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Bioremediation of Hydrocarbon-Contaminated Soil

BACKGROUND: Abundant release of organic and inorganic compounds into the environment occurs each year as a result of human activities. In some cases, those releases are deliberate and well regulated (e.g., industrial emissions) while in other cases they are accidental and largely unavoidable (e.g., oil/chemical spills). Many of those compounds are both toxic and cumulative in terrestrial and aquatic environments. Soil, surface and groundwater contamination is the result of sustained accumulation of those toxic compounds in excess of permissible levels. Petroleum hydrocarbon (Crude Oil) contamination could be due to oil tanker accidents or tank ruptures or process leaks or well test (DST) or well-simulation or drilling activities resulting in marine and terrestrial spills. Crude oil mainly contains alkanes and aromatics apart from asphaltanes and NSO. Among the alkanes higher straight chain alkanes and polycyclic aromatic compounds do not usually degrade by traditional methods. Bioremediation, the degradation or transformation of contaminants by microorganisms could be a safe, effective, and economic alternative to traditional methods of remediation and further can be used in conjunction with a wide range of physical and chemical technologies which would be reducing the surface tension phenomenon normally associated with hydrocarbon spillage on substrate like soil/water.

METHODOLOGY: More than 1700 m^3 of contaminated soil was segregated from brittle and hardened rocky material and layered with a network of air adduction pipes to form a bio-pile.

Segregation Starts

Layer and Dosing

During layer constructions, the moisture and nutrient concentrations in the soil were set at an optimal level to promote and accelerate the development of a hydrocarbonphile bacterial population. The bacterial culture, S-Oil Treat was used as a structuring agent to mix with the soil. During treatment, the zigzag-piping network circulated air and maintained healthy reproductive conditions for the bacterial soil aided by rich nutrient Nutrient- 8 (rich in Nitrogen and Phosphorous) and accelerated the decomposition of Hydrocarbon, promoted by drastic reduction of surface tension by AQ 2000. The stubborn rocky material was pretreated with AQMA 2000 (accelerated). Ample nutrient supply (Nutrient 8 based on Nitrogen and Phosphorous) engendered the sustained bacterial action.

Layering Continues

A

Layering and Watering Continues

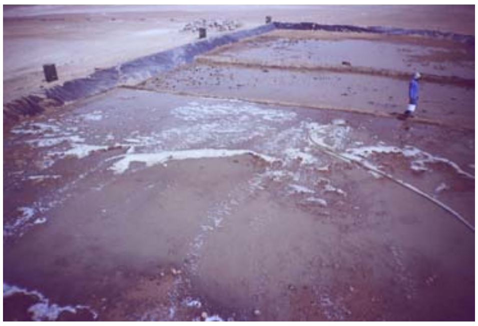
water injection system was incorporated through the same aeration adduction pipes so that bacteria would multiply and prevent the soil from drying out. The leachate was settling by gravity on a high-density polyethylene (HDPE) geo-membrane surface with incessant percolation up and down.

These **infiltration galleries** which as dynamic in-situ treatment systems are designed to stimulate microbial activity and subsequent hydrocarbon degradation by circulating nutrient and oxygen-amended water through hydrocarbon-contaminated soil. The re-circulating leach beds are in a way similar to slurry reactors. They in fact aerate and mix nutrients with contaminated soil, and can be considered as **on-site bioreactors.**

Laying of Adduct Pipes & Aeration

The bio-pile was monitored daily for **24 days** to control the temperature and moisture, as well as the concentration of oxygen, carbon dioxide, and volatile organic compounds in the circulating gaseous effluent. Not only were contaminant levels dramatically decreased as a function of time and to a permissible level over a period of three weeks. The bio-remediated soil is found to be acceptable, based on the analytical profile, for use as backfill for location/road formation on the property.

Process Continues



Dosing, Watering and Aeration in Last Phase

An overall statistical summary shown hereunder gives the panorama of the reactive additives, which forms the core activity of the bioremediation process. A graphical portrait is shown on the last page.

Additive	Functional Feature	Quantity-Kg	Quantity -L
S-Oil treat	Bacterial Culture	10.0	-
Nutrient 8	Soil Nutrient with Nitrogen & Phosphorous	90.0	-
AQ 2000	Surfactant	-	600
OSR (OT 8)	Surfactant with Bacterial culture for stubborn contamination	-	125
AQMA	Surfactant with Bacterial culture for double stubborn contamination	-	25
Water	Bacterial life subsistence	-	274, 000

SAMPLING & ANALYSIS OF HYDROCARBON CONTAMINATED SOIL: Soil samples are collected for laboratory analysis at the bio-remediation site both prior to and after treatment. The EPA guidelines, which are given in the form of tabular columns (please vide **tables I, II, III, IV A and IV B**) are strictly followed throughout execution.

