Remediation of a Former Sour Gas Plant in Central Alberta

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Abstract
The nearly forty-year operation of this former sour gas plant owned by Acclaim Energy Trust Inc. (hereinafter called "Acclaim") resulted in the contamination of the soil with benzene, toluene, ethylbenzene, xylenes (BTEX) and petroleum hydrocarbons (PHC) fractions 1 through 4 (F1 through F4). Following dismantling, detailed site assessments were performed to delineate the nature and extent of the impact. This allowed for a volume estimate of hydrocarbon-contaminated soil, which was integral in ascertaining an appropriate remedial option.

The remedial objectives were to obtain compliance with the generic Tier 1 *Alberta Soil and Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities*. More specifically for surface, fine-grained soil designated for industrial land use.

The project presented numerous challenges, one of which was effectively managing the range of hydrocarbon contamination present (specifically the F3 hydrocarbon fraction), in a cost effective and timely manner. In addition to this, the contamination was found at varying depths, ranging from 1.8 to 14 m below ground surface. These factors, combined with the typical seasonal conditions, required comprehensive treatment monitoring and expert site coordination.

Given the nature and extent of the contamination, Biogenie S.R.D.C. Inc. (hereinafter called "Biogenie") developed, proposed, and implemented an *in situ* Bioremediation Treatment System (IBT) for the 27,000 m^3 of hydrocarbon-impacted soil on site. This solution was selected because of the minimization of soil handling, containment and subsequent treatment of soil within the identified area of contamination, and the minimal disturbance to the surrounding community. Also, the *in situ* biopile was proven to be most suitable since this method reduces the concentrations of hydrocarbons rather than transferring the soil to landfill where the liability associated with contaminated soil still exists. Once the installation of the remediation system was completed and treatment of the contaminated soil commenced, Biogenie successfully degraded the BTEX and PHC (F1 through F4) concentrations below the selected remediation criteria within 19 months.

Introduction

By definition, biodegradation refers to the breakdown of organic substances by microorganisms. The act of reducing the concentrations of specific contaminants to within desired standards through biodegradation can be further defined as bioremediation. This refers to the process by which living organisms such as bacteria, fungi, and/or protozoa act to degrade hazardous organic contaminants or transform hazardous inorganic contaminants to environmentally safe levels in soils, subsurface materials, water, sludges, and residues. As with most natural processes, the

biodegradation, and more specifically bioremediation, of the contaminants within the soil can be accelerated beyond the ambient rates through precise monitoring and adjustment of the soil chemical, physical, and microbiological parameters. The understanding and enhancement of these factors is what Biogenie relied upon and utilized for the site remediation of this former sour gas plant owned by Acclaim, located in Acheson, Alberta.

As stated above, the history of this site includes nearly 40 years of operations as a sour gas processing plant. Located 3 km west of Edmonton, Alberta, the former ICG Acheson Gas Plant began processing sour gas in 1952 from the Chevron D3-A Pool and other area facilities. It continued this until its purchase in 1988, when the plant was dismantled in preparation for decommissioning. Several site assessments were completed from 1996 to 2003 to determine the nature and extent of contamination present. Following these investigations, site designations were assigned based on contaminant type, with hydrocarbon-impacted areas designated as HC. In 2004, well into the decommissioning and remediation of the site, Acclaim purchased the property and continued the existing treatment options which had been implemented on site.

Remedial Criteria Selection

A crucial component to any site remediation is the selection of appropriate criteria. The soil concentrations of BTEX as well as PHCs (F1 through F4) were compared to the Alberta Tier 1 Hydrocarbon Guidelines presented in the *Alberta Soil and Water Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities* (ASWQG) (Alberta Environment, September 2001). The criteria selection took into account the following five considerations: land use, grain size, potential discharge of contaminated groundwater into an adjacent surface water body, protection of potable groundwater, and protection of buildings with slab-on-grade construction. In order to obtain an unconditional closure of the site, the following pathways were included: Soil Ingestion, Soil Dermal Contact, Plant/Invertebrate Soil Contact, Soil Ingestion by Livestock or Wildlife, and Protection of Groundwater for Livestock Watering. Among the applicable criteria, the most stringent were selected. It should also be mentioned that guidelines for surface soil and subsoils (>1.5 m depth) are presented in the ASWQG. However, subsoil guidelines are only applicable within 15 m of an oilfield wellhead; since there were no wellheads on site, the subsoil guidelines were excluded.

As this site is owned by Acclaim and located in an industrial-zoned area adjacent to the operating Acheson gas plant, the guideline for industrial land use was applied.

