Research Journal of Applied Sciences, Engineering and Technology 2(7): 654-660, 2010
ISSN: 2040-7467

Submitted Date: August 11, 2010 Accepted Date: September 13, 2010 Published Date: October 25, 2010

Assessing the Effectiveness of Land farming in the Remediation of Hydrocarbon Polluted Soils in the Niger Delta, Nigeria

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Abstract: Hydrocarbons pollution of soils has constituted environmental issues over the years. The biggest concern associated with hydrocarbon pollution in the environment is the risk to farmlands, fisheries and potable water supplies contamination. Several remediation techniques exist (Bioremediation and Non-bioremediation), which aim at reducing the hydrocarbon content of the polluted soil and water with their varying degrees of success. Thus land farming, one of the bioremediation remediation techniques is viewed as a more viable remediation options for hydrocarbon polluted soils. The study therefore was instituted to assess the effectiveness of land farming (Enhanced Natural Attenuation) in the remediation of hydrocarbon polluted sites in the Niger Delta. Soil samples from ten (10) sites polluted and remediated sites in the Niger Delta; that is five (5) samples each from the swampy and well drained sites and subjected to Laboratory analysis. The results were further analysed using both descriptive and inferential statistical tools of percentages, regression analysis and student t-test. The results of the soil analysis show 14.54 to 82.24% and 16.01 to 50.54% reductions in the TPH and PAH concentrations after land farming respectively. This shows high level of efficacy in the use of the Land farming as remediation technique. However, the efficacy varied between the swampy and well drained soils; reductions in the hydrocarbon levels of the soils in the water-logged or swamp areas were lower and slower than that of the well drained soils. This shows that the soil microbes were able to degrade the hydrocarbons faster in the well-drained soil probably because of the favourable soil conditions like pH, moisture, and nutrient. To ameliorate this problem, more effective way of bio-remediation for swamp area should be pursued like phyto-remediation; this is the use of higher plants to enhance the remediation of soils contaminated with recalcitrant organic compounds.

Key words: Hydrocarbons pollution, land farming, Niger Delta, Polycyclic Aromatic Hydrocarbons (PAH), remediation, Total Petroleum Hydrocarbon (TPH)

INTRODUCTION

Crude oil and Natural Gas are the main sources of foreign exchange to the Nigerian economy. In fact, it contributes to as much as 95% to Nigeria budgetary expenditures (Owugah, 2001). Oil and Natural gas are found in the geological structures underlying mangrove and associated coastal ecosystems of the Niger Delta. Therefore, the Niger Delta is the centre of intensive and extensive oil exploration and production activities. Unfortunate enough is that oil exploration and exploitation activities have inevitably resulted in several incidences of oil spills, causing extensive deforestation and subsequent degradation of the environment in the past (Idoniboye-Odu, 1981; Nwangwu and Okoye, 1981; Odu, 1982; Baker, 1982). Thus, it has been the main source of worry and sorrow to the people of Niger Delta region as a whole, as this has polluted both the water bodies and land terrestrial ecosystems.

One of the biggest concerns associated with petroleum pollution in the environment is the risk to farmland, fisheries, and potable water supplies contamination since most of the people's livelihood depends on farming, fishing and usage of water for the domestic purposes.

Until about 1970 there was little widespread awareness of the worldwide scope of soil contamination or its health risks. In 1980 the U.S. comprehensive Emergency Response Compensation and Liability Act (CERCLA) was passed to establish, for the first time, strict rules on legal liability for soil contamination. It stimulated the identification and cleanup of thousands of sites and also raised awareness of property buyers and sellers to make soil contamination a focal issue of land use and management practises. Crossley (1970) observed that each year in the U.S., thousands of sites complete soil contamination cleanup, many by using microbes that "eat up" toxic chemicals in soil, many others by simple

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excavation and others by more expensive high-tech soil vapour extraction or stripper tower technology. At the same time, efforts proceed worldwide in creating and identifying new sites of soil contamination, particularly in industrial counties other than the U.S., and in developing countries which lack the money and the technology to adequately protect soil resources. In the Niger Delta, the natural recovery of crude oil from polluted soils is slow and communities affected by such cases are denied of their agricultural lands for a long time. Remediation of hydrocarbon polluted sites has been the alternate that the people of Niger Delta are left with to mitigate damage to human health, bio-physical environment and socio-economic environment.

