

SOIL REMEDIATION OF A FORMER POWER PLANT SITE IN TULITA, NORTHWEST TERRITORIES

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ABSTRACT

The Dene Hamlet of Tulita is located east of the Great Bear Lake, at the junction of the Mackenzie and Great Bear Rivers, in the Sahtu region of the Northwest Territories. For 22 years, this Hamlet hosted a power generating plant whose operations, together with some accidental petroleum hydrocarbon (PHC) spills, caused a high level of soil contamination, specifically in the peat layer found in the soil. The dismantling of the former power plant and subsequent decommissioning of the site required that the site be remediated. Project challenges stemmed from the high level of soil contamination (up to 185,000 mg/kg in the peat layer) and the remote location of the community, which is only accessible by plane and barge during the short summer season. As the site was located in the center of the Hamlet, efforts were made to minimize the project impacts (odours, noise, dust, safety) to the surrounding community members.

The project commenced in June 2002. The remediation guidelines used were Canada-Wide Standards (CWS) for PHC in soil, from the Canadian Council of Ministers of the Environment (CCME). In order to achieve the remediation objectives established for this project, Biogenie used its proprietary treatment process, the *In situ* Biopile. A volume of 8,100 m³ was treated inside the land treatment area (LTA) at an average depth of 3.0 m below ground surface. At the start of the project, the average PHC (Fractions 1 to 4) concentration was 12,500 mg/kg ($n = 26$). After 14 months of treatment, this concentration was reduced to 2,496 mg/kg ($n = 27$) representing an average removal rate of 80%. This paper outlines each major stage of the project, focusing mainly on the technical and human challenges that were encountered and how they were overcome.

INTRODUCTION

Tulita, traditionally known as Fort Norman, is located on the banks of the Mackenzie River, at the junction of the Great Bear River. It is located at 64° 54 N latitude and 125° 34 W longitude and is 523 km directly southeast of Inukvik and 624 km northwest of Yellowknife.

Tulita has a population of approximately 400 people. The community mainly consists of Slavey Indians of the Dene Nations along with a fairly large Metis population. The region is located within the Sahtu Settlement Area and is subject to the terms and conditions in accordance with the Sahtu Metis Dene Comprehensive Land Claim Agreement.

The impacted site currently under treatment is located in the middle of the Tulita village and is surrounded to the west by a storage yard and a cemetery, to the north by a swamp and a bush area, to the east by an old garage, and to the south by a storage area with a shed and buildings. According to the site characterization, the impacted area was estimated at 3,250 m² which should have corresponded to a maximum volume of soil to be treated of 6,500 m³.

The soil itself was composed of fine material, from sandy silt at the surface to silty clay at a depth of 1.5 m. A peat layer, which corresponds to the former natural topsoil, was present throughout the site. This 20-cm thick layer was highly contaminated. Composed of organic matter, it has acted, over the years, as a sponge absorbing and trapping hydrocarbons. Thus, a high concentration of hydrocarbons was present in this layer due to the nature of the matrix.

The remedial criteria retained for this site were the Canada-Wide Standards (CWS) for Petroleum Hydrocarbon Concentrations (PHCs), Fractions 1 to 4 (F1 to F4), Tier 1, Industrial/Commercial Land Use, No Protection for Groundwater, Fine-Grained Soil, Surface Soil (Table I). Since no volatile compounds (such as benzene, toluene, ethylbenzene and xylenes (BTEX)) were detected during the initial site investigation, these contaminants were not considered for the establishment of the remediation objectives. The applicable criteria were selected for the following reasons:

