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Crude Oil Polluted Niger Delta Environment: Conservation Techniques for Survival

Ebiye Asuka[1*], Oku Hyginus O[2], Alexander Chinago B[3]

[1]Department of Geograpy and Environmental Management, Ignatius Ajuru University of Education, Rumuorlumeni, Port Harcourt, Nigeria
[2]Department of Geograpy and Environmental Management, Ignatius Ajuru University of Education, Rumuorlumeni, Port Harcourt, Nigeria
[3]Department of Transportation Planning and Logistics, Captain Elechi Amadi Polytechnic, Port Harcourt, Nigeria

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***Corresponding author:** Ebiye Asuka

Abstract

The environment is the home of man, and anything that affects it affects man. In exploration of crude oil in the Niger delta of Nigeria, there is abundant risk to man and his environment. From inception of crude oil exploration in Niger Delta in 1956 till date the soil, river, animals, fishes, man and the environment has suffered terribly as a result of on form of pollution or another. It has been observed among other things that the release of crude oil and refined petroleum products in terrestrial and aquatic environment results in long term threat to all forms of life. It has also been observed that the presence of crude oil and spent lubricating oil in the soil adversely affects the physical, chemical and microbiological properties of the soil. It has also been discovered that crude oil affect the germination, maturity and growth of crops. Crude pollution also destroys aquatic lives and incapacitates flying creatures. Majority of Niger Deltans depend on agriculture, therefore to survive there must be a conservation and remediation techniques. This work discovered that the most effective remediation techniques that can be used in the Niger Delta region include organic treatments and inorganic treatment. The available types of remediation include Physiochemical processes, Thermal processes, and Biological processes, Biodegradation, Bioremediation and Phytoremediation. The aforementioned remediation techniques will go a long way to improve the environment. However, the best form of oil exploration in Niger delta should be the one with zero pollution tolerance.

Keyword: Contaminated soil, Crude oil, Niger delta, Oil pollution. Remediation and soil fertility.

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1.0: INTRODUCTION

Environmental problems can be classified into two – the natural and the anthropogenic. The natural factors include – Soil wash and sheet erosion, Coastal erosion and Marine erosion, Flooding, particularly coastal flooding and river flooding, Drought and desertification. While the Anthropogenic factor are – Oil pollution, oil well blow-outs and other associated discharges, Overpopulation and squatter settlement, Industrial waste, water, soil and air pollution, Urban waste, non-biodegradable waste and used oil, International waste dumping, Biodiversity loss, etc. This work concern itself with remediation of oil pollution which has and is devastating the fragile oil rich region of Nigeria, the Niger Delta region (Chinago, 2021).

Oil pollution is a worldwide threat to the environment and the remediation of oil-contaminated soils, sediments and water is a major challenge for environmental research (Chorom *et al.*, 2010).

The Niger Delta region is the Centre of petroleum production and development activities in Nigeria. The region consists of 9 oil producing states (Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Ondo, Imo and Rivers (Okonkwo *et al.*, 2015). The region is endowed with large oil and gas reserves, hence oil exploration and exploitation has been on-going for several decades in the region. The first commercial oil discovery in the Niger delta was confirmed at Oloibiri oil field in the then Rivers State, now Bayelsa State, in January 1956 by Shell D'Arcy (later Shell–British Petroleum) and a second oil field was later discovered at Afam in Rivers State (Vassiliou, 2009). In February 1958, Shell British Petroleum started exporting crude oil produced from Oloibiri and Afam oil fields in Port Harcourt (Aniefiok *et al.,* 2013). Since then other oil wells were discovered in the region and were/are still being exploited by other multinational oil companies such as Mobil, Elf, Chevron, Agip, etc.

The oil industry has contributed immensely to the growth and development of Nigeria's economy. However unsustainable oil exploration activities has rendered the Niger Delta region one of the five most severely petroleum damaged ecosystems in the world (Anifowose, 2008). Studies have shown that the quantity of oil spilled over 50 years as a result of oil related activities in the Niger Delta was a least 9-13 million barrels, which is equivalent to 50 Exxon Valdez spills (Federal Ministry of Environment Abuja, 2006).

Oil spill incidents have occurred in various parts and at different times in the Niger Delta's aquatic and terrestrial environments. These spills have been associated with sabotage, corrosion of pipes, carelessness during oil production and oil tanker accidents (Nwilo and Badejo, 2005). The release of crude oil and refined petroleum products in the terrestrial and aquatic environments result in a long term threat to all forms of life (Balba *et al.,* 1998).