Efforts to remediate the negative impact of hydrocarbon pollution on the water and soil has resulted to several devices such as Remediation by Enhanced Natural Attenuation (RENA) which involves many techniques including Land farming by bio stimulation or bio augmentation of soil biota with commercially available micro flora (Ebuehi *et al*., 2005). Land farming is a Surface-soil remediation technology for petroleum contaminated soils that reduces concentration of hydrocarbons through biodegradation to a level that is safe for human health and the environment. It specifically involves the tilling and spreading of escalated soils to enhance the biodegradation of petroleum hydrocarbon (EPA, 1994). In other words, this 'low tech' biological treatment method involves the controlled application and spread-out of organic waste on the soil surface, and the incorporation of the waste into the upper soil zone.

The problematic: The need to restore the crude oil contaminated soils of the Niger Delta environment to the pre-oil spill pollution condition cannot be over-emphasized. Significant quantities of material contaminated with elevated levels of petroleum hydrocarbons are produced year after year from operations such as oil well drilling, leaking underground storage tanks, and surface spills (Nwilo and Badejo, 2005).

More than four decades of oil exploration and production activities have left a severely degraded environment in the Niger Delta. Spills- the uncontrolled discharge of oil or its by-products including chemicals and wastes, which mainly occurs through equipment failure, operational errors, or wilful damage- have been identified as the main source of environmental damage in the region over time (Nwilo and Badejo, 2005). After many years, during which these adverse effects either received scant attention or were simply ignored, fresh efforts have been mounted in recent years by both environmentalist Non-governmental Organisations (NGOs) and oil multinationals to remedy the situation. The sandy river banks/waterways along the oil producing areas of the Niger Delta and Coastal shoreline beaches have been at the risk of heavy and regular impact by major oil spills in this region which has become a recurrent issue in the past two and half decades .

Several remediation techniques exist to combat the menace of hydrocarbon pollution of the soil with varies degrees of successes and imposing costs which deter many polluters from doing adequate and effective remediation. Thus it becomes imperative that the technology that would drastically reduce the nuisance of hydrocarbon pollution of soils in the Niger Delta be seriously investigated. Land farming is viewed as a veritable bioremediation technique of soil contaminated with crude oil. Therefore, the fundamental questions that arise are: what is the efficacy of land farming in reducing hydrocarbon contents in contaminated/polluted soils in the Niger Delta? Does its efficacy vary with the nature of the soils involved? Providing answers to these questions form the major challenge of this study.

The study area: The Niger Delta is described as a unique ecological zone by virtue of its size and geophysical configuration (Mmom, 2003). It is one of the world's largest wetlands covering an area of approximately 70,000 km^2. Located in the south-south geopolitical region of Nigeria. It lies between latitude 4º and 6º North of the equator and longitude 5º and 7º East of Greenwich.

Along the coast, the Niger Delta as shown in Fig. 1, it stretches from the Benin river in the West to Bonny river in East, while in land, it begins a few miles below Aboh at a point where river Niger bifurcates into river Nun and Forcados into the Atlantic West at the South, stretching over 160 miles (Udo, 1975; Iyalla, 2001).

The Delta could be described as a prism that was formed by the accumulation of sedimentary deposits transported by rivers Niger and Benue. Within the flood plains, the river splits into six major tidal channels and innumerable smaller outlets. Fluvial sediments are deposited throughout the Delta with sand and silt suspension during both high and low flood regimes. The region experiences very high annual rainfall ranging between 3000 to 4500 m with double maxima characteristics of July and September peaks.

