IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 6, June 2015.
www.ijiset.com
ISSN 2348 – 7968

Oil Spill Bioremediation Using Soil Blending Technique, Over A Bionutrient: A Niger Delta Case.

Ohia, Nnaemeka; Iyiegbu, Hillary
Federal University of Technology, Owerri – Nigeria

Abstract

Activities of the oil and gas industry which include exploration, production and transportation activities are on-going in various part of Nigeria. These activities however, are not without direct impact to the environment and ecosystem. A major category of this environmental impact is the discharge of petroleum hydrocarbon or crude oil into the environment, which leads to the contamination of the soil and underground water. Soil and underground water is the ultimate sink for most petroleum contaminants, such as Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX); Aliphatic and Polycyclic Aromatic Hydrocarbons (PAHs). These compounds are some of the volatile organic compoundsfound in petroleumderivatives.

This study presents the use of soil blending technique, over an activated persulfate oxidant (bionutrient) as a site restoration technique that may be employed in a variety of contaminated site cleanup programs. This is due to the ability of the technique in biodegrading significantly, the petroleum hydrocarbon contaminants at an inexpensive rate. Soil samples were collected from contaminated site, and analyzed before and after remediation. A set of physical and laboratory based analysis were carried out before and after remediation. After the remediation, a significant reduction of Total Petroleum Hydrocarbon (TPH) and BTEX was observed in the contaminated soil and underground water to be below DPR intervention value and detection limit respectively. Gas chromatography fingerprints showing the peak of individual organic compounds were as well obtained for BTEX and TPH respectively.

Key words: Bioremediation; bionutrients; persulphate oxidant; Aliphatic and Polycyclic Aromatic Hydrocarbons (PAHs); Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX); Total Petroleum Hydrocarcon; Below detection limit (BDL)

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1. Introduction

Petroleum exploration and production in the Nigeria's Niger Delta region and export of oil and gas resources by the petroleum sector has substantially improved the nation's economy over the past five decades. (Kamalu et al., 2011). The incidence of oil spillage constitutes serious soil degradation in the Niger Delta. The area currently faces series of ecosystem depletion as most soil flora and fauna are destroyed. Oil spills from the activities in the oil industry in the region affect the environment in the operational areas, right of ways (ROW) and third party areas. These result from equipment failures, leaks from corroded equipment and vandalisation (sabotage). The spilled crude oil from the source, through a plausible transport mechanism and exposure

pathway, gets to the receptors - soil, vegetation, surface and ground water, marine environment, animals and humans - and pollute the environmental media. (Etuk et al., 2013).

According to (Dana and Bauder, 2007), bioremediation is defined as use of biological processes to degrade, break down, transform, and/or essentially remove contaminants or impairments of quality from soil and water. Bioremediation is a natural process which relies on bacteria, fungi, and plants to alter contaminants as these organisms carry out their normal life functions. Metabolic processes of these organisms are capable of using chemical contaminants as an energy source, rendering the contaminants harmless or less toxic products in most cases. Three methods of Remediation are in use on Land - Remediation by Enhanced Natural Attenuation (RENA), Remediation by Stabilization / Solidification and Low Temperature Thermal Desorption. The RENA technique is the predominant method in use and may be applied in-situ (treating the soil on site) or ex-situ (removing the soil to be cleaned elsewhere and returned site). A general definition of natural attenuation is the reduction in toxicity, mass and/or mobility of a contaminant without human intervention owing to both physical (e.g. dilution, sorption and precipitation) and biological processes (bio-degradation) (Kate and Kristin., 2015). However, the use of different types of bio-nutrient, has given rise to diverse technological method of application, based on peculiarity. This therefore distinguishes one application approach from another. For the purpose of this study, the concept of an activated persulfate oxidant (bionutrient) technology, as presented in this study will require the application of Soil Blending Technique–i.e. Excavation and homogenization of contaminated soil with an activated persulfate oxidant (bionutrient). This technique is ideal for the contaminated and polluted sandy clay soil that was utilized for this pilot test. Petroleum hydrocarbon contamination ofsoils and sediment is a global concern because ofthe toxicity and refractory character of thearomatic components in the absence of oxygen (Ite et al., 2012). PAHs, which make up about 5% by volume,are a widespread class of environmental chemicalcontaminants of anthropogenic or natural origin(Stroud et al., 2007). This study/pilot test will also consider the effect and extent of remediation achieved by the proffered technology and bionutrient.

1.1 Objective of Study

Due to the cumulative impacts of past and present petroleum exploration and production operations, the Niger Delta has beenseen as one of the most polluted places in theworld due to severe contamination associated with the operations of petroleum industries and therefore needs adequate remediation. (Kamalu et al., 2011).

Bioremediation is gaining significant attention these days due to its economical and eco-friendly nature. Therefore, this study aims to provide a pragmatic view of the processes involved in bioremediation along with the issues to be considered when dealing with a proposal for bioremediation of petroleum hydrocarbon contaminated soil and underground water.