The site lithology generally consisted of silty clay, silt, or fine-grained sandy silt, overlying medium-grained sand, becoming coarser at depth. Laboratory analysis determined that the majority of soil on site was fine-grained although infrequent and discontinuous layers of coarse-grained material were present. As the fine-grained soil predominately controls the migration through the subsurface, the site was assessed using fine-grained criteria.

The Protection of Groundwater for Freshwater Aquatic Life and Wildlife Watering pathways may both be excluded in cases where there are no surface water bodies (e.g. creek, lake, slough, etc.) within 300 m downgradient of the site whereby downgradient is defined as any direction within 45 degrees either side of the direction of the groundwater flow. As no surface water bodies were present within 300 m downgradient of the site, the Protection of Groundwater Aquatic Life pathway was excluded. All other potential exposure pathways have been considered.

To be protective of human health and the environment, the ASWQG criteria for industrial land use with a fine-grained soil for the Ingestion of Potable Groundwater was selected as the most stringent exposure pathway for BTEX. From the ASWQG criteria for industrial land use with a fine-grained soil, Soil Contact (plants and invertebrates) was selected as the most stringent exposure pathway for PHCs (F1 through F4). Table I provides a summary of the selected criteria.

Table I: Summary of Selected Criteria

Parameter	Guideline[(1)] mg/kg	Soil Classification	Exposure Pathway
Hydrocarbons			
Benzene	0.073	Fine	Ingestion of Potable Groundwater
Toluene	0.86	Fine	Ingestion of Potable Groundwater
Ethylbenzene	0.19	Fine	Ingestion of Potable Groundwater
Xylenes	25	Fine	Ingestion of Potable Groundwater
PHC F1 (C_6-C_{10})	660	Fine	Soil Contact (Plants and Invertebrates)
PHC F2 (C_{10}-C_{16})	1,500	Fine	Soil Contact (Plants and Invertebrates)
PHC F3 (C_{16}-C_{34})	2,500	Fine	Soil Contact (Plants and Invertebrates)
PHC F4 (C_{34}-C_{50+})	6,600	Fine	Soil Contact (Plants and Invertebrates)

(1): Alberta Soil and Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities (AENV, 2001). Industrial Criteria with Fine-Grained Soil

Assessment of Site Condition Prior to Installation of Remedial System

Remedial activities began on site in 2000 and focussed on the glycol- and acid-contaminated soils. Hydrocarbon-contaminated areas HC1 and HC2 were not addressed until 2003 when Biogenie was commissioned to bioremediate the BTEX and PHCs (F1 through F4). As a first step, a supplementary environmental site investigation was completed in July 2003 to assess the chemical, physical, and microbiological conditions of the soil on site as well as to more precisely estimate the volume of hydrocarbon-contaminated soil within areas HC1 and HC2.

The main findings from the environmental site investigation were as follows: In area HC1, soil with hydrocarbon contamination was located between 1.8 and 6.6 m below ground surface and covering 3,150 m^2. In area HC2, impacted soil was identified between 4.8 and 8.4 m below ground surface and covering an area of 3,300 m^2. A final estimated volume of 27,000 m^3 of soil with hydrocarbon concentrations above regulatory criteria was present in these areas.

The groundwater conditions were also assessed utilizing monitoring wells which had been installed in 1996 to measure the levels and flow direction. The water table was found to fluctuate at a depth of 16.5 to 19.5 m, well below the known delineated maximum depth of soil contamination. No evidence of hydrocarbon impacts to the groundwater was discovered.

Selected Technology

Various treatment options and technologies for the remediation of the site were assessed based on site conditions, criteria selection, cost-effectiveness, site and surrounding community disturbance, and the volume of contaminated soil. The advantages and disadvantages of the various technologies are listed in Table III.

Table III: Summary of Treatment Options

Option	Disadvantages	Advantages
Landfill	- Does not remediate soil, only transfers to long-term storage (liability remains) - Large amounts - Traffic concerns due to the trucking involved (nearby residences with children, dust from transport, noise etc.)	- Short timeframe for site remediation
Windrow	- Large amount of space required for soil treatment - Abundant soil handling - Excavation is open for long periods of time which encompasses odour (BTEX, PHCs (F1 and F2)) and safety issues - Timeframe for remediation is 1 to 2-years and performance is influenced by the weather (too dry or wet) - Liner required for treatment area - Traffic concerns due to the trucking involved (nearby residences with children, dust from transport, noise etc.	- Does not require disposal at a landfill
Allu Bucket	- Abundant soil handling - Transfers contamination from one medium to another (soil to air) - Danger of benzene inhalants to neighbours - Increasing concerns from Alberta regulators with regards to this application	- Short timeframe for site remediation
***In Situ* Biopile**	- Timeframe for remediation longer than landfill option	- Minimizes soil handling and traffic - No open excavations during remediation - Small work area required with minimal odours (benzene) - Minimizes transfer contaminants from one medium to another

Based on the review of the remedial options, Biogenie chose an *in situ* Biopile process in order to achieve the site specific remediation objectives. The *in situ* Biopile consisted of both surface and subsurface piping connected to an engineered air injection unit on site in order to enhance the natural biodegradative process by providing the aeration required for aerobic degradation of petroleum hydrocarbons. The system was constructed within a land treatment area and divided into parcels that were used throughout the project as management units for each activity (excavation, sampling, etc.).