Oil drilling in or near mangrove shorelines has significant adverse environmental impacts. Mangrove forests are well known for their vulnerability to oil spills since floating oil settles with the tide and smothers both breathing and feeder roots. The spills also knock - off resident micro-organisms responsible for fertility of soil (Okpokwasili and Amanchukwu, 1988).

Soil fertility may be defined as the capacity of the soil to support the growth of plants on sustained basis under given conditions of climate and other relevant properties of land (Aina and Adedipe, 1991). Loss of soil fertility through loss of soil organic matter, leaching of nutrients, loss of the nutrient-laden topsoil, changes in soil-pH, reduction in cation exchange capacity, salinization, water logging and other forms of soil degradation are major problems associated with agricultural productivity in the oil producing areas of Nigeria.

In a study conducted for NEST/Ford Foundation in the Niger Delta, NDES (1999), reported that soil fertility loss and declining crop yield, among others, were of "high priority" because these were found to be indirect sources of pressure on natural resources and community structure, especially amongst the poor. The reality of these and other socio-economic effects in areas where oil pollution has already taken place, and their anticipation in areas prone to experience oil spill, have continued to provoke concern in the Niger Delta region.

Many studies have investigated the environmental pollution in the Niger Delta yet the pollution problems continue to occur and very little clean up takes place (Sojinu *et al.*, 2010). The result is that more and more farmland is being lost to oil pollution incidents. It is not an overstatement to say that delays to and inadequate clean-up has aggravated environmental damages and peoples' human rights especially their right to health, water, food and livelihood (Gaughram, 2013).

2.0: Effect of Crude Oil Pollution on Soil

Baker (1976), in the study of marine ecology pollution found out that, the presence of crude oil and spent lubricating oil in the soil adversely affected the physical, chemical and microbiological properties of the soil. In relation to the findings of Baker, Kayode *et al.* (2009), evaluating the effect of pollution with spent lubricating oil on the physical and chemical properties soil, also confirmed same.

Amadi *et al.* (1993), in the study of the effects of original inorganic nutrient supplement on the performance of maize in oil polluted soil further confirmed that because the physical, chemical and microbiological properties of crude oil polluted soil is adversely affected, these in turn affect the germination of crop seeds and impede on the growth of cultivated crops. This was also supported by Dejong (1980), in the study of the effect of crude oil spill on cereals.

The effect of crude oil and spend lubricating oil pollution on soil properties and growth of plant is dependent on their concentrations in a given soil. Beyond 3% concentration, these oils have been reported to be increasingly detrimental to the functional ability of the soil and plant growth (Ekundaya *et al*., 1989; Chukwu and Udoh, 2014).

Alloway and Ayres (1979), Ebong *et al*. (2007) and Kayode *et al*. (2009), in their respective studies also opined that soil pollution with crude oil and spent lubricating oil destroys soil structure, increased bulk density, soil porosity reduction in soil capillary, aeration and nutrients availability and uptake by plants.

Shukry *et al.* (2013), in their study of the effect of petroleum crude oil on mineral nutrient elements, soil properties and bacterial biomass of the rhizosphere of Jojoba, revealed that "malondialdehyde (MDA) concentration increased in jojoba leaves when grown in petroleum oil polluted soil especially at 2% and 3% crude oil. And that, Na, Mg and Ca decreased while K increased in shoots of jojoba. In roots Na and Ca increased however K and Mg decreased with increasing crude oil concentration in the soil. Heavy metals, Cu, Mn, Cd and Pb increased in both shoot and root with increasing crude oil concentration while, Zn decreased comparing with the control. In soil, N and K decreased meanwhile Cu, Fe, Mn and Zn as well as organic matter increased with increasing crude oil concentration. Soil was free from P while, the addition of inorganic fertilizers improved P content. Bacterial account was significantly increased at the end of the experiment at 1% and 2% crude oil especially after addition of inorganic fertilizers. The electric conductivity and MDA of the leaves increased with increasing crude oil concentration.

The addition of inorganic fertilizers to crude oil contaminated soil decreased the electric conductivity and MDA comparing with crude oil only".

They concluded that the observed changes in composition of mineral elements in jojoba plants could be attributed to the cell injury and disruption in the cell membrane, heavy metal accumulation and toxic nature of the petroleum oil. And that soil contaminated with crude oil has a highly significant effect of reducing some mineral element composition of Jojoba plants.

Uquetan *et al.* (2017), in the study of the effect of oil pollution on soil properties and growth of tree crops in Cross River State, Nigeria. The effects of crude oil and spent lubricating oil on germination of cocoa, pawpaw and mango seeds were tested. The results revealed that the germination rate in unpolluted soil was higher than soil samples treated with crude oil and spent lubricating oil. The effect increased as concentration of treatment increases. The reduced germination is adduced to the fact that volatile fractions of oil could enter the seed coat and induce unfavourable conditions for seeds germination. Also soils polluted with crude oil and spent lubricating oil show poor wettability, reduced aeration and compaction and increased propensity to heavy metal accumulation. These observations are in agreement with Udo and Fayemi (1995), Kayode *et al*., (2009), Osuji and Nwonye (2007).

Uquetan *et al.*, further revealed that in terms of growth, normal luxuriant growth occurred at the control and while in the polluted soils plant growth was a function of the degree of pollution in each treatment level. This finding is in agreement with Udo and Fayemi (1975), Toogood and Rowell (1997), Odu (1978), Amakin and Onofegha (1983) and Asuquo *et al*., (2001), who maintained that seedling growth rate is a function of the treatment concentration. The differential growth retardation may be due to impaired transpiration and photosynthesis, poor aeration and root penetration.

In terms of physiochemical properties, they also revealed that the results on mechanical analysis of soil suggested that the effect of crude oil and spent lubricating oil on soil texture resulted in a slight increase in the silt content as compared to the control due to compaction of soil particles. The redox potential decreased markedly in lower treatment concentrations.

They concluded that, the agricultural use and management of soil is largely dependent on the characteristics and qualities of the soil. And that oil pollution had significant influence on soil properties and crop growth which render such soils temporarily unsuitable for cropping for some time before being degraded. Oil pollution increases soil organic carbon, total nitrogen and total hydrocarbon. Available phosphorus, exchangeable K+, Na+, Ca2+ and ECEC decreases with increase in treatment concentration. Heavy metals in the soil were highly variable as Fe, Mn, Pb contents were increased as treatment concentration increases. Oil pollution had a depressing effect on Cd. To minimize this problem, liming, fertilization, enhanced ploughing and harrowing are recommended. Farmers are advised not to cultivate an oil polluted soils until remediation processes are carried out on the land.

2.1: Application of Organic Treatment on Crude Oil Polluted/Contaminated Soil in Nigerian

Roling *et al*. (2002), examined bacterial dynamics and crude oil degradation after nutrient amendment and found out that the nutrient enhancement increased bacterial counts which impacted significantly with hydrocarbon attenuation.

Adekunle (2011), investigating bioremediation of soil contaminated with Nigerian petroleum products (5% v/w) of spent engine oil, using composted municipal waste, used plant height to assess the toxicity of oil to germination of maize found out that there was difference in height between the treated soil and the control (soil without oil or compost). The experiment lasted for 90 days. She pointed out that plant height in the control was 33.8 cm within one week of germination and 46.7 cm in the second week. While the plants grown in diesel contaminated soil, treated with compost recorded only 7.6 cm in the first week and 38 cm on day 14. This shows that the level of toxicity reduces with time as the treatment is applied of the oil contaminated soil. And that toxicity of petroleum product on plants' height could vary, depending on different factors like type of oil, climatic conditions, treatment, planting period as well as species of plant.

Similarly, Chindo (2014), using Compost to Reduce Oil Contamination in Soils, investigated the ability of compost to improve the fertility of the Nigeria crude oil contaminated soil, using tomatoes to determine seedling germination. He revealed that "germination of seeds without the addition of compost was adversely affected by the oil pollution. There was total inhibition to growth at initial 10% oil level

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suggesting that 10% oil concentration is above the trigger level for plant growth. The addition of compost diluted the contamination levels producing approximately 50% increase in overall germination observed within 5 weeks. Plants grew in soil with the least diluted content of 7.5% oil level. Soils treated with compost recorded higher biomass yields compared to those not treated with compost. This suggests that compost improved the quality of contaminated soils and sustained the yield of tomatoes seeds".

He also revealed that there was a marked decrease with time in the percentage of total petroleum hydrocarbon (TPH) in all the soil samples. The percentage removal was lowest in crude oil contaminated soils without addition of compost. After five weeks of bioremediation, the percentage reductions for Soil at 5%, Soil 7.5% and Soil 10% oil level without addition of compost were 30%, 39% and 32% respectively. While the TPH analysis for the test conditions using Niger Delta soil with 50% Compost at 5%, 7.5% and 10% oil levels were 34, 62 and 86% respectively.

He further revealed that, the addition of compost improved the degradation of n-alkane and more specifically the fraction C_{21} to C_{25}. This is seen as a welcome development since the Nigeria Bonny light crude oil, comprises approximately 57% n-alkanes.

Chindo (2014), concluded that the use of compost, as a bioremediation material for treatment of crude oil contaminated soil is a cheaper option. This is against the background that given the cost of and accessibility to inorganic fertilizers especially in Nigeria when compared to the abundance of biodegradable material for composting.

Obiakalaije *et al*. (2015), in the study of crude oil contaminated soil from Isaka mangrove in Okirika local government area of Rivers state, pointed out that the crude oil contaminated soil was treated with three different organic wastes (goat manure, poultry droppings and cow dung), for a period of 28 days. They revealed that, the total heterotrophic bacterial count and hydrocarbon utilizing bacteria counts in all soil samples amended with various waste were higher compared to counts for unamended soil. This could be attributed to the presence of appreciable quantities of nitrogen and phosphorous in animal waste, two necessary nutrients for bacterial biodegradation activities. And also, the presence of indigenous microorganisms in the animal waste could also be responsible for the higher total heterotrophic and hydrocarbon utilizing fungal counts in amended samples. They also observed that the total heterotrophic bacteria, total hydrocarbon utilizing bacteria, total heterotrophic fungi and total hydrocarbon utilizing fungi increased with time during the study. This resulted in a corresponding removal of hydrocarbon with time particularly in the nutrient amended samples.

Soil amended with goat manure had the highest total heterotrophic bacterial count of 3.09x106cfu/g, followed by poultry droppings which had a count of 2.69x106cfu/g on the 28th day.

They further revealed that bacteria isolated from study were mainly gram negative bacteria. This is in agreement with the findings of Kaplan and Kitts (2004) that oil polluted soils are dominated by gram negative bacteria. While the hydrocarbon utilizing fungi isolated from the study were *Aspergillus, Candida, Rhizopus, Fusarium, Mucor, Penicillium, Rhodotorula*and*Aspergillus* species. In aquatic environments of petroleum producing area of Nigeria, *Candida, Rhodotorula, Saccharomyces, Sparobolomyces, Aspergillusniger, A.terreus, Blastomyces* sp., *Botryodipodiatheobromas, Fusarium* sp., *Nigrospora* sp., *Penicilliumchrysogenum, P.glabrum, Pleurofragmium*sp. And *Trichodermaharzaianum* are the major hydrocarbon utilizing fungi usually isolated (Obire, 1988).

They concluded that, the results of this study showed that contaminated soil amended with goat manure, poultry droppings, cow dung and the control sample showed 87.1%, 78.6%, 70.7% and 32.1% loss in total petroleum hydrocarbon respectively. Contaminated soil amended with goat manure showed the highest percentage total petroleum hydrocarbon loss. And that, amendment of the crude oil polluted soil with the various organic waste stimulated higher microbial proliferation in soil.

2.2: Application of Inorganic Treatment on Crude Oil Polluted/Contaminated Soil in Nigeria

Ebuehi *et al*. (2005), in the study of remediation of crude oil contaminated soil by Enhanced Natural Attenuation technique, used a farmland settlement contaminated with crude oil located in Rumuekpe, Rivers State, Nigeria, for the study. Remediation by enhanced natural attenuation (RENA) is a land farming treatment technology for intervention in petroleum hydrocarbon contaminated soils in the Niger Delta regions (Odeyemi and Ogunseitan, 1985). The test soil obtained was sandy soil. The preliminary process of bioremediation took a period of 10weeks. The bioremediation process comprises field experiment and laboratory simulation, with some physiochemical and microbial analyses. Soil sample was taken from a depth of 0.30metres. The concentration of total petroleum hydrocarbon (TPH), nitrogen and phosphorus were determined, while the total heterotrophic bacteria (THB) and total hydrocarbon utilizing bacteria (THUB) were committed. These physiochemical parameters were monitored once every two weeks for a period of 10weeks.

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According to Ebuehi *et al.* (2005), the following Remediation by Enhanced Natural Attenuation (RENA) techniques were employed to treat the contaminated farmland.

2.2.1: Spiking of Test Soils

The soils were spiked with water uniformly to soften the soil and to allow the water penetrate the soil matrix.

2.2.2: Initial Tilling

The soils were tilled in a week after they were spiked, that is mixing the soil and breaking the lumps. This was done using shovel, composite samples were collected and sent to the laboratory for physiochemical and microbial evaluation.

2.2.3: Secondary Tilling

The soils were tilled and homogenized a week after the initial tilling. The lumps were broken to very fine particles with a shovel and a rake. The essence of the tilling and homogenization was to uniformly distribute the petroleum contaminants and break up the soil lumps to fine particles thereby increasing the surface area. The composite samples were taken for analysis.

2.2.4: Windrow Construction

Windrows/ridges were constructed after the secondary tilling of the test site. The ridges measured about 2feet high and 4feet wide. The windrows are made to achieve better aeration and optimize the efficiency of the attenuated processes in action, which exposes the microorganisms to oxygen, and aids in the biodegradation process of the petroleum hydrocarbon. Soil samples were taken for analysis.

2.2.5: Breaking down of Windrows

The windows broken down, after standing for between three (3) and four (4) weeks, after construction. Soil samples were taken for analysis.

2.2.6: Addition of Water

Water was added to the sandy soil to enhance the biodegradation of the petroleum hydrocarbons by the microorganisms when it penetrates the soil.

2.2.7: Addition of Fertilizer

Fertilizer application was done manually by sprinkling the fertilizer over the contaminated area. The process enhances the biodegradation of the petroleum hydrocarbon.

They revealed that the RENA technique is a very effective way of carrying out bioremediation, which helps soils, contaminated with crude oil reach the ALARP condition. This is a point reached, where no significant breakdown or reduction in the concentration of the contaminant can be achieved economically and sustainably. They also revealed that TPH degradation was successful since there was significant reduction in TPH population during the bioremediation process, which showed little or no contamination. And also that the THUB increased until there was no more contamination before a reduction, showing that the hydrocarbon-utilizing bacteria had now migrated to other soil locations since it feeds on petroleum hydrocarbon. They also indicated that the reduction of nitrogen and phosphate in relation to reduction in TPH indicate that nitrogen and phosphorus concentration can be used as fertilizers to the microbes that also use them to degrade the petroleum hydrocarbons. They further revealed that the accelerated growth of THUB during the bioremediation process is indicative of the ability of indigenous microorganisms to adapt to the presence of the contaminants and bring about their transformation to reduce levels of contamination in the soil. And that the reduction in the concentration of petroleum hydrocarbon contaminant from a crude oil polluted farm site depends on the interplay of biotic and abiotic factors.

They concluded that the manipulation of these factors during remediation enhanced natural attenuation (RENA) process brought about a marked reduction in the concentration of the contaminant after which the ALARP level is reached.

Ayotamuno *et al.* (2006) carried out bioremediation of a crude oil polluted agricultural soil in Port Harcourt for a period of six weeks, reported a range of 50 to 95% reduction in degradation of total hydrocarbon (THC) content of crude oil polluted soil, treated with different amount of mineral fertilizer.

Chorom *et al.* (2010), evaluated bioremediation of a crude oil - polluted soil by application of fertilizers. The bioremediation consist of strategy of actively aerating the soils and adding fertilizer in order to promote oil biodegradation by indigenous microorganisms. The objective of their study was to investigate whether agricultural fertilizers (N, P, K) enhance the microbial degradation of petroleum hydrocarbons in soil. The crude-oil polluted soil was divided into 3 treatment sample-containers, which were extending horizontally 40 cm × 40 cm and of depth 30 cm. The 9 containers were such that the depth and exposed surface-area of the soil, and in turn its temperature, nutrient concentration, moisture content and oxygen availability, could be controlled. Three containers did not receive any treatment (control); in 6 containers with 5 Kg crude-oil soil, 4 g and 8 g of 20–10–10 NPK fertilizer were applied, respectively, twice during the remediation period, i.e. at two-week intervals. Thus, the equivalent of 1 and 2 ton/ha of fertilizers were applied. The treatment soils were kept under controlled humidity 60 percent of F.C. (field capacity), and temperature condition (30ºC), to create appropriate environment for the activity of crude-oil decomposing microorganisms. In order to remove the effect of the lack of oxygen and preparing aerobic soils conditions, the soils were mixed twice per week by shovel for 5 up to 10 weeks. Soil sample were analysed for hydrocarbon-degrading heterophic bacteria count and some soil chemical properties. Residual oil was measured by oil soxhlet extraction method, and gas chromatography.

They then revealed from the results obtained that the hydrocarbon-degrading and heterotrophic bacteria count in all the treatments increased with time and heterotrophic bacteria population increased from 6×10^3 cfu/g soil to 1.4×10^8 cfu/g soil. Also, soil C/N ratio decreased from 6 to 3. The results indicated that the applied fertilizer increased the degradation of the hydrocarbons compared with the control. Gas chromatography results showed that normal paraffin and isopernoid (Phitane and Pristane) decreased in the range of 45 to 60 percent in all treatments. Furthermore, the results showed that the application of fertilizers at 2 ton/ha rate in oil-contaminated soil lead to greater rates of biodegradation after 5 weeks indicating the feasibility of bioremediation.

Agarry and Ogunleye (2012a), studied enhanced bioremediation of soil artificially contaminated with spent engine oil ex situ. Inorganic NPK fertilizer and non-ionic surfactant concentration were used as independent bio-stimulation variables with the primary objective evaluating total petroleum hydrocarbon (TPH) reduction as dependent variables. After 42 days, there was a 67.20% reduction in TPH concentration. Using numerical optimization technique based on desirability function, they revealed the optimum values for bio-stimulation agent studied to achieve 67.20% degradation of TPH was 4.22g and 10.69ug/g for NPK and non-ionic surfactant respectively. Furthermore, Agarry *et al.* (2012), using kerosene as source of TPH and inorganic NPK (4.30g) as source of nutrients, obtained total petroleum hydrocarbon degradation of 75.06%. The better performance of NPK in reducing TPH in kerosene contaminated soil when compared to spent engine oil contaminated soil was probably due to the presence of lighter chains of hydrocarbons in the latter as revealed by chromatographic results.

In the light of the above, this study will review the various methods of remediation of the Nigerian crude oil impacted soils/sediments, with more emphasis on the application of organic / inorganic treatment, a form of bioremediation.

3.0: remediation of soil /sediment polluted with organic pollutants

Remediation methods are available to decontaminate the soils/sediments with slowly degradable and/or toxic organic pollutants. The chemicals like petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), volatile organic hydrocarbons (benzene, toluene, ethylbenzene, xylenes (BTEX), phenolic compounds, cyanides, and chlorinated compounds such as polychlorinated biphenyls (PCB), pentachlorophenol (PCP), volatile halogenated hyfrocarbons, chlorinated pesticides, polychlorinated dibenzodioxins (PCDD), polychlorinated dibenzofurans (PCDF) and organosynthetic pesticides can be removed from the contaminated soil through different remediation methods (Mohapatra, 2006).

3.1: TYPES OF REMEDIATION

There are four steps involved in the remediation of any contaminated site. These include:

1. A preliminary assessment: This involves the identification of those conditions at a site that pose an imminent threat to human health and the environment.
2. Selection and implementation of appropriate interim remedial measures: It addresses any imminent hazards that may exist at a site.
3. Site investigation and remediation technology feasibility study: In this stage the nature and extent of contamination are defined, and potential final remedial methods are identified and evaluated.
4. Selection of final remedial methods: Selection processes are taken into account based on results of the site investigation, including effectiveness of different remedial methods, the time necessary for complete clean-up and the overall treatment cost (Cutright and Lee, 1994; Colleran, 1997).

There are two major types of soil treatment: *In situ* (where the soil is treated at the site of contamination) and *ex situ* (in which case the soil is excavated and transported to another site for treatment).

3.2: Physico-Chemical Processes for Remediation (Clean Up) of Crude Oil Contaminated Soil/Sediments

3.2.1: Soil Excavation

This is the mechanical removal of contaminated soils to off- sites either for burying or burning. The process is however very expensive as a contractor has to be hired to take away a layer of ground. Another problem with excavation is that the place from which the layer is removed is made prone to erosion and other environment damaging agents (Araruna *et al*., 2004).

3.2.2: Soil Washing

Soil washing is an *ex situ* treatment process applicable to a broad range of organic, inorganic and radioactive contaminants in soil (Anderson, 1993). It involves the use of liquid/ water sometimes combined

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with chemical additives and a mechanical instrument to scrub soils. This removes hazardous contaminants and concentrates them into smaller volumes (Wood, 2002).

Hazardous chemicals easily adhere to silt and clay unlike sand and gravel particles. During soil washing therefore, the silt and clay are mechanically separated from the uncontaminated coarse soils (Wood, 2002). The contaminated fine sand can then be disposed or treated accordingly while the coarse sand is retained as backfill. The effectiveness of this method has been shown to be less than 80% though efficiency increases when hot water is used (Wood, 2002). It is therefore mostly used as a pre-treatment method for final cleaning up of soils / sediments.

3.2.3: Soil Vapour Extraction (SVE)

This method is a relatively simple physical process of cleaning up crude oil contaminated soils/sedimens. SVE is a physical treatment process for in situ remediation of volatile contaminants in vadose zone (unsaturated) soils (EPA, 2012). SVE also referred to as in situ venting or vaccum extraction. This is based on mass transfer of contaminants from solid (sorbed) and liquid (aqueous or non-aqueous) phases into the gas phase, with subsequent collection of the gas phase contamination at extraction wells. Extracted contaminant mass in the gas phase (and any condensed liquid phase) is treated in aboveground system. In essence, SVE is the vadose zone equivalent of the pump-and-treat technology for ground water remediation (Wikipedia, 2018).

The process of SVE is carried out by applying a vacuum through a system of underground wells which pull up contaminants to the surface as vapour or gas. Air is sometimes introduced to enhance the process. Soil vapour extraction is frequently used to remove chlorinated hydrocarbons, especially trichloroethylene (TCE) from the soil (Imamura *et al*., 1997).

4.0: Thermal Processes for Remediation (Clean Up) of Crude Oil Contaminated Soil/Sediments

4.1: Thermal Desorption

This is a more recent clean up method. It involves heating up crude oil contaminated soils to temperatures of 200- 1000°F at which contaminants with low boiling point vapourize and desorb (physically separate) from the soil ((Troxler *et al*., 1994; Elgibaly, 1999). This method is also termed Low Temperature Thermal Desorption or Low Temperature Thermal Volatilization, due to its use of low temperature. It is also called thermal stripping or soil roasting (Anderson, 1993).

Most times during thermal desorption, contaminating hydrocarbons are vapourized and ignited. The remaining by-products are removed from the system by convection and treated by filters or second stage re-ignition or by an air emission treatment system (Wood, 2002). On the other hand, they can generally be treated in a secondary treatment unit (e.g. after burner, catalytic oxidation chamber, condenser or carbon adsorption unit) prior to discharge to the atmosphere. After burners and oxidizers destroy the organic constituents while condensers and carbon adsorption units trap organic compounds for subsequent treatment or disposal. Depending on the organics present and the temperature of the desorper system, thermal desorpers can cause complete or partial decomposition of some of the organic constituents (Anderson, 1993; Troxler *et al*., 1994). Afterwards, soil is cooled, remoistened for dust control and stabilized to prepare them for disposal/reuse by depositing them on-site or as landfill covers to be incorporated into asphalt (Anderson, 1993).

Up to 90% efficiency has been recorded with thermal desorption in removal of crude oil hydrocarbon contaminants from soils. Thermal desorption has three major pitfalls. It is expensive, time consuming and hazardous (Wood, 2002). However, thermal desorption seems to be a very promising method for cleaning up crude oil contaminated soil because it is simple and avoids all the difficulties associated with digging up the soil for disposal or cleanup (Elgibaly, 1999).

4.1.1: Incineration

This implies burning off the contaminants from the soil surface using fire. According to US EPA, at high temperatures (i.e. between 1,600°F and 2,500°F) incineration takes place, and hazardous wastes including crude oil are destroyed from the soil and toxic elements are reduced to basic elements (mainly hydrogen, carbon, chlorine and nitrogen). The basic elements then combine with oxygen to form stable non-toxic substances such as water, carbon dioxide and nitrogen oxides.

Contaminated soils are normally first excavated and carried to off-site facilities before incineration is effected (Bassam and Battikhi, 2005). Disadvantages of incineration include: high operational cost due to high energy requirement, the large space involved and the dangers of environmental pollution (Araruna *et al*., 2004; Bassam and Battikhi, 2005).

4.2: Biological Processes for Remediation (Clean Up) of Crude Oil Contaminated Soil/Sediments

Biological treatment involves the use of microorganisms, plants and other biological systems to clean-up oil contaminated soil. Biological processes are used to treat excavated soils, saturated and unsaturated soil *in situ*, and recovered ground water (Eckenfelder and Norris, 1993).

4.3: Microbial Degradation of Crude Oil (Biodegradation)

Biodegradation of organic waste is an increasingly important method of waste treatment (Atlas, 1981). Biodegradation has many advantages; it uses inexpensive equipment, environmentally friendly nature of the process and simplicity (Nadean *et al*., 1993).

Microorganisms play an important role in the clean-up of crude oil contaminated environment. The use of microorganisms in the clean-up of an oil spill comes in after a large amount of the oil has been removed by various physical and chemical methods (Okpokwasili and Amanchukwu, 1988).

Microbial degradation is made possible because microorganisms have enzymatic systems that breakdown the crude oil, utilizing it as a source of carbon and energy (Ijah and Antai, 1988; Antai and Mgbomo, 1989).

Microorganisms capable of utilizing petroleum hydrocarbons in their metabolism are widely distributed in soils. They are mostly found in the surface soil in the vicinity of an oil field and also in petroleum-contaminated soils (Bossert and Bartha 1984; Antai and Mgbomo 1989). Crude oil degrading microorganisms have been identified and include bacteria, yeast, filamentous fungi and algae (Atlas, 1981; Ezeji *et al*. 2005). The major bacteria genera implicated in crude oil degradation in both soil and aquatic environments comprise mainly *Pseudomona*s, *Achromobacter*, *Athrobacte*r, *Actinomycetes*, *Flavobacterium*, *Micrococcus* and *Nocardia* (Atlas 1981; Bossert and Bartha 1984; Okpokwasili and Nnubia 1999).

However, microbial degradation does not always lead to complete disappearance of oil constituents (Wardly-Smith, 1983).

4.4: Bioremediation

Bioremediation is the act of adding fertilizers or other materials to the contaminated environment such as oil spill sites, to accelerate the natural biodegradation process. Bioremediation of petroleum-contaminated soil is adopted principally to improve the bio-physicochemical properties of soil through the augmentation of soil nutrients in order to stimulate growth and multiplication of indigenous micro-flora (Dragun, 1993; Holiday and Deuel 1993).

Bioremediation is considered one of the most promising methods for dealing with a wide range of organic contaminants, particularly petroleum hydrocarbons (Balba 1993). Two basic methods are available for obtaining microorganisms to initiate the bioremediation: bio-augmentation in which adapted genetically coded toxicant degrading microorganisms are added (Okpokwasili *et al*. 1986) and bio-stimulation which involves the injection of necessary nutrients to stimulate the growth of indigenous microorganisms (Lee and Levy, 1991). A combination of bio-augmentation and bio- stimulation with indigenous hydrocarbon utilizers would be effective in the remediation of crude oil polluted tropical soils (Odokuma and Dickson, 2003).

A wide range of bioremediation strategies is being developed to treat contaminated soil. Selecting the most appropriate strategy to treat a specific site can be guided by considering three basic principles: the amenability of the pollutant to biological transformation to less toxic product (biochemistry); the accessibility of the contaminant to microorganisms (bioavailability); and the optimization of biological activity (bioactivity) (Ezeji *et al*., 2007).

Some large scale bioremediation technologies used in treatment of contaminated soils include windrowing, bio-piling, bio-venting, land farming and composting. Windrow techniques are constructed by mixing the contaminated soils with the composting material and placed in elongated piles. Bio-pile involves the construction of soil piles above ground with the contaminated soils placed within the bund area. The piles are aerated using air injection or vacuum extraction to either push or pull air through the piles to ensure the transfer of oxygen and therefore aerobic degradation of the organic contaminants. Bio-venting combines the capabilities of soil venting and enhanced bioremediation to cost-effectively remove light and middle distillate hydrocarbons from vadose zone soils and the groundwater table. Soil venting removes the more volatile fuel components from unsaturated soil and promotes aerobic biodegradation by driving large volumes of air into the subsurface (Hinchee and Arthur 1991). Land farming is a well-known biological method used in the treatment of petroleum hydrocarbon contaminated soil. The system involves periodic tiling of the ground to induce aeration, controlled moisture content and addition of nutrients to enhance microbial degradation of the contaminants. The contaminated soil is excavated onto a designed lined bed (to avoid leaching) and mixed with a controlled