was to be installed in such a manner as to minimize disruption to the local community during construction and during the life of the remediation project; and
- Waste disposal was to be minimized.

In addition to the recovery wells, the final design incorporated a process building, utility building, treatment tank and over 2,000 lineal meters of piping throughout the neighbourhood.

**PROCESS EQUIPMENT**

The SEACOR team considered various types of mechanisms to facilitate the DPE system and founded the final equipment design on the aforementioned factors. A rotary lobe blower was selected for soil vapour extraction, downhole pneumatic pumps were selected for groundwater depression and pumping, and an air sparge tank with granular activated carbon backup was chosen for treatment of the extracted groundwater. An air emissions stack would be implemented to allow for dispersion of any extracted soil vapours into the atmosphere. Two heated and insulated buildings (Utility and Process) were constructed on-site to house the mechanical equipment and a heated and insulated sparge tank was installed adjacent to the buildings for groundwater treatment.

The Utility Building was comprised of the following main equipment components;

- Air Compressor;
- Compressed Air Dryer;
- Air Tank, Pressure Regulator and Pneumatic Valve; and
- Sparge Blower

The Process Building was comprised of the following main equipment components;

- Soil Vapour Extraction (SVE) Blower;
- Inlet Separator and Air Filter;
- Sediment Filter;
- Granular Activated Carbon Vessels;
- Pneumatic Check Valve; and
- Water Discharge Totalizer
The Treatment Tank was comprised of the following main equipment components;

- Sediment Chamber;
- Aeration Chamber; and
- Transfer Pump

All of this equipment is powered electrically and are controlled by a Programmable Logic Controller (PLC) located in the Utility Building. Various controls and level switches are incorporated into the equipment and the PLC programming to ensure that safe and efficient operations are maintained.

**DISTRIBUTION PIPING**

Distribution piping from the extraction wells to the Utility Building, Process Building and Groundwater Treatment Tank was required to handle the following fluid streams:

- Compressed air (clean) to drive the downhole pneumatic pumps
- Soil vapour extraction (contaminated air); and
- Groundwater pumping (contaminated water)

With the reality that the remediation efforts might take several years to complete, it was important to design and construct the off-site distribution piping to withstand our Canadian climate for such a length of time.

**Compressed Air Piping**

The compressed air distribution lines were constructed of 25 mm Kitec pipe, which is semi-flexible aluminum pipe encased within crosslinked polyethylene. All of the fittings were mechanical compression or crimp-style compatible with and equal in strength to the pipe. The Kitec piping and fittings were necessary to withstand the soil loading and traffic loading. It also had to withstand the DPE system operating pressure for the pneumatic pumps that range from 175 kPa (25 psi) to a maximum of 860 kPa (125 psi).

The compressed air distribution lines were continuous where buried below ground and connections were only installed at designated manholes or extraction well roadboxes in order to be readily accessible. Approximately 650 m of the Kitec compressed air pipe was installed.

**Vapour Piping**

The vapour lines were constructed of DR17 high-density polyethylene (HDPE) pipe. This pipe was selected over conventional Schedule 40 or 80 polyvinyl chloride (PVC) pipe as it is designed for greater soil loads and traffic loads and has superior chemical resistance properties. In addition it is able to withstand the negative pressures applied by the DPE blower that typically range from 12.5 kPa (50 inH₂O) to 30 kPa (120 inH₂O).
All of the fittings were also HDPE compatible and equal in strength to the pipe. Fittings such as couplers, elbows and tees were connected by electro-fusion or butt fusion. Refer to Figures 1 and 2 below.

Approximately 550 m of SVE pipe in sizes of 50 mm, 75 mm, 100 mm, and 150 mm was installed underground.

Figure 1: HDPE electrofusion coupler.  

Figure 2: Butt fusion (50 mm) process.

Groundwater Piping

The groundwater return lines were also constructed of DR17 HDPE pipe for the same reasons identified previously. It easily had the capacity to handle the pneumatic pump pressures that range from 175 kPa (25 psi) to 350 kPa (50 psi). All of the fittings were also HDPE compatible and equal in strength to the pipe.

Approximately 650 m (2,100 ft) of 50 mm groundwater pipe was installed underground.

CONSTRUCTION TENDER

A request for proposal and a tender document was issued to environmental service contractors for the construction and installation of the process equipment and for the infrastructure. The tender document detailed all of the requirements and materials needed for the successful completion of the work. It outlined general information and requirements, bid information, contract conditions and supplementary conditions as well as detailed material specifications, quantities and design drawings.