- **Tier 1:** the site did not present special characteristics which would justify the evaluation of Tier 2 or Tier 3 levels. Therefore, Tier 1 was the level applied for this project;
- **Industrial/Commercial:** the site was classified as commercial/industrial, it has been used for industrial activities (power station) and was surrounded by other industrial sites (maintenance garage, storage yard for heavy equipment);
- **Protection for Groundwater** was not applicable since:
 - no groundwater was used in Tulita;
 - no wells are found in Tulita;
 - the permeability would be too low (silty clay) to supply potable water in sufficient yield;
 - no groundwater was found during the site investigation.
 - No water surface body within 10 m from the site.
- **Fine-Grained Soil:** the soil analyzed corresponded to the fine grain definition according to CCME's CWS;
- **Surface soil criteria for full depth remediation:** the site was located in the middle of the village (high exposure and potential redevelopment). Subsurface criteria apply only below 1.5 m, which was approximately the depth of the contamination.

Table I: Tier 1 CWS Levels for Surface Soil (Industrial Use, No Protection of Groundwater, Fine-Grained Soil) (mg/kg)

Land Use	Soil Texture	Fraction 1 (C ₆ -C ₁₀)	Fraction 2 (>C ₁₀ -C ₁₆)	Fraction 3 (>C ₁₆ -C ₃₄)	Fraction 4 (>C ₃₄₊)
Industrial	Fine-grained soil ¹	660	1,500	2,500	6,600

¹ Soil having a median grain size <75 µm.

SELECTED TECHNOLOGY

A review of potential technologies that could have been implemented on the site was performed. Among all possibilities, the following were considered for the remediation of the site, but were then discarded for different reasons.

- **Thermal destruction:** too expensive and irrelevant in such a location;
- **Landfarming:** given the limited available space as well as the high level of contamination, this technology was not suitable;
- **Ex situ bioremediation:** would require additional space and would involve extensive handling of soil (transportation) to the designated treatment area;
- **Traditional in situ bioremediation (vertical venting system):** would not be efficient to reach the selected criteria.

Biogenie’s proposed technology was the *In situ* Biopile. This technology has been used by the company for many years in similar projects and has demonstrated a high level of efficiency. It basically consists of installing wells in the contaminated zone in order to provide the aeration required for PHC biodegradation and to condition the soil on a regular basis in order to promote optimal treatment conditions throughout the impacted material.

This innovative process offers many advantages, such as reduction of soil handling and elimination of soil transportation (no trucks are required). It is also readily applicable on-site (inside the property) and is efficient enough to reach the selected remedial criteria for the site. The efficiency of the *In situ* Biopile, in terms of total hydrocarbon removal, generally varies between 70% and 90%, depending on site-specific conditions. As such, based on the site assessment and investigation data (EBA, 1999), an estimation of the initial PHC concentrations has been performed and the results, as well as expected residual concentrations after treatment, are presented in Table II.

Table II: Expected PHC Concentrations (mg/kg) at the Beginning and End of the Soil Treatment

Description	Fraction 1 (C₆-C₁₀)	Fraction 2 (>C₁₀-C₁₆)	Fraction 3 (>C₁₆-C₃₄)	Fraction 4 (>C₃₄ +)
Expected initial PHC concentration	2,200	6,000	4,800	900
Expected efficiency	90%	80%	60%	40%
Residual concentration after remediation	220	1,200	1,920	360
Remedial criteria	660	1,500	2,500	6,600

REMEDICATION APPROACH

The area on the site where the Biopile was constructed was identified as the land treatment area (LTA). The LTA was divided into 12 parcels measuring 15 m x 15 m (grid) which were used throughout the project as management units for each activity (excavation, sampling, etc.).

The excavation work was undertaken in the eastern portion of the LTA and progressed towards the west until it reached the end of the contaminated area. Excavation pits beyond the limit of the LTA were also dug where previous site characterization studies indicated the presence of impacted material above the applicable criteria. This contaminated soil was also transferred to the LTA for treatment.

For each of the 12 parcels of the LTA, composite samples, made up of at least 5 sub-samples from the most contaminated areas (based on visual observations), were utilized for chemical analyses. A proportion of 10% of all field samples were also collected as duplicates.