Collection methods and their appropriate application area are shown in Table I.

Table I – Soil Collection Methods and Their Application

Collection Method	Depth of Collection	Applications
Surface Sampling	0-15 cm	• Recent Spills • Low migration rates (e.g. clay soils)
Test Pit	0-5 m	• Shallow contamination • Complex stratigraphy • Heterogeneous fill
Borehole	0 m to Bedrock	• Deep contamination • Dispersed spill • Prevents cross-contamination • Best method for identifying volatile contaminants
OTHER: Soil Pile	**N.A.**	• **To determine contaminant levels in a mound of excavated soil that is potentially contaminated**
Tank Pit	N.A.	• After removal of underground storage tank

Since the aim is to determine contaminant levels in a mound of excavated soil which was not homogenous in terms of contamination, with some areas having a larger extent of contamination, seven samples at varying spreads (levels) were taken (as per Table I & II) to obtain a consistent profile and analyzed. Grab sampling was followed by moving from less contaminated to the most contaminated area. The sampling equipment used was made of stainless steel and sufficient care was taken that the sampled soil particles are not larger than 2 mm.

Table II – Sampling Requirements for Excavated Soil

SOIL VOLUME (cubic meters)	# of Sampling Locations
0-375	4
376-750	5
751-1500	6
1501-3000	**7**
Each Additional 1500	One Additional Sample

As per EPA guidelines, by following Table III, since the contamination could be attributed only to Crude Oil, **Total Hydrocarbons (TPH) as Fuel Oil and Polycyclic Aromatic Hydrocarbons (PAHs)** were determined for the seven samples.

Table III – Soil Hydrocarbon Analysis

Petroleum Product	Analysis Type	Sample Containers
Unleaded Gasoline	A, B	1 (120 ml)
Regular Gasoline, Aviation Gasoline	A, B, D	1 (500 ml); 1 (120 ml)
Fuel Oil, Diesel Fuel, Kerosene, Jet Fuels, Mineral Oil/ Spirits, Motor Oil	A, C, H	2 (250 ml); 1 (120 ml)
Petroleum Solvents	A, C, G	2 (250 ml)
Waste Oil, Any Waste Petroleum Product	A, C, E, F, G, H	3 (250 ml); 1 (500 ml)
Unknown Petroleum or Hydrocarbon Mixture	A, B, C, E, G, H	1 (500 ml); 2 (250 ml)
Crude Oils, Hydraulic Fluids	**C, H**	**2 (250 ml)**
Coal Gasification	H	1 (250 ml)

A – Benzene, Ethylbenzene, Toluene, Xylenes (BETX)
B – Total hydrocarbons (TPH) as Gasoline
C – Total Hydrocarbons (TPH) as Fuel Oil
D – Lead
E – Lead, Chromium, Cadmium
F – Polychlorinated Biphenyls (PCBs)
G – Phenols
H – Polycyclic Aromatic Hydrocarbons (PAHs)

After 24 days of bioremediation, a similar sampling exercise was carried out to cover the whole extent of the spread by sampling at different layers resulting in seven grab samples. They were all checked for PAHs and TPH and the results are shown in **Table IV A.**

Table IV A - Analytical Summary

Sample	1	2	3	4	5	6	7
Before Treatment							
TPH (ppm m/m)	900	1350	800	1300	600	900	1300
PAHs (ppm m/m)	75	160	65	160	50	80	150
After Treatment							
TPH (ppm m/m)	<5	<5	<5	<5	<5	<5	<5
PAHs (ppm m/m)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

The mixture of samples before and after bioremediation are pouched and displayed in the next page and the MSDS (Material Safety data Sheets) are appended subsequently to establish that only environmentally friendly non-toxic additives are used to accomplish the task of bioremediation and the whole series of operation of bioremediation are vividly and sequentially portrayed in the following pages.

The EPA guidelines pertaining to the admissible soil clean-up levels (Table IV B), further confirm the suitability of the bioremediated soil for location and road formation work.

Table IV B - Soil Clean-up levels (PPM m/m-dry weight)

Parameter	Agricultural	Residential/ Parkland	Commercial/ Industrial
Benzene	0.05	0.5	5
Ethyl Benzene	0.1	5	50
Toluene	0.1	3	30
Xylene	0.1	5	50
TPH as Gasoline	40	400	2000
TPH as Fuel Oil	40	400	2000
PCBs	0.5	5	50
Phenols	0.1	1	10
Cadmium	3	5	20
Chromium (total)	750	250	800
Lead	375	500	1000

Soil Mass VS Additives