The implementation of the treatment system began in September 2003, and installation was completed by December 2003. The piping network was installed into a series of cells until the 27,000 m^3 of impacted soil had produced the *in situ* Biopile. During excavation, the floor and walls were sampled in order to confirm the limits of the impacted area. All of the areas attained the target remediation criteria, except for a section in the southwest corner.

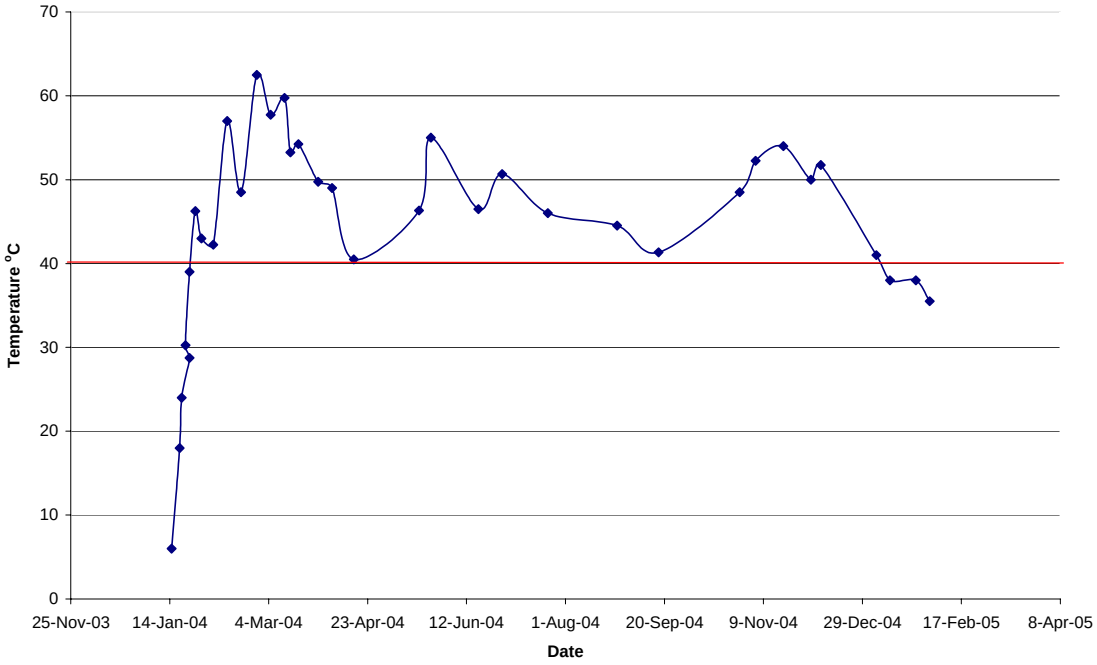
Excavation of impacted soil in the southwest corner of the IBT was "chased down" to a depth of 14 m below ground surface but, due to safety reasons with the proximity to the power lines, pipelines, and property boundaries, excavation was ceased. Soil conditions from this area have been assessed and are currently being risk managed to ensure contaminant migration is not occurring.

Results

For maximum efficiency, the soil temperature, nutrient concentration, moisture, and pH levels were monitored during soil remediation, ensuring optimal conditions for biodegradation. Soil turnings were completed in April 2004, December 2004, and May 2005 to aid in the destruction of preferential air channels in the soil, promoting increased air and nutrient dispersal throughout the matrix.

Soil temperature measurements were collected from a thermocouple grid installed during system construction on a weekly to monthly basis from January 2004 to January 2005 and are displayed in Figure 1. It can be seen that the initial soil temperature, prior to system installation, was approximately 7 °C. Once bioremediation of the soil was initiated, the temperature rose to a range of 40 to 72 °C for the duration of the monitoring period. These elevated temperatures were used as an indicator of the amount of contaminant biodegradation occurring within the *in situ* Biopile during the remedial process.