The tender was structured so that the environmental service contractor would assume the responsibility of prime contractor. SEACOR was to participate in the construction as a representative of the owner and would conduct continuous review and documentation of the progress, monitor the quality of the installation and assist with change orders or modifications to the design if required during construction.
The main components of the tender included:

1. General Contractor Requirements
   a. Health and Safety program and record
   b. Insurance and WCB standing and history
   c. Similar project experience

2. Scope Definition
   a. Segmenting work into well-defined portions
   b. Establish portion according to locations, service type or material quantities
   c. Provision of detailed drawings and specs (civil, mechanical, electrical etc.)

3. Detailed Schedule
   a. Link milestones to payments
   b. Establish substantial performance, consequences and holdback provisions

4. Change Order Process
   a. Clearly defined process to apply for change orders
   b. Process managed by owner’s representative

5. Quality Assurance/Quality Control (QA/QC)
   a. Contractor is subject to inspection and audit of work

CONSTRUCTION ACTIVITY

The work was completed in 3 phases. The first phase included installation of the utility, process and treatment equipment on-site. Also within the first phase was the construction and installation of the underground piping infrastructure on-site. This allowed for remediation to commence on-site at source areas while the installation of the infrastructure off-site could be completed.

The second phase and third phase of the construction focused on the installation of the underground infrastructure off-site throughout the residential neighbourhood. This work was staged into two phases as it involved a significant area and it was deemed appropriate to minimize any disruption the activity would have along public roadways, laneways and boulevards. It was also divided into two stages so that the construction activity could be conducted in summer months as opposed to winter when excavating through frost, pouring concrete and finishing asphalt repairs are not favorable. For purposes of this paper, we will only discuss the second and third phases in greater detail as it was logistically more involved and difficult to undertake.

A SEACOR representative was on-site at all times, predominantly in a QA/QC role to document that the design specifications were being implemented by the contractor. The client representatives also made regular visits during construction to review progress and to update local residents on the schedule of the work. Keeping the local community informed of the project and the status of construction was an essential part of ensuring the project would be completed to the satisfaction of all stakeholders.

In addition to notifying area residents of the activity, other municipal departments were involved in various capacities. The contractor had to perform all construction activities
along the roadways, laneways and boulevards in an environmentally responsible manner. Construction practices had to comply with municipal erosion and sediment control standards and all concrete and asphalt removed had to be replaced in same or better condition and subject to review by the local municipal inspector. As this work was being conducted in an older residential neighbourhood, the client requested that the contractor finish landscaping along the boulevard and any affected private driveways to an as good or better condition than previously.

**Phase 2 & 3**

Phase 2 and 3 involved the excavation of approximately 400 m of open trench to a depth of 1.2 m bgs and approximately 50 m of directional drilling. The open trench was excavated along a laneway that separated two rows of residential homes, along a grassed boulevard and along the center of a street. Directional drilling was conducted beneath a major roadway to minimize traffic disruption.

The narrow constraints of the laneway and 3 separate underground natural gas mains, secondary services into the residential lots and overhead power services limited the rate at which the open excavation could be safely completed. Hydro-excavation (daylighting) of the various services was conducted as the excavation progressed.

The shallow depth of the trench required that insulation be used to protect the vapour piping and the groundwater distribution piping from freezing during winter. Although the vapour piping was expected to only handle air, moisture and humidity in the pipes from the extraction wells could produce frost conditions that would reduce the air flow capacity. The distribution piping from the extraction wells to the Process Building and Groundwater Treatment tank was heat-traced with self regulating 10 watt/m explosion proof wire. Cellular concrete insulation known as Cematrix™ CMI-475 (http://www.cematrix.com/) was used to fill the base of the trenches around the pipes. The Cematrix™ material was selected over conventional styrofoam insulation as it required significantly less labour and offered sufficient thermal conductivity and insulating value. A geothermal model was used by the supplier based on the applications at this site prior to selecting the mix of Cematrix™. The results of the model also suggested that the power usage required by the heat-trace wire would be less than 2 watts/m. Figure 3 shows Cematrix™ being poured into a section of open trench.