Although the Niger Delta can be roughly categorized into four ecological sub-zones (coastal barrier Islands, mangrove, fresh water swamp forest and the lowland rainforest), the mangrove is the largest and dominant eco-sub zone.

In terms of socio-economic development, the region could be described as being a "rich region with poor people". It is blessed with abundant Crude Oil and Natural Gas, which is the main stay of Nigeria's economy. Apart from crude oil and natural gas, the

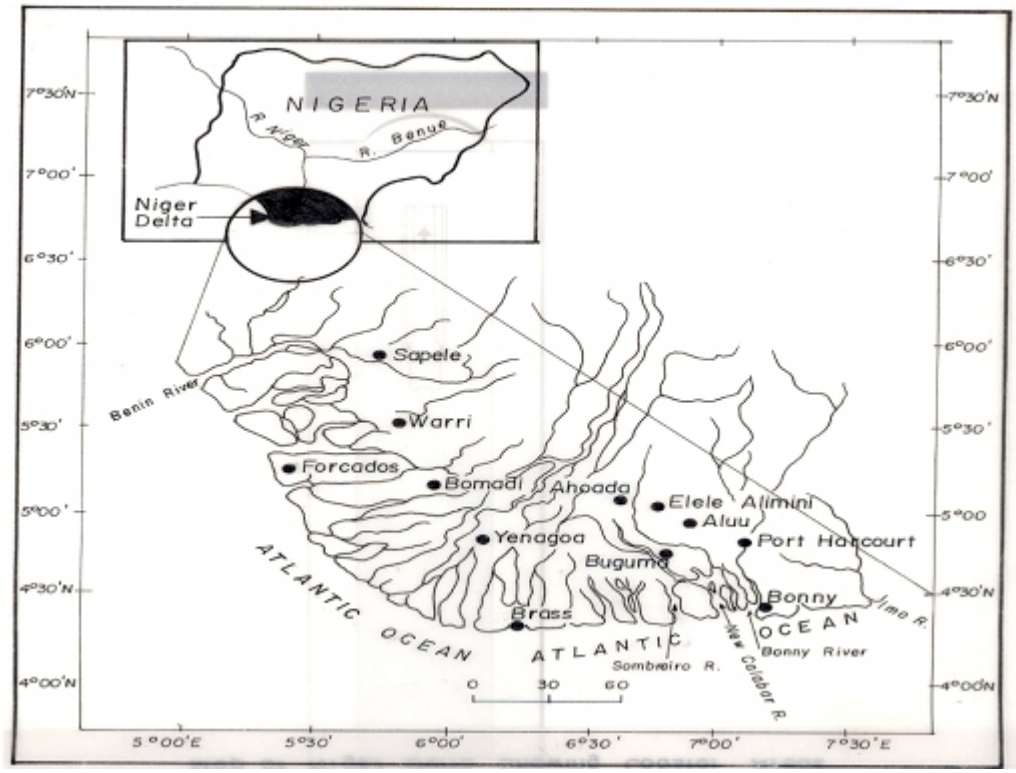

Fig. 1: Physiographic map of the Niger Delta

mangroves offer a lot of biological resources on which the rural livelihood depend. The region is poorly drained with development difficulties. Based on its physiographic configuration, it covers five states of Nigeria (Akwa Ibom, Bayelsa, Delta, Edo and Rivers states). The Niger Delta with a population over 10 million people is one of the industrial and commercial hubs of Nigeria. It is the home of Nigeria's Oil and Gas Industries and a commercial nexus in Nigeria because of its coastal location. In fact, it is witnessing rapid economic growth and little or no development.

MATERIALS AND METHODS

For purpose of this study, ten (10) sites, five soil samples from Obigbo area representing well-drained soils and five soil samples from Cawthorne Channel area representing the water-logged (Swamp) area were chosen for sampling and also a control sample for each of the sampling Area (Table 1).