This study therefore seeks to;

1. Ascertain the Total Petroleum Hydrocarbon (TPH), nitrogen and phosphorus levels. Benzene, Toluene, Ethylbenzene and Xylenes (BTEX) and Polycyclic Aromatic Hydrocarbons (PAHs) in a contaminated field The Niger Delta region.
2. Demonstrate the effectiveness of an activated persulfate oxidant (bionutrient) and its soil blending technique concept in bio-remediating petroleum hydrocarbon contaminated (oil spill) sites in the Niger Delta field.
3. Evaluate the performance of the bio-treatment technology. This would be achieved by sampling the soil before and after remediation.
4. Enhance the indigenous bacteria via the addition of oxygen and nutrients to degrade petroleum hydrocarbon to carbon dioxide and water using soil blending technique.

1.2 Background of study

Over the years a vast area of the Niger Delta (in Nigeria) have been polluted by petroleum hydrocarbon (oil spills), from facilities owned by oil producing companies within the area. The main sources of oil spill land pollution in the Niger Delta are equipment failure, oil blowouts from the flow stations, leakages from aged and corroded network of the pipelines, operational mishap, sabotage and vandalization of the oil pipelines by the local militant groups.(Nwilo et al., 2006). The degree of hydrocarbon contaminated soil and underground water bioremediation in a general sense, is based on the heaviness of spill and contamination. When a particular field or site is heavily impacted and the soil and/or underground water is polluted, it becomes absolutely important to remediate such field, so as to salvage the environment from further damage. This has given rise to the exploitation of various bioremediation technologies by government agencies producing companies within the area.

The ecological devastation associated with the activities of multinational oil companies have adversely impacted upon the original occupations of the inhabitants of Niger Delta. For example, petroleum contamination has negatively impacts on agricultural productivity and some people, who originally engaged in farming and fishing, are facing loss of livelihoods through contaminated land and marine environment. Over the past 50 years, the multinational oil companies have failed to swiftly deal with environmental contamination resulting from oil spills, bunkering and discharges of petroleum–contaminated wastes in the Niger Delta. (Aaron. K. k., 2005).

Due to the cumulative impacts of past and present petroleum exploration andproduction operations, the Niger Delta has beenseen as one of the most polluted places in theworld due to severe contamination associatedwith the operations of petroleum industries and therefore needs adequate remediation. (Kamalu et al., 2011).

2.0 Materials and Methods

A site contaminated with crude oil located within the region was used for this study. The test soil obtained was sandy and sandy clay soil at different depths. The process of bioremediation, from start to finish took a period of 28 weeks. The bioremediation process comprises field experiment and laboratory simulation, with some physiochemical analyses. Soil sample was taken from a depth of 0.5-2.5metres. They were be taken using a hand auger into sample containers, free from hydrocarbon contamination. This process is called augering. The data sets, to be analyzed include; TPH (total petroleum hydrocarbon, nitrogen and phosphorus levels) and BTEX (benzene, toluene, ethylbenzene, and xylenes). These physiochemical parameters were monitored before and after remediation.

Soil blending technique will be employed with the use of an activated persulfate oxidant (bionutrient) technology. The soil blending technique involved:

1. Site Clearing: The site was cleared of contaminated vegetations and carbonized materials. These carbonized materials where gathered as keep at designated area for further waste management operations.
2. Spiking of Test Soils: The soils were spiked with water uniformly to soften the soil and to allow the water penetrate the soil matrix.
3. Soil Sampling and Analysis: Soil samples were taken from the pilot test site before remediation commenced from 0-2.5 meters depth at three spots (A, B and C). The spots coordinates were marked using a GPS and samples were taken using a hand auger into sample containers, free from hydrocarbon contamination.. The soil samples were taken for immediate physico-chemical analysis.
4. Excavation/Homogenization of Impacted Soil:The large site area was divided into smaller cells, and the petroleum hydrocarbon contaminated soil was excavated to a depth of 3metres using an excavator in order to expose the depth of impact and stimulate aerobic microbial activity within the soil. The persulfate oxidant was prepared by mixing (activating) each 55 Ib of the persulfate oxidant, with 10 Ib of lime. The cell dimensions and bionutrient loading requirements are determined (350 square meter area of cell is to 110 Ib of activated persulfate oxidant), after which the activated persulfate oxidant was broadcasted manually by hand over each cell. Each cell was afterwards blended with the designated activated persulfate oxidant ensuring that site wide distribution is achieved. In some instances, where the target zones are thicker than 5 feet or where site conditions warrant it, each cell is subdivided into lifts of

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5 feet. Each lift is mixed separately with predetermined quantities. The entire soil column was blended and allowed for two weeks ensuring that proper vertical distribution and remedial goal were achieved.