Styrofoam and spray foam insulation was used inside extraction well roadboxes and on fittings inside access manholes.
In addition to the open trench work, the pipelines were required to cross a major avenue. Instead of closing the avenue and rerouting traffic, directional drilling was conducted. The initial engineering design had called for drilling below the frost zone and between a municipal water supply line and sanitary sewer. However, field verification of as-built utility depths differed from the plans made available by the municipality at the time of the design. As such, it required that the directional drilling be conducted above the utility services within the frost zone.

The original design planned for piping to be located below the frost zone so there was no intention of insulating the pipes that would be pulled under the roadway by the directional bore machine. The directional drilling contractor bored beneath the roadway and installed a 305 mm diameter steel casing. After the vapour, groundwater and compressed air piping was pulled through the casing, Cematrix™ was pumped into it. The Cematrix™ in combination with the heat-trace would provide insulating value to protect the pipes within the frost zone.

Concrete manholes with steel traffic rated lids were placed at either end of the directional bore where the steel casing was exposed. This was done in order to facilitate the various piping connections, valves and electrical connections for heat-trace wire. Figure 4 shows a plan view of the directional bore and manholes.

Directional drilling was also conducted for a 40 m stretch of pipeline that was required along a boulevard on the north side of the avenue. The boulevard was grassed but it also contained three mature birch trees along the proposed distribution line route. An arbourist was consulted to provide guidance. Birch trees have a shallow and delicate root system. Ground disturbance from open trenching or from construction traffic could
adversely affect the trees. To avoid this potential affect, it was determined that directional drilling at a depth below the frost zone would be a more reasonable approach. Open excavation was only conducted at extraction well locations to tie into the distribution lines.

The contractor completed line integrity testing to ensure that the system was tight (leak proof). The compressed air Kitec lines and the SVE HDPE pipe was tested by applying pressure using a portable generator. These tests involved progressively increasing the pressure into the lines to a specified value that exceeded the expected operational pressures. It enabled the contractor to identify if and where fittings required tightening or replacement. Pressure testing was also conducted on the groundwater return lines by surcharging the pipes with clean water to a specified value that exceeded the expected operational pressures. The contractor completed this work at the conclusion of each major work phase and after all the trenching had been backfilled.

**SUMMARY**

The installation of an in-situ remediation system such as DPE on public lands in an older residential neighbourhood can be a daunting task. The uncertainty of private and public utility locations can make engineering design and implementation of a plan difficult. The requirements for numerous municipal standards and specifications can complicate the engineering and construction of a DPE system.

The following components of the work were critical to its success:

- **COMMUNICATION:** The client informed the local residents and business owners of the proposed activity and regularly updated them on the progress and schedules of the off-site construction. The client and a SEACOR representative were readily available to listen to the local community and address any concerns they might have during the construction.
- **DESIGN:** A detailed design founded on site pilot test data was completed.
- **TENDER:** A tender document was issued that clearly outlined the expectations, material and specifications for the contractor to adhere to.
- **QA/QC:** Regular monitoring and inspection of the construction activities ensured that the off-site infrastructure was completed appropriately and to the satisfaction of the client and stakeholders.

There were some experiences during the project that could be useful to anyone implementing a remedial system on 3rd party lands, particularly in streets and laneways. Some tips for those considering to implement an off-site system:

- **PHASE THE WORK:** Be ambitious to minimize disruption time on 3rd parties (ie. traffic etc) but more importantly be realistic with construction schedules. Also, be respective and courteous of local resident/business activities and hours of operation. Schedule and plan activities to minimize or avoid disruptions.
- **CONTINGENCY PLANS:** Consider developing contingency plans for portions of a design that may be founded on assumed site conditions (ie utility depths).
- **CONSTRUCTION SITE BOUNDARIES:** When working off-site it is very difficult to establish a “safety fence”. It is critical that supervisors plan the layout of protective safety barriers and construction routes on a daily basis and whenever conditions change.

As a brief prelude to what we hope will be a future paper and presentation at Remtech, the DPE system has been operating successfully for approximately 1 year utilizing on-site and off-site extraction wells. The results are very encouraging. The utility, process and treatment equipment has worked with little interruption or down-time and has easily met the water discharge and air discharge needs. Exceptional hydrocarbon removal rates have been realized predominantly through vapour removal and have ranged from 30 L/day to 150 L/day. Groundwater production has been enhanced by the vacuum system and a reciprocating effect is occurring as desaturation of the capillary fringe is enabling more removal and reduction of the residual and dissolved phase hydrocarbons to occur.