All soil samples were subjected to complete analysis for pH, organic carbon, total nitrogen and available phosphorus for fertility characterization, Mechanical analysis for soil texture, Heavy metal analysis, and hydrocarbon concentration levels (TPH, BTEX and PAH).

Regression Analysis was used to express the relationship that exists between the concentrations of pollutants in the two sets of soil of the study areas. This can be expressed as:

Table I: Sample sites

Sites	Name	Site location
1	OBG_a	Behind Obigbo Flow station at Obigbo North, Igbo Etche road
2	OBG_b	6'' Obigbo - Ogale Delivery Line at Komkom
3	$CAWC_a$	Behind Cawthorne Channel one (CAWC1) flowstation location within Samkiri and Kengemakiri Community in Bonny LGA
4	OBG_c	Well 24L flowline at Obigbo
5	$CAWC_b$	Behind Cawthorne Channel two (CAWC2) flowstation located within Giftikiri and Elekalabari Community in Degema LGA
6	$CAWC_c$	Along Cawthorne Channel Well 41 flowline
7	$CAWC_d$	Along Cawthorne Channel Well 29T flowline
8	$CAWC_e$	Along Cawthorne Channel Well 37L flowline
9	OBG_d	Along Well 36L flow line at Obigbo
10	OBG_e	Along Well 34L flow line at Obigbo

Source: Soil survey, 2006

$$Y = a_0 + a_1 x$$

$$a_1 = \frac{\Sigma Xy - X\Sigma y}{\Sigma X^2 - \overline{X}\Sigma X}$$

$$a_0 = \bar{y} - a_1 x$$

$$r = \sqrt{\frac{a_0 \Sigma y + a_1 \Sigma X.y - \bar{n}(y)^2}{\Sigma y^2 - \bar{n}(y)^2}}$$

here, Y (the dependent variable), is the concentration of pollutant in the remediate soil, X (the independent variable), is the concentration of pollutant in the polluted soil, a_o is the regression constant and a_1 is the regression coefficient. The regression coefficient defines the effect of the landfarming on the hydrocarbon concentration in the soils, while Students t-distribution test was used to explain the variation between the means of the polluted soils and that of the remediate soils; given as:

$$t- = \frac{X_b - X_2}{\sqrt{\frac{\delta^2}{n_1} + \frac{\delta^2}{n_2}}}$$

δ is the standard deviation

$$\delta_1 = \sqrt{(X_1 - X_1)^2 / n-1}$$

$$\delta_2 = \sqrt{(X_2 - X_2)^2 / n-1}$$

x_1 is the sample mean for the polluted sites.
X_2 is the sample mean for the remediate sites
N is the population sample

RESULTS AND DISCUSSION

The measurable physicochemical properties in this research were pH, Textural Class, Nutrients (N, P, C), TPH, BTEX, PAH and Heavy Metals (Pb, Zn, Cu, Cr, Co, Cd, Ni, Hg, As, Ba). The results of physiochemical parameters of soil from the various sample sites before the on-set of remediation and after remediation from March to November, 2006 are presented.

In this study, Low pH values were recorded from all the sites. The values were between 4.20 and 5.50. The pH values were found to be above the limit of FMENV, DPR and WHO (Table 1). For biodegradable pollutants like petroleum products, bio-stimulation of microbiology processes is usually encouraged by adjusting soil pH. The pH can be raised by applying lime (calcium and magnesium compound) or lowered by applying sulphur or aluminium sulphate. The pH of the soils ranged between 4.20 and 5.50. The highest value was recorded at site I with a value of 5.50. The pH values did not vary much from site to site.