From a bioremediation perspective, the major concern for the Tulita site was the presence of a peat layer which, over the years, had absorbed and trapped the hydrocarbons. This material, which contains high concentrations of hydrocarbons bound to the organic matter, was refractory to biodegradation mainly because of the low bioavailability of the contaminant in this matrix. In order to avoid compromising the attainment of the remedial objectives for this site, we proposed segregating this peat layer and treating it in a separate parcel.

For the parcel containing the peat, special conditions were applied, according to this specific material. These conditions include pH correction, soil mixings, specific

quantities of nutrients and moisture content control. Even if this parcel was managed separately, the remediation criteria remained the same for the other soil.

RESULTS

Just before treatment, in July 2002, characterization of the LTA revealed that most parcels (approximately 96%) had at least one PHC fraction above the remedial criterion. As shown in Table III, the LTA average concentrations for F1, F2 and F3 were all above the selected criteria for the site, with an initial F2 concentration being more than 4 times higher than its remedial objective.

The first 2 months of treatment were very successful in reducing the initial PHC levels in the soil, decreasing the total hydrocarbon concentration by nearly 40% (Figure 1). The intense biological activity, confirmed by an elevated temperature in the soil, thus helped achieve, after only 2 months of treatment, the remedial objectives for F1 and F3. F2 therefore became the limiting parameter to completely achieve the remedial criteria for the site. However, the following treatment season (summer 2003) did not show as much degradation; total hydrocarbon levels only slightly decreased over the period.

An extensive investigation was therefore undertaken at the end of the second year of treatment (end of summer 2003) in order to identify the potential inhibitors to the biotreatment at the site. Previous full-scale work performed by Biogenie in northern regions never showed such a long time frame without significant hydrocarbon removal (Pouliot *et al.*, 2001; Pouliot *et al.*, 2003). Among all analyses performed, special attention was paid to the pH level, moisture content, temperature, nutrient levels and indigenous microbial densities. It was found, based on the results, that nitrogen and phosphorus levels in the soil were likely to be insufficient in order to sustain microbial activity during the remediation process. As such, temperatures in the LTA were lower than usual, confirming the non-optimal treatment conditions during the second year of treatment. Microbial densities, on the other hand, were well within the range at which high biodegradation rates can be observed. It is likely that the lack of nutrients caused the indigenous microorganisms to become significantly less active, thus decreasing the rate at which the hydrocarbons were removed from the impacted soil.

Table III: Evolution of CCME PHC (F1 to F4) Concentrations During the Remediation Work

Description	Fraction 1 (C₆-C₁₀)	Fraction 2 (>C₁₀-C₁₆)	Fraction 3 (>C₁₆-C₃₄)	Fraction 4 (>C₃₄+)
Remedial Criteria	660	1,500	2,500	6,600
Average LTA concentrations (mg/kg)				
July 2002 (Initial)	987	6,933	3,828	749
Sept. 2002 (2 months)	617	4,843	1,946	178
July 2003 (12 months)	234	3,309	2,070	389
August 2003 (13 months)	360	2,977	2,098	418
June 2004 (23 months)	185	3,038	2,023	427
August 2004 (25 months)	119	1,531	1,212	221
October 2004 (27 months)	80	1,133	1,066	217
Elimination Rate (%)	92	84	72	71

Concentrations above CCME criteria are shown in bold.

At the beginning of the third season (June 2004), an appropriate addition of specific nutrients was therefore performed. An increase in soil temperature was immediately observed and hydrocarbon concentrations began to decrease accordingly. The same pattern in hydrocarbon degradation occurred with the F2 and the re-establishment of the appropriate treatment conditions allowed for the associated criterion to be met in October 2004, considering the average F2 concentration in the LTA (Figure 2).