5. Back Filling: The excavated area was backfilled/leveled with top soil collected from an uncontaminated location and the treated soil.
6. Soil Sampling and Analysis: Soil samples were taken from the pilot test site after remediation from 0-2.5 meters depth. These samples were taking from the initial marked GPS coordinates (spots A, B and C) and the samples were taken using a hand auger into sample containers, free from hydrocarbon contamination. The soil samples were taken for immediate physico-chemical analysis.

Results and data for the soil and underground water analysis was collected in partnership with environmental protection agencies within the region. The sample results for the analyzed soil collected before and after bioremediation will be tabulated and graphically represented below. This will help to ascertain the progress and effectiveness of the bioremediation approach.

3.0 Results

3.1 Sample Characteristics

Table 1: Physical analysis of soil sample from point A before remediation

SAMPLE /DEPTH	COORDINATE	CHARACTERISTIC
Surface	N: $04^0$41’50.3” E: $007^0$14’37.8”	No Hydrocarbon smell, no visible contamination, sandy soil.
0m – 0.5m		No Hydrocarbon smell, no visible contamination, sandy clay soil.
1.5m		Organic material smell, No Hydrocarbon smell, no visible contamination, sandy clay soil.

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Table 2: Physical analysis of soil sample from point B before remediation

SAMPLE /DEPTH	COORDINATE	CHARACTERISTIC
Surface	N: $04^0$41’50.6” E: $007^0$14’37.5”	Strong Hydrocarbon smell, heavy visible hydrocarbon contamination, sandy soil.
0.5m		Strong Hydrocarbon smell, visible hydrocarbon contamination, sandy clay soil.
1.5m		Very light Hydrocarbon smell, very light visible hydrocarbon contamination, sandy clay soil.
2.5m		Very light Hydrocarbon smell, no visible hydrocarbon contamination, sandy clay soil.
Sample taking was discontinued after 2.5m depth because there was no visible presence of hydrocarbon contamination in soil.		

Table 3: Physical analysis of soil sample from point C before remediation

SAMPLE /DEPTH	COORDINATE	CHARACTERISTIC
Surface	N: $04^0$41’50.4” E: $007^0$14’37.1”	No Hydrocarbon smell, no visible contamination, clean sandy soil.
0m – 0.5m		No Hydrocarbon smell, no visible contamination, clean sandy clay soil.
1.5m		No Hydrocarbon smell, no visible contamination, clean sandy clay soil.

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3.2 Laboratory Analytical Report before Remediation.

Table 4: Report For Hotspot A (Soil).

S/NO	PARAMETER	SAMPLE POINT/DEPTH (m)	SAMPLE TYPE	CONCENTRATION (mg/kg)	DPR INTERVENTION VALUE	DETECTION LIMIT
1	TPH (mg/kg) Soil	0.15	SOIL	14.45	5000mg/kg	0.0001mg/kg
		0.5		174.8		
		1.5		2062.2		
(BTEX) PROFILE						
1	Benzene	(A) 0-0.15m	SOIL	BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(A) 0.5m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(A) 1.5m				
1	Benzene			46600.00mg/kg	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			1.08mg/kg	40mg/kg	
4	m,p-xylene			2.93mg/kg	130mg/kg	
5	o-xylene			BDL	25mg/kg	

Table 5: Report Hotspot B (Soil).

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S/NO	PARAMETER	SAMPLE POINT / DEPTH	SAMPLE TYPE	CONCENTRATION (mg/kg)	DPR INTERVENTION VALUE	DETECTION LIMIT
1	TPH (mg/kg)	(B) 0-0.15m (B) 1.5m (B) 2.5m	SOIL	5816.7 8947.76 6597.9	5000mg/kg	0.0001mg / kg
(BTEX) PROFILE						
1	Benzene	(B)0-0.15m	SOIL	BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(B) 1.5m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(B) 2.5m				
1	Benzene			22800.00mg/kg	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			0.55mg/kg	40mg/kg	
4	m,p-xylene			6.95mg/kg	130mg/kg	
5	o-xylene			4.38mg/kg	25mg/kg	

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Table 6: Report for Hotspot C (Soil).

S/NO	PARAMETER	SAMPLE POINT / DEPTH	SAMPLE TYPE	CONCENTRATION (mg/kg)	DPR INTERVENTION VALUE	DETECTION LIMIT
1	TPH (mg/kg)	(C) 0-0.15m (C) 0.5m (C) 1.5m	SOIL	BDL 165.92 780.97	5000mg/kg	0.0001mg/kg
(BTEX) PROFILE						
1	Benzene	(C) 0-0.15m	SOIL	BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(C) 0.5m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(C) 1.5m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	

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3.3 Laboratory Analytical Report after Remediation.

Table 7: Report For Hotspot A (Soil).

S/NO	PARAMETER	SAMPLE POINT/DEPTH	SAMPLE TYPE	CONCENTRATION (mg/kg)	DPR INTERVENTION VALUE	DETECTION LIMIT
1	TPH (mg/kg)	(A) 0-0.15m (A) 0.5m (A) 1.0m	SOIL	163.2 138.84 155.7	5000mg/kg	0.0001mg / kg
(BTEX) PROFILE						
1	Benzene	(A) 0-0.15m	SOIL	BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(A) 0.5m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(A) 1.0m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	

Table 8: Report for Hotspot B (Soil).