The degree of acidity or alkalinity is considered a master variable that affects nearly all soil properties - chemical, physical and biological. Some organisms are unaffected by a rather broad range of pH values; others

Table 2: pH values of the sampled sites

Sites	pH values	Description	Sites	pH values	Description
1	5.50	Slightly acidic	6	4.90	Acidic
2	4.20	Acidic	7	4.25	Acidic
3	4.35	Acidic	8	4.40	Acidic
4	5.30	Acidic	9	5.10	Slightly acidic
5	4.81	Acidic	10	4.51	Acidic

may exhibit considerable intolerance to even minor variations in the pH. It influences aggregate stability as well as air and water movement. It determines the fate of many soil pollutants, affecting their breakdown and possible movement through the soil and into the groundwater (Akpofure *et al*., 2000). It is a major controller of plant nutrient availability and of microbial reaction in soils. The amount of acid or alkali in the soil determines the availability of many nutrients for plant growth and maintenance. If the pH of soil is too high or too low, the nutrients are either locked onto the soil particles or are washed out of the soil. Most plants grow best when the soil pH is between 5.5 and 6.5 (on the slightly acid side of neutral). The pH of the soil greatly affects the solubility of the minerals. Strongly acidic soils (pH 4 to 5) usually have high concentrations of soluble aluminium and thereby affect plant growth. Nitrogen fixation and decomposition activities are also hindered in strongly acidic soil.

The study areas are within the rain forest zone and mangrove swamp of the Niger Delta. The rain forest currently exists in patches within the study area due to urbanization and extensive cultivation for agricultural development. The soils were sandy loam. The sand fractions of the soils are dominated by medium sand particles, which averaged between 51.7 and 59.2% as shown in Table 2. The soils of the swamp are fine, organic and very poorly drained clay content of about 60% located within a mangrove tidal flat area of Niger Delta. The soils have high silt and clay with a range of 40-97%. This is evidenced in Table 3 and the remainder being fine sand. The soil texture is clay with various intergrades of sand-clay. The fineness of the soil reduces rate of percolation of liquid and gaseous substances within these soils. Water logging and the organic nature of the soil further aggravate this. Thus, as Nwankwo and Irechukwu (1981) observed, in the event of oil or chemical spill, movement of the contaminant downwards will be impeded by the fineness of soil material. Classification of the textural class showed that sites in the Mangrove Swamp area were silty-clay in nature, while sites in the upland area were loamy-sand.

Soil texture affects how well nutrients and water are retained in the soil. Clays and soils with high organic matter hold nutrients and water much butter than sandy soils.

As water drains from sandy soils; it often carries nutrients along with it. When nutrients leach into the soil,

Table 3: Textural Class of soil samples

Class	Sand	Loamy sand	Sandy loam	Loam or silt loam	Clay loam	Clay
Texture	15% clay or silt	15-20% clay or silt	21-50% clay or silt	>51% clay or silt	20-30% clay	>31% clay
Study area	-	-	Obibgo	-	-	CAWC

Source: EIA for Obigbo, 2006; EIA for Cawthorne Channel/Akaso Integrated Oil Development and Associated Gas Utilization Project, 1998

Table 4: Concentrations of hydrocarbons in the soils before and after landfarming (mg/Kg)

	Parameters					
	Before remediation			After remediation		
Sites	TPH	PAH	BETEX	TPH	PAH	BETEX
1	5159.45	3037.02	0.10	916.00	1502.20	BDL
2	3123.32	2100.45	1.83	629.10	1268.35	BDL
3	4268.01M	3689.01	0.20	1180.00	2980.00	BDL
4	5149.104	585.60	0.08	2024.55	3851.22	BDL
5	4450.00	2986.08	0.15	1230.13	1705.00	BDL
6	3218.00	2866.51	0.98	2750.02	2003.60	BDL
7	6512.65	4149.12	1.58	4693.25	3310.34	BDL
8	4876.00	3769.40	0.20	3719.84	2400.01	BDL
9	5022.21	2305.84	1.65	1087.00	1525.80	BDL
10	3112.64	2225.64	1.09	2553.04	1390.30	BDL

Source Soil survey, 2006

they are not available for plant to use. An ideal soil contains equivalent portions of sand, silt, clay and organic matter. The texture of a soil is determined by particle size and the proportional amount of these size particles within anyone soil sample. Soils are classified as follows; sand; 15% clay and/or silt, Loamy sand; 15-20% clay and/or silt, sandy loam; 21-50% clay and/or silt, loam or silt l0am; 51% or more of clay and/or silt, Clay loam: 20-30% clay, Clay: 31 or more clay.

