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Achievement of Provincial Guidelines for Partially Treated Soils (Historical Sites)

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1. INTRODUCTION

Petroleum exploration and production related activities generate impacted material from several sources including, but not limited to invert drilling waste, flare pits, pipelines, underground and aboveground storage tanks and sumps. Bioremediation of treatable material is progressively being favored over landfill disposal as the preferred waste management option. Bioremediation enables the generator to eliminate his or her environmental liability and remains one of the most economical alternatives.

To be successful, a biotreatment process needs to adapt to the type, level and age of contamination, along with other constraints, such as location of the material. However, to efficiently biodegrade material that has taken millions of years to generate, the use of microbes is required as well as controlled environmental conditions. The parameters that must be controlled include: type of electron acceptor (oxygen, nitrates, sulfates, slow release peroxide), nutrients (nitrogen, phosphorous, micro-nutrients), temperature, pH, bioavailability of the contaminant (controlled by use of bio-activators, improving physical properties of the material), water activity of the substrate, removal of by-products.

Upon biotreatment start-up, microbial activity is high, as most of the contaminants are bioavailable (Linz & Nakles, 1997). As treatment progresses, remaining hydrocarbons become less accessible to the microbes (within soil pores, chemically bonded to the matrix), and this decrease in bioavailability reduces the microbial activity. Eventually, the bioavailability of the contaminants becomes the main limiting factor for efficient biodegradation. In cases where initial contamination levels are significantly higher than the desired criteria bioavailability tends to become even more of a limiting factor prior to reaching remediation objectives.

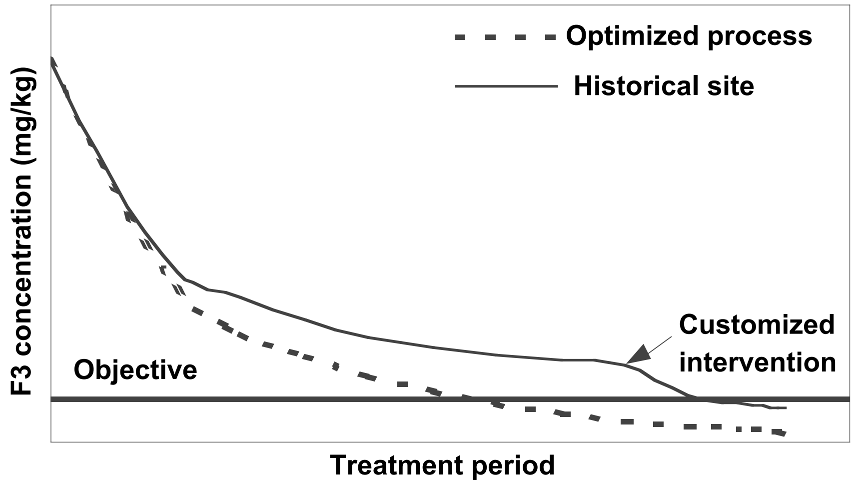

Figure 1 Typical biodegradation curve of a biotreatment process and illustration of a customized intervention on an historical site

Organic compounds, such as petroleum hydrocarbons, are progressively sorbed or sequestered into the matrix (soil or sediments), thus reducing their bioavailability. However, this phenomenon alone does not explain every case where biodegradation is unsuccessful. When specific compounds remain after partial biodegradation, limited bioavailability can't be accounted for, especially when compounds, more soluble, have disappeared. It is thus believed that some inherent recalcitrance of specific compounds could also explain part of this issue (Huesemann, 1997).

Due to the potential for hydrocarbon concentrations to plateau at levels slightly higher than desired end points, carefully designed and monitored biotreatment processes need to be conducted in order to maintain controlled conditions and reach guidelines. This paper presents two cases where unsuccessful biotreatment processes had reached a plateau for the treatment of impacted material (also known as historical sites) in the province of Alberta. The use of a customized bioprocess made it possible to reach provincial guidelines for Case 1. Case 2 was started in July 2003 and is ongoing.

2. CASE-STUDY 1

A bioremediation project of an historical site was initiated near Rocky Mountain House. The soil was impacted with petroleum hydrocarbons. The source of contamination was reported to have originated from an abandoned flare pit and a buried pit of unknown origin. The activities outlined within this paper were conducted in 2002.

The site was initially surveyed on February 3, 1958 and was drilled as an exploratory well. Reportedly, three previous biotreatment attempts were unsuccessfully conducted at this location. The previous treatment procedures and methodologies along with timelines were not available. The contaminated soil volume was estimated at 5,000 m^3 and was placed on-site into nine windrows. Hydrocarbon levels had reached a plateau with levels remaining above provincial guidelines.

The impacted soil was contaminated with petroleum hydrocarbons (between 1,000 – 2,300 mg/kg in the F3 fraction). The targeted remediation goals were the Alberta Tier 1 hydrocarbon guidelines for fine-grained surface soil using a natural area landuse (soil contact): 800 mg/kg (Alberta Environment, 2001). The scope of work was to complete treatment of the soil by way of bioventilation with a forced air system and was scheduled to be completed within a six-month period. The selected approach and its timeframe were estimated following a site visit and a physico-chemical characterization.