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S/NO	PARAMETER	SAMPLE POINT / DEPTH	SAMPLE TYPE	CONCENTRATION (mg/kg)	DPR INTERVENTION VALUE	DETECTION LIMIT
1	TPH (mg/kg)	(A) 0-0.15m (A) 1.5m (A) 2.5m	SOIL	19.49 39.68 87.28	5000mg/kg	0.0001 mg/kg
(BTEX) PROFILE						
1	Benzene	(B) 0 - 0.15m	SOIL	BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(B) 0.5m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(B) 1.0m				
1	Benzene			BDL		0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	

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Table 9: Report for Hotspot C (Soil).

S/NO	PARAMETER	SAMPLE POINT/DEPTH	SAMPLE TYPE	CONCENTRATION (mg/kg)	DPR INTERVENTION VALUE	DETECTION LIMIT
1	TPH (mg/kg)	(C) 0 - 0.15m (C) 0.5m (C) 1.5m	SOIL	188.8 BDL 1.84	5000mg/kg	0.0001mg / kg
(BTEX) PROFILE						
1	Benzene	(C) 0-0.15m	SOIL	BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(C) 0.5m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	
		(C) 1.5m				
1	Benzene			BDL	1mg/kg	0.001mg/kg
2	Toluene			BDL	50mg/kg	
3	Ethylbenzene			BDL	40mg/kg	
4	m,p-xylene			BDL	130mg/kg	
5	o-xylene			BDL	25mg/kg	

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4. Discussions of Results.

In summary of the investigation, the profile of contaminations before and after remediation are shown in respective tables linked with their respective hotspots and depth. The main contaminants considered were TPH and BTEX. Significant changes where observed, alongside other changes while making comparism of the state of the soil before and after bioremediation took place. (See Tables 1-9)

Soil: Significantly, maximum concentration of TPH for soil before remediation was 8947.76mg/kg at a depth of 1.5m in hotspot B and 6597.90mg/kg at a depth of 2.5m in hotspot B, the BTEX (Profile) values at depth 2.5 in hotspot B where, benzene was 22800mg/kg (above detection limit and above DPR intervention value), toluene was below detection limit, ethylbenzene was 0.55mg/kg (above detection limit and below DPR intervention value), m,p-xylene was 6.95mg/kg (above detection limit and below DPR intervention value) and o-xylene was 4.38mg/kg (above detections limit and below DPR intervention value). (See table 2). But after remediation report shows that at hotspot B (Soil), physical analysis before remediation revealed that at coordinates: N: $04^0$41’50.6”, E: $007^0$14’37.5”, at 0m-2.5m depth we have a clean soil, no hydrocarbon smell and no visible presence of hydrocarbon. (See appendix). Laboratory analytical report reveals that at 1.5m and 2.5m depth TPH concentration reduced to 39.68mg/kg and87.28mg/kg respectively and the BTEX (Profile) reduced below detection limit (see table 6).

The increase of TPH concentration after remediation at 0.15m depth in hotspot A and C respectively was taken note of. This increase was as a result of migration from surrounding polluted sites. Hotspot A and C are located close to the boundaries of other polluted site, hence its result was slightly affected. However none of the increment was in any way close to the DPR intervention value.

Efficient biodegradation using soil blending technique over an activated persulfate oxidant has been demonstrated. There has been a reduction of hydrocarbon contaminants mass or concentration with time, below detection limit and the DPR intervention value. Cost effectiveness of the process is evident, if compared to conventional methods. Final pictorial view of the initially polluted site, shows the survival of cultivated vegetations. These evidences certify the site remediated.