Similarly, in this study, soil samples were examined to determine if there were reductions in the hydrocarbon content in the soils after Land farming. Concentrations of Total Petroleum Hydrocarbon (TPH) in all the sites were found to have reduced as shown in Table 6. However, all the sites recorded values greater than 50 mg/kg of DPR limit but below 500 mg/kg allowable limit for industrial areas. All the recorded values for BTEX, were Below Detection Limits (BDL). There were reductions in the PAH values recorded for all the sites which ranged from 1268.35 to 3851.22 mg/kg. There were slight reductions in the PAH values recorded in all the sites of the swamp area even after Land farming, this gives rise to the possibility of biodegradation being more effective in well-drained soils than in water-lodged soils or swamp areas. However, the TPH values were well below the allowable limit for industrial areas but above the Department of Petroleum Resources and Federal Ministry of Environment limits (50 mg/kg) for remediate soils (Table 4).

Many soils naturally have varying but trace amount of heavy metals even in undisturbed environment. These amounts can be changed because many industrial processes produce heavy metals which if not properly and carefully controlled end up in the environment in soils and water. Any increase in these heavy metals indicates that there is contamination. When the concentrations of these heavy metals such as cadmium reach certain levels they can become toxic to plants. Lead when taken into the body enters the blood stream from where it is redistributed to soft tissues and the skeleton. Lead may cause blood enzyme changes, anaemia, hyperactivity and other subtle neuro-behavioural effects. They assume particular importance when considering bio-accumulation because there is no indication currently that most of them are used by animals in their metabolic processes. Contamination in soil may have detrimental effect in any microbes. It can result to heavy metal toxicity (EPA, 1997).

Heavy metal analysis in soil appears to be more useful in detecting sources of pollution since the soils are likely to be sinks for pollutants. Most of the heavy metals analyzed in this study have lower concentrations after land farming except for barium. The heavy metals analyzed are also notable constitutes of crude oil. It was observed in this study that Co, Cd, Ni, Hg, As and Ba had

Table 5: Concentration of heavy metals in the soils before (mg/Kg)

	Before									
Sites	Pb	Zn	Cu	Cr	Co	Cd	Ni	Hg	As	Ba
1	13.09	8.39	14.48	1.25	BDL	2.73	0.88	BDL	BDL	BDL
2	2.72	4.64	15.87	5.07	BDL	1.78	1.33	BDL	BDL	BDL
3	10.36	17.12	4.37	1.69	BDL	3.57	1.24	BDL	BDL	BDL
4	7.45	10.06	12.14	1.67	BDL	2.56	0.72	BDL	BDL	BDL
5	0.38	17.11	5.10	10.87	3.26	BDL	13.60	BDL	BDL	BDL
6	33.30	36.80	4.08	0.05	0.86	4.10	11.56	BDL	BDL	52.91
7	1.56	6.87	2.88	4.96	2.54	0.97	5.88	BDL	1.20	BDL
8	0.59	27.86	5.72	8.61	3.27	BDL	12.74	BDL	BDL	BDL
9	1.32	28.54	3.24	6.68	0.96	BDL	12.56	BDL	BDL	44.00
10	4.67	11.96	65.30	16.00	5.06	1.56	16.14	0.03	0.05	BDL

Source: Soil studies, 2008

Table 6: Concentration of heavy metals in the soils after remediation (mg/Kg)