2.1 Site-Specific Challenges

The soils in this region typically exhibit a silty loam to silty clay loam soil texture. This region is the second wettest area in Alberta (RRTAC 93-7, 1993). The combination of these two factors tends to limit the quality of air exchange, a parameter of prime importance in bioremediation. The use of a forced air system was identified as a remedy to this situation. The absence of electricity on-site made it necessary to have a generator installed on-site.

This site was an active oil and gas location and had piezometers installed at various locations throughout the site, which presented additional constraints regarding the selection and on-site movement of heavy equipment. The on-site subsoil was soft due to increased moisture levels which necessitated the use of Rig Mats over and active underground pipeline.

2.2 Fieldwork

The first phase of the fieldwork was completed within three weeks and included preliminary screening of material not compatible with air distribution, incorporation of selected amendments, followed by the construction of specifically engineered biopiles. A synthetic liner and a cover liner were used to prevent potential leaching impacts and to maintain optimal soil environmental conditions throughout the treatment process, respectively. Overall, the incorporation of specific bulking agents increased the total mass of the material to be treated by less than 5%.

Once in biopiles, the second phase consisted of the remediation itself, in which the soil was monitored and various parameters were optimized to ensure timely degradation of contaminants within the soil. Based on the analytical results obtained six weeks into the project, soil treatment was halted and confirmatory sampling proceeded in order to confirm that remediation phase was complete (Table 1). Treatment of the biopiles was completed within three months of project initiation.

Table 1 Biotreatment completion of impacted material by means of achieving optimal conditions for indigenous microflora (Case-study 1: Rocky Mountain House area)

Description	**Before intervention**	**After intervention**
Number of samples	n = 9	n = 15
Average F-3 fraction (mg/kg)	1744	427
Standard deviation @ 95 % confidence (mg/kg)	200	40
Meet the F-3 fraction goal of 800 mg/kg (%)	0	100

3. CASE-STUDY 2

As was the case in the previous case-study, this historical site was initiated near High Prairie. The soil was impacted with petroleum hydrocarbons. According to available information, the source of contaminated soil originated from a former flare pit. The activities outlined within this paper were initiated in June 2003 and are on-going.

Based on partial documents, one attempt at biotreatment was initiated in 2000 and was unsuccessful. Data regarding treatment procedures and methodologies was incomplete. During this treatment attempt, the contaminated soil volume was estimated at 1,350 m^3 and was ultimately placed on-site into two uncovered piles. A plateau had been reached for more than a year, with levels remaining above provincial guidelines.

As is the case with most contaminated soil originating in flare pits, this soil was contaminated with petroleum hydrocarbons primarily in the F3 fraction (with levels between 1500 and 3200 mg/kg). The targeted remediation goals are the Alberta Tier 1 hydrocarbon guidelines for fine-grained surface soil using an agricultural landuse (soil contact): 800 mg/kg (Alberta Environment, 2001). A biotreatability study was first conducted in order to properly select the bioremediation process and estimate timeframe of treatment. Following this study, a biotreatment process was identified to complete treatment of the soil by way of bioventilation with a forced air system and was scheduled to be completed within a sixteen-treatment month period.

3.1 Site-Specific Challenges

The soils at this site exhibited a combination of silty clay (SiC), clay (C) and heavy clay (HC) soil texture (RRTAC 93-7, 1993). Although this region is not identified as a wet region, several precipitation events during the fieldwork portion of the project forced the shut-down of field operations on five separate occasions. The physical properties of the soil were the primary challenge with this project. The use of bulking agents, along with a forced air system made it possible to increase the quality of air exchange. The absence of adequate electricity supply made it necessary to have a generator installed on-site for the first two months.

Due to on-going production related activities, the area available for treatment was limited. As a result, the soil was processed and constructed into a single biopile. In addition, the use of heavy equipment was also limited due to existing infrastructure on-site.

3.2 Fieldwork

Due to large amounts of precipitation, the first phase of the fieldwork was completed in four weeks, and included screening, incorporation of selected amendments and bulking agents, followed by the construction of a specifically engineered biopile. The biopile was protected from additional precipitation events with the use or a cover liner. To prevent any leaching impacts, a synthetic liner was used under the biopile and all process water was collected and contained. Overall, the incorporation of specific bulking agents increased the total weight of material by less than 8 %.

Since mid-July 2003, bioremediation of the soil has been active. The soil is currently being monitored for various parameters. Table 2 shows initial concentration of the soil before intervention.

Table 2 Biotreatment completion of impacted material by means of achieving optimal conditions for indigenous microflora (Case-study 2 - High Prairie area)

Description	Before intervention	After intervention
Number of samples	n = 4	Expected by the end of 2004 field season
Average F-3 fraction (mg/kg)	2425	
Standard deviation @ 95 % confidence (mg/kg)	704	
Meet the F-3 fraction goal of 800 mg/kg (%)	0	

4. CONCLUSION

One of the primary constraints to bio-treatment for these two locations was the wet density of the impacted soils. In both cases, the fresh bulk density was significantly high and saturation index was elevated. The addition of highly effective/low rate bulking agents, along with a proper incorporation and placement into biopiles have made it possible to use a forced air system to efficiently supply air transfer to the soil.

The typical cost is expected to range between $25 and $65 per tonne for this approach. By properly engineering the biopiles and ensuring a sufficient air exchange ratio, it is believed that optimal conditions within the soil ensure that the targeted remediation objectives are met.

5. REFERENCES

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