Figure 1: Soil Temperature Profile from October 2003 to February 2005 for Cell A2



As stated above, soil concentrations of hydrocarbons were also monitored during the soil treatment activity by collecting and analyzing soil from each cell unit. Final analysis indicated that soil concentrations of BTEX and PHCs (F1) were reduced to below detection limits in all cells, and concentrations of PHCs (F2 through F4) were reduced to amounts below the applicable guidelines. This was verified in June 2005 through a sampling campaign of a third party consulting company. It was confirmed that a total of 27,000 m^3 of hydrocarbon-impacted soil was successfully remediated through use of an *in situ* Biopile to within applicable criteria.

Figure 2: Soil Chemical Results – PHC (F3) Soil Concentration Profile from October 2003 to June 2005

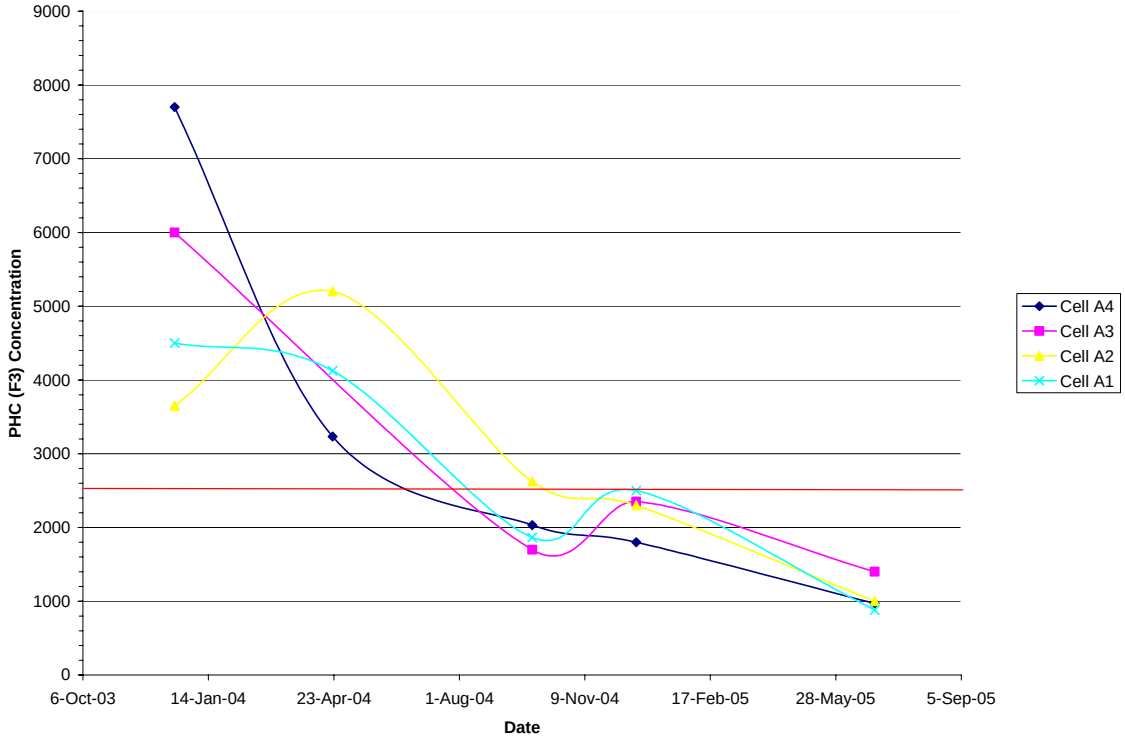


Figure 2 illustrates the concentrations of PHCs (F3) within the A series of cells during each sampling event. As shown, the PHC (F3) concentration of the soil from cell A4 was reduced by 87%, from an initial amount of 7,700 mg/kg to 970 mg/kg (or to amounts less than regulatory limits), in approximately 19 months of bioremediation.

Discussion and Conclusion

The success Biogenie achieved on this project was due to our understanding and assessment of the site prior to commencement of the remedial work. The unique challenges presented by this project included a soil contamination consisting of PHC (F3) concentrations over 5 times the regulatory guidelines with depths of impact that ranged from 1.8 to 14 m below ground surface. The work area was confined within the active plant site boundaries thereby limiting the space available to work in as well as treat the soil.

Understanding these characteristics and limitations made the *in situ* Biopile the right solution for this site. The choice of this technology allowed the soil remedial criteria to be achieved at a cost-effective rate while limiting soil handling, minimizing disruptions to the surrounding community, and most importantly, remediating the soil instead of filling the province's already strained landfills.

A proven technology that Biogenie has extensive experience with, the *in situ* Biopile, successfully achieved the remedial objectives for the 27,000 m^3 of hydrocarbon-contaminated soil formerly present on this site.

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