Although the average hydrocarbon concentrations for each fraction decreased below their respective remedial criterion, 3 parcels were still showing soil concentrations above 1,500 mg/kg for the F2 after the last sampling period in October 2004. Since the terms of the proposal/contract specified that each of the 12 parcels had to meet the CCME remediation criteria, the treatment period had to be extended for another season. It is expected that a new set of samples will be collected in July 2005. Considering the elevated temperatures in the LTA soil during the months following the tilling of October 2004, we are confident that the remediation objectives will be met by that time.

Looking at the global efficiency of the treatment process implemented on the site, this project is another example of the full potential of Biogenie's proprietary *In situ* Biopile. The elimination rates presented in Table III (October 2004) are all above the expected reduction initially anticipated for each of the 4 fractions of the CCME for PHCs.

The higher PHC levels in the LTA at the beginning of the project are certainly in part responsible for the extra season of treatment required to meet the remediation objectives for the site.

Figure 1: Evolution of Total F1-F4 Concentrations During Treatment (Average LTA Concentrations).

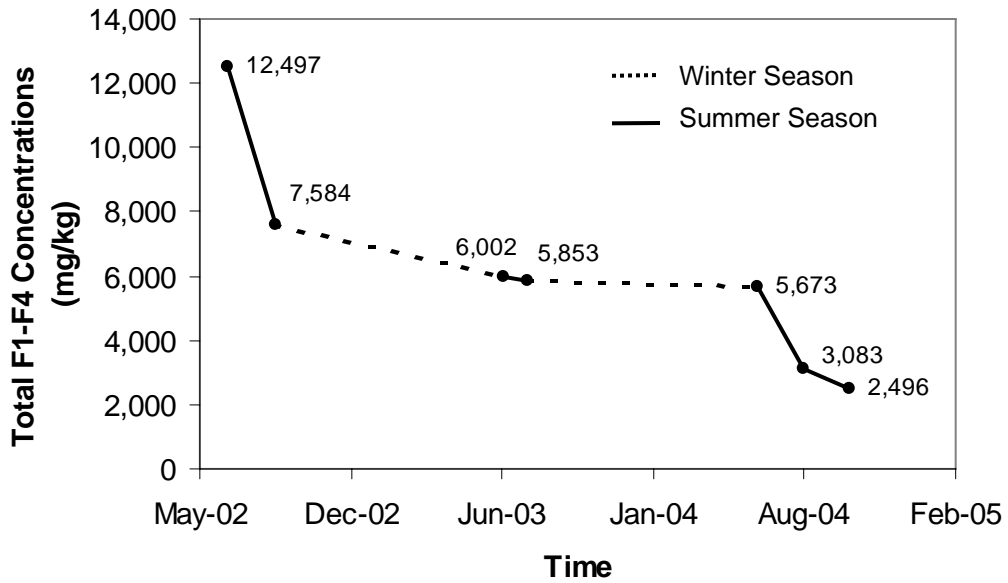
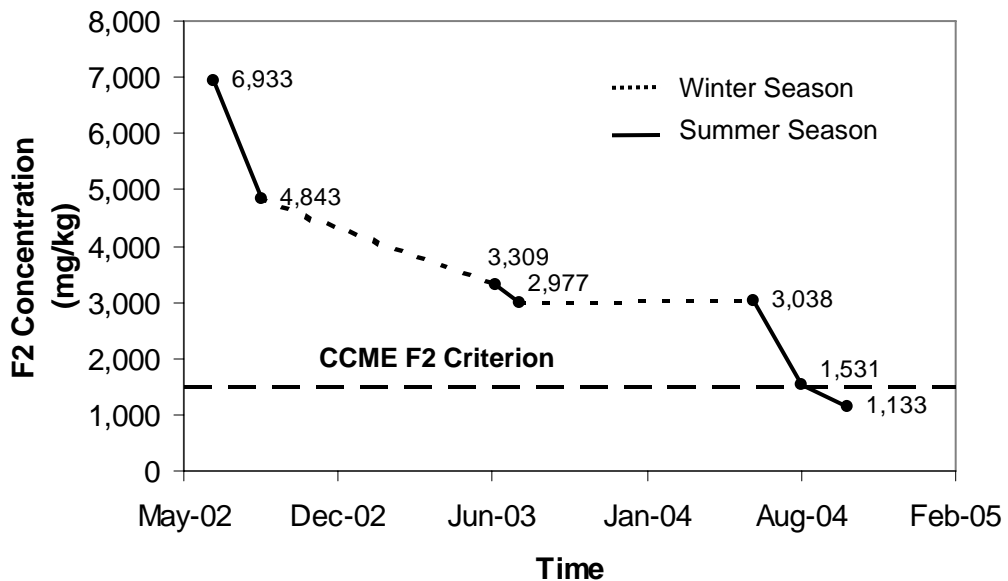