	After remediation									
Sites	Pb	Zn	Cu	Cr	Co	Cd	Ni	Hg	As	Ba
1	1.25	17.93	8.64	BDL	BDL	BDL	BDL	BDL	BDL	BDL
2	0.26	10.04	9.35	0.56	BDL	BDL	BDL	BDL	BDL	BDL
3	0.79	22.62	9.12	0.53	BDL	BDL	1.15	BDL	BDL	BDL
4	1.16	30.11	14.70	BDL	BDL	BDL	BDL	BDL	BDL	61.05
5	2.31	86.80	4.05	0.87	BDL	BDL	1.86	BDL	0.001	45.21
6	16.70	2.76	1.40	BDL	0.576	BDL	5.00	BDL	BDL	BDL
7	0.12	28.15	2.34	1.68	1.07	BDL	BDL	BDL	BDL	BDL
8	3.40	4.51	3.88	0.58	BDL	BDL	2.45	BDL	BDL	75.00
9	0.21	23.70	1.59	0.71	BDL	BDL	1.16	BDL	BDL	BDL
10	8.60		12.65	0.87	0.464	BDL	3.34	BDL	BDL	17.27

Source: Soil studies, 2008

most of their values below detection limit after land farming. It confirmed the fact that microbe s play a crucial role in the reduction of heavy metal concentrations in soils. Some of the increases in the heavy metal levels after land farming could be attributed to Heavy metal concentration, a problem associated with most bio-degradation technique of soil decontamination of hydrocarbon contaminated soils. The results of the heavy metal analysis before and after land farming are shown in Table 5.

CONCLUSION

Degradation of petroleum hydrocarbons in poorly drained soils and aquatic systems had not been given much attention in Nigeria. Thus, this study discovered a general reduction in the total hydrocarbon concentration in the various soil samples after land farming. However, some of the Heavy metal values recorded after land farming was observed to have increased. The hydrocarbon concentration levels of the well-drained soils (upland) were observed to be lower than that of poorly drained or waterlogged soils of the swamp areas; this could probably be attributed to the terrain as excessive moisture reduces the available oxygen for aerobic bacteria activity.

High soil acidity was also discovered as an inhibiting factor in the activities of soil microbes in breaking down hydrocarbons levels. Also, microbial metabolism is inhibited by low nutrient level which is basically the case for poorly drained Niger Delta soils. All these environmental factors were discovered as limiting factors to the land farming effectiveness in the Niger Delta region. Despite these limitations, experience has proven that land farming, if properly performed, is an effective method for the removal of hydrocarbons from affected soils especially the lighter hydrocarbons. However, a great deal of available land and time can be required to accomplish hydrocarbon destruction. Also, the effectiveness of land farming is highly dependent on site-specific conditions. As mentioned previously, physical and chemical soil properties, sites hydrogeology, ambient temperature, and a variety of other factors influence the effectiveness of land farming.

Also, Land farming may not be used to treat soils with hydrocarbon levels of more than 50,000 ppm. In addition, no standard procedure is available for determining the allowable loading of land farms and the time required for biodegradation of the petroleum compounds in the soil. This lack of procedure makes many land farming operations to become a trial and error procedure with no assurances that the design will be successful in remediating the contaminated soil. However, land farming could still be used for sites in the upland area of the Niger Delta since they are better drained and easily accessible.

Finally, the study discovered that though Land Farming is an economical bioremediation technique for polluted soils, its' efficacy depends on the nature of the soil. It is more efficacious in well drained soils than in moist soils. Thus in the Niger Delta, where most of the soils are poorly drained, the application of Land farming as a remediation technique may be limited especially when it has to do with recalcitrant hydrocarbon compounds. However, as the study has shown, land farming can be applied as remediation technique to deal with hydrocarbon pollution on well drained soils in the Niger Delta and other areas of the world with similar problem of hydrocarbon pollution.

ACKNOWLEDGMENT

The author wishes to acknowledge the contributions of my post graduate student at Enugu State University of Science and Technology-Ochuba Augusta for assisting in providing useful data for this study. Am also indebted to other authors whose works are cited in this study.

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