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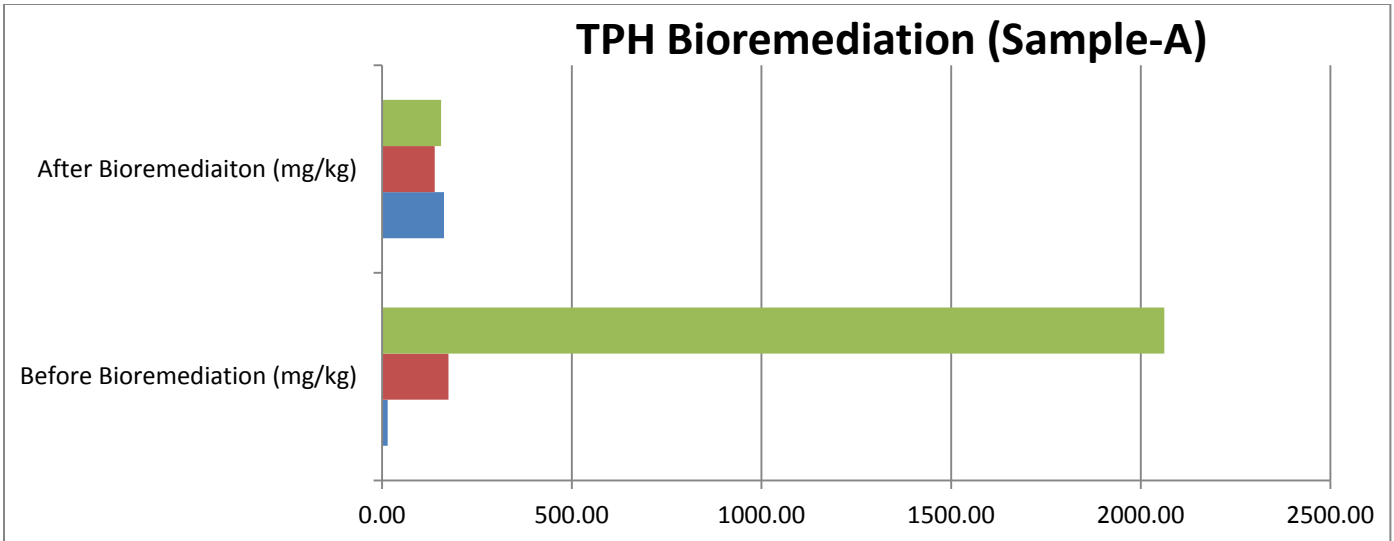
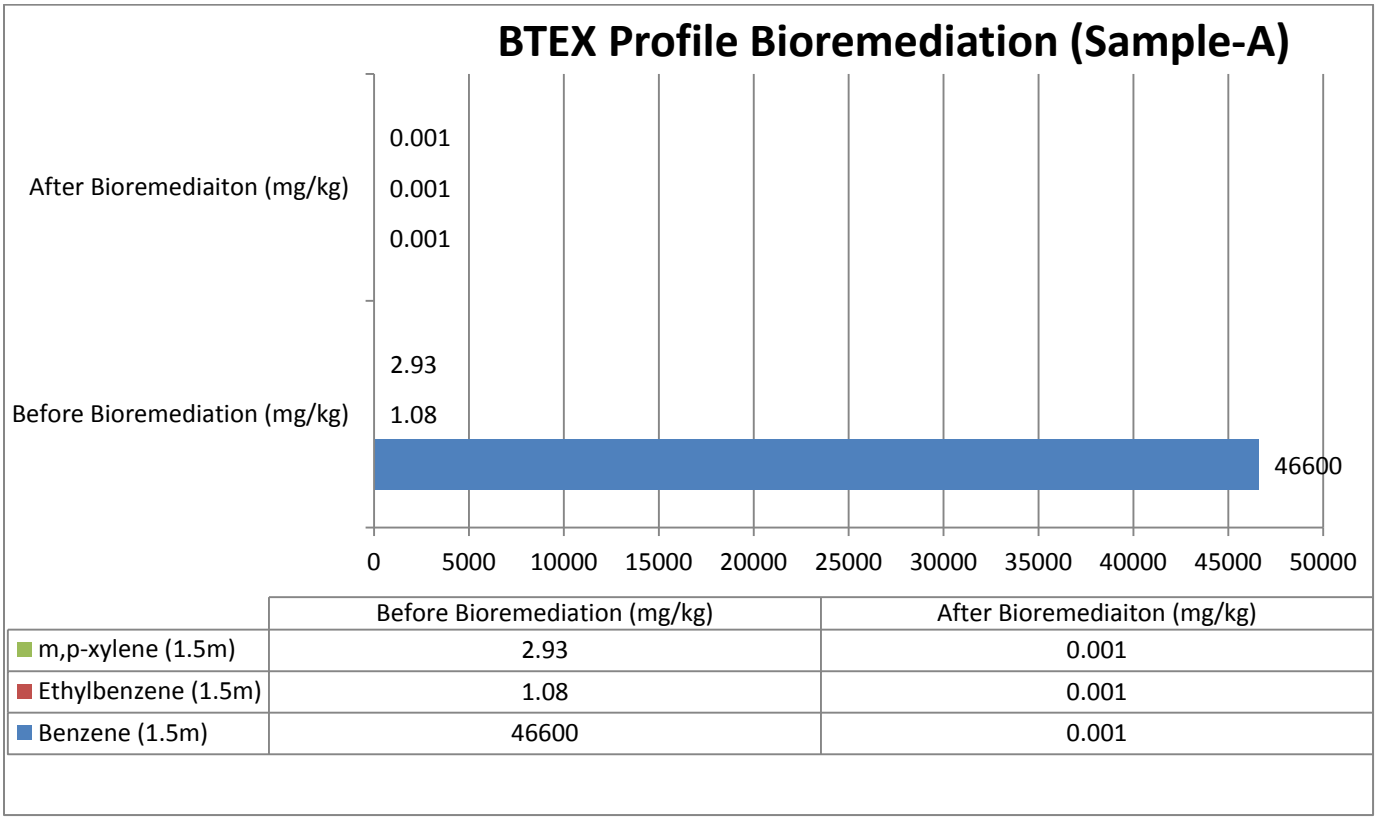


	Before Bioremediation (mg/kg)	After Bioremediaiton (mg/kg)
1.5m of Sample Depth	2062.20	155.7
0.5m of Sample Depth	174.80	138.84
0.15m of Sample Depth	14.45	163.2

Figure. 1.0: Graphical Representation of TPH on Sample-A Before & After Remediation.



	Before Bioremediation (mg/kg)	After Bioremediaiton (mg/kg)
m,p-xylene (1.5m)	2.93	0.001
Ethylbenzene (1.5m)	1.08	0.001
Benzene (1.5m)	46600	0.001

Figure. 2.0: Graphical Representation of BTEX Profile on Sample-A Before & After Remediation.

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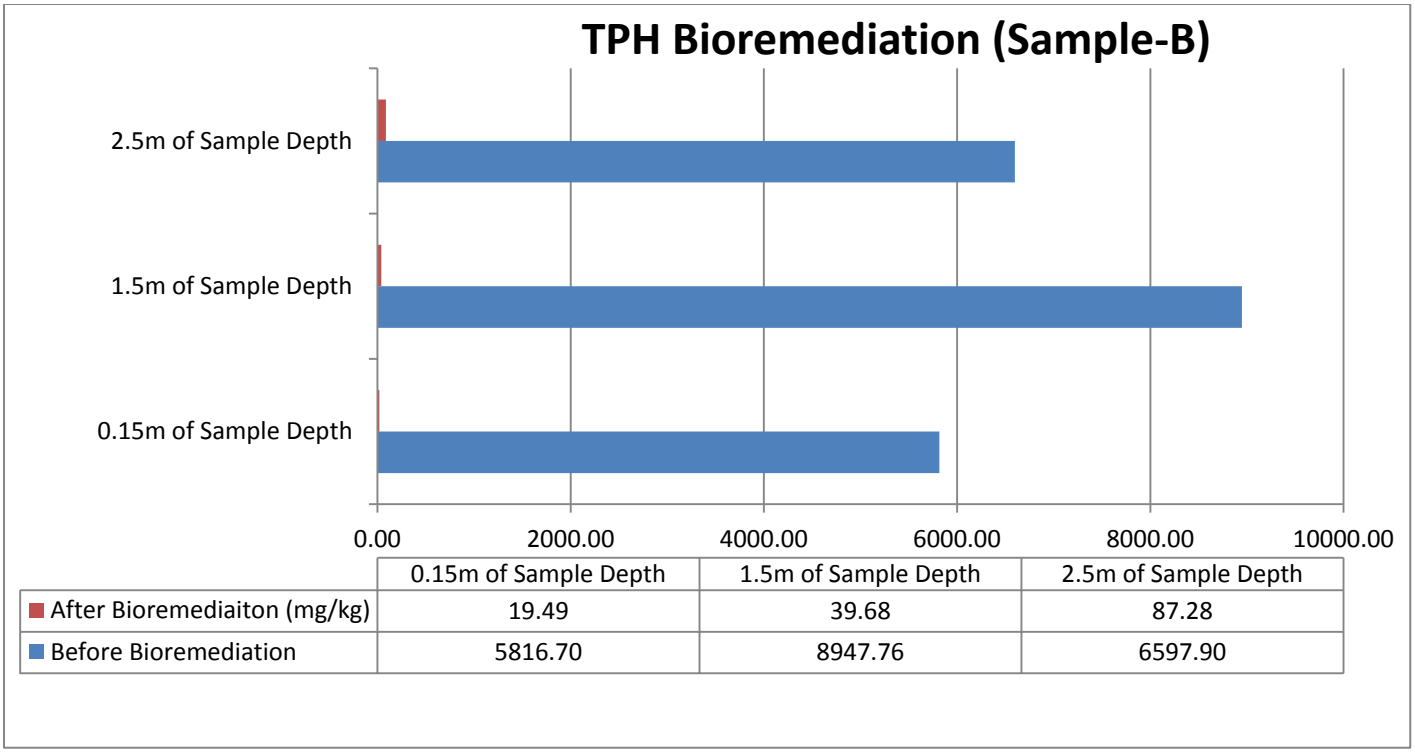
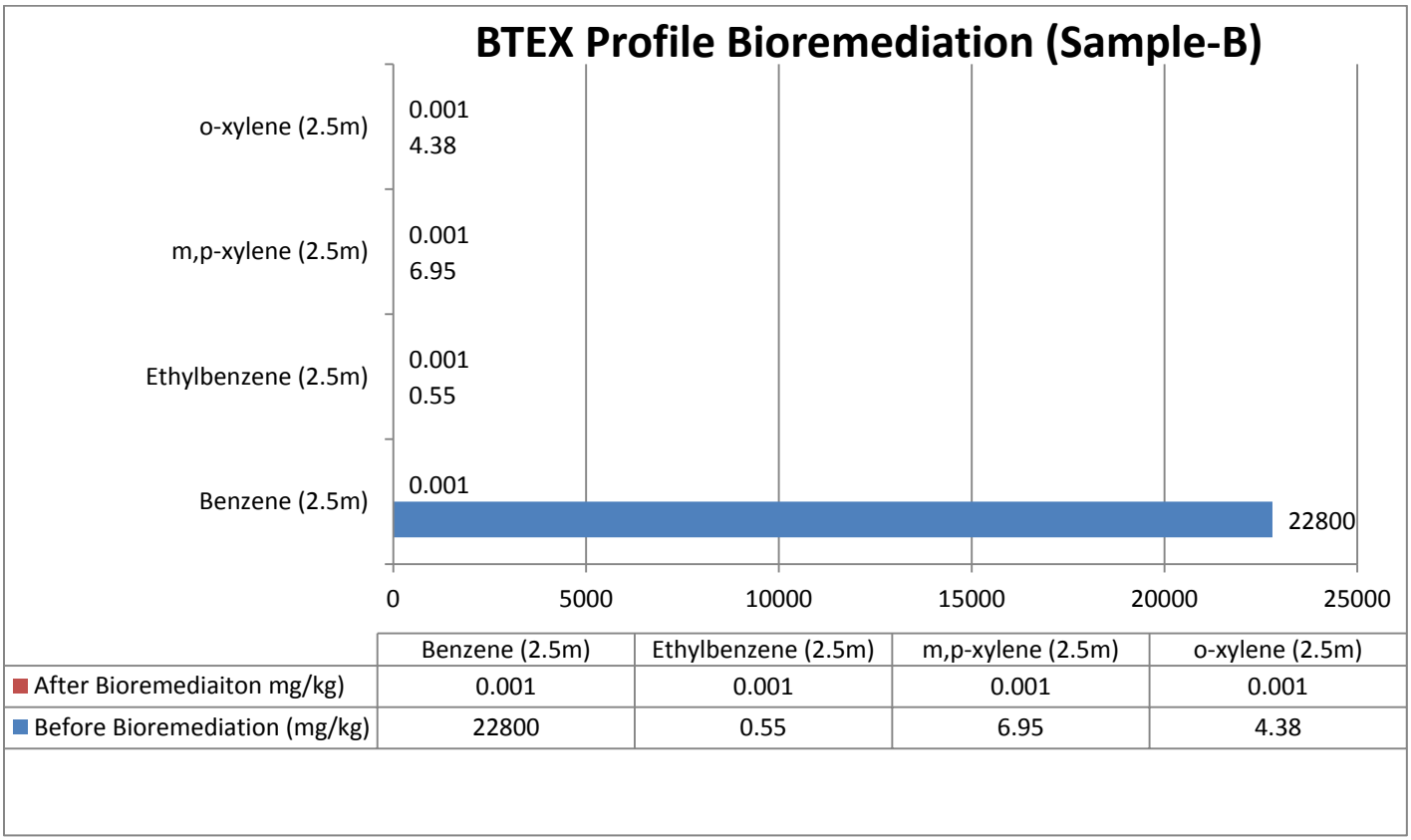


	0.15m of Sample Depth	1.5m of Sample Depth	2.5m of Sample Depth
After Bioremediaiton (mg/kg)	19.49	39.68	87.28
Before Bioremediation	5816.70	8947.76	6597.90

Figure. 3.0: Graphical Representation of TPH on Sample-B Before & After Remediation.



	Benzene (2.5m)	Ethylbenzene (2.5m)	m,p-xylene (2.5m)	o-xylene (2.5m)
After Bioremediaiton mg/kg)	0.001	0.001	0.001	0.001
Before Bioremediation (mg/kg)	22800	0.55	6.95	4.38

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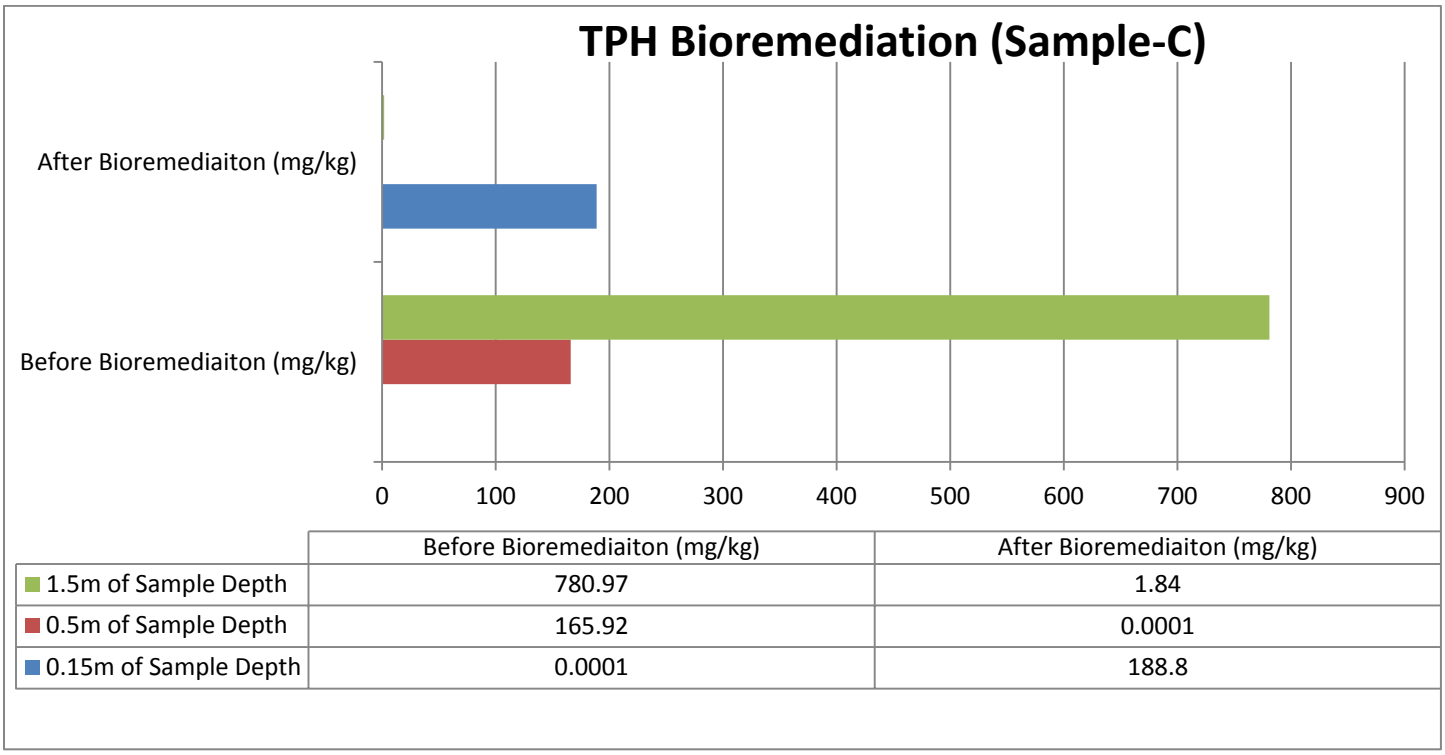
Figure. 4.0: Graphical Representation of BTEX Profile on Sample-B Before & After Remediation.



	Before Bioremediaiton (mg/kg)	After Bioremediaiton (mg/kg)
1.5m of Sample Depth	780.97	1.84
0.5m of Sample Depth	165.92	0.0001
0.15m of Sample Depth	0.0001	188.8

Figure. 5.0: Graphical Representation of THP on Sample-C Before & After Remediation.

5. Conclusion and Recommendation

By comparing laboratory obtained data before and after remediation, information was acquired, which led to a better understanding of processes, taking place at the contaminated site.

Oil spill bioremediation using soil blending technique over an activated persulfate oxidant has shown great promise, in its effectiveness and comparatively inexpensive rate. It is notable that 99 percent biodegradation of BTEX and TPH, below DPR intervention value was achieved, judging by the laboratory analytical report before and after remediation. Further researches in this field can result in the development of most efficient and less time consuming technologies. Although public attitudes toward bioremediation are generally favorable, the lack of knowledge on how it affects the environment, could affect the acceptability of their use. Before bioremediation techniques to be used widely, their efficacy and safety will have to be convincingly demonstrated and communicated to the public.Evidence of biological destruction (biodegradation) of petroleum (PAH, TPH and BTEX) from the contaminated soil. Since a major advantage of bioremediation is destruction, it is important and significant to demonstrate that biodegradation is occurring or has occurred. The evidence is expected to come primarily from comparison of the soil sample analysis taken before and after the material is

subjected to the treatment process (soil blending technique over an activated persulfate oxidant) to stimulate biodegradation.Multiple lines of evidence show that biodegradation of PAH, BTEX and TPH occurred during the demonstration.

5.1 Recommendation:

- During site (soil and underground water) remediation surrounding contaminated site should be barred or containment should be initiated by physically using an underground barrier of clay, cement or steel. Containment can also be initiated chemically by imploring chemical reactive substances to immobilize contaminants from migrating from surrounding contaminated site, into the site being remediated.
- Oil and gas firms should use best management practices to reduce or prevent instances of oil spill.

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Appendices

Figure 6.0: Showing Hotspot GPS marking.

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Figure 7.0: Showing excavation of contaminated soil.

Figure 8.0: Showing hand broadcasting of activated persulfate oxidant.

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Figure 9.0: Showing survival of vegetation after remediation.