Figure 2: Evolution of F2 Concentrations During Treatment (Average LTA Concentrations).



DISCUSSION AND CONCLUSION

The remediation of the former power generating plant site in Tulita began in July 2002 and to date, 3 treatment seasons have been completed. The last intermediate sampling, which took place in October 2004, showed an overall PHC remediation rate of 80% (considering all 4 PHC fractions) since the beginning of the remediation program. This decline allowed for each PHC fraction to reach its respective clean-up criterion, based on the average contaminant concentration in the LTA. However, the equivalent of 2 parcels (out of 12) still have at least one fraction above the remedial criteria and further treatment is required in order to reach their remedial criteria. Once the treatment objectives have been attained, the treatment unit will be decommissioned and the site will be available for future development.

It is however important to emphasize that, although the remediation objectives were not fully met within the time frame initially planned, the selected technology and approach for the site should not be questioned. To date, the removal rates observed on each of the 4 CCME fractions were higher than what was originally expected, with 92% for F1, 84% for F2, 72% for F3 and 71% for F4.

Not only the selected technology allowed to achieve such treatment performances, it also presented numerous advantages. It reduced soil handling which prevented the suspected contaminants from spreading to the surroundings, minimized the use of machinery (no trucks needed), thus reducing overall disturbance which is an important factor in terms of dust control and allowed to save time and space during the remediation work. The on-site Biopile also offered the flexibility of accepting new impacted soil from other locations in Tulita during the second treatment season (summer of 2003), using the same space and equipment as initially planned. It allowed for strategic measures to be implemented, especially with regards to the segregation of the highly impacted peat layer which could have prevented the remediation criteria to be met, should this specific material have been initially incorporated to the rest of the soil to be treated. The system also offered, to a certain extent, the possibility of controlling the treatment condition within the LTA. This important factor favoured the metabolic activity of the indigenous microorganisms, which is highly exothermic, thus allowing the treatment season to be extended during the cold season (even in December and January). Finally, the use of biotreatment will allow for the re-utilization of the treated soil on the site. No waste will therefore be produced and no backfill material will be required when the treatment is over.

As for all remediation projects undertaken by Biogenie in northern regions over the years, involvement of local people was a key factor of success for this project (Pouliot *et al.*, 2001).

Finally, Biogenie faced many challenges during this specific project. Firstly, the initial PHC concentrations in the LTA were higher than expected, which had direct consequences on the achievement of the remediation objectives within the initially planned time frame. The intensive investigation performed in August 2003 on the nature of the contaminant also revealed a high degree of weathering which certainly reduced the

capability of the indigenous microorganisms to degrade these hydrocarbons. These two factors, combined with the fact that a significant amount of new contaminated soil was added to the LTA in 2003 after excavating in depth, explain the need for an extra year of treatment in order to achieve the remediation criteria for all parcels of the LTA.

The lack of available nitrogen and phosphorus in the soil during the second treatment season was certainly another factor that may have contributed to the extension of the treatment period. However, with an adequate investigation, the limiting factor to biodegradation was identified and proper corrective measures were immediately implemented. Biological degradation of the hydrocarbons was successfully reactivated shortly after the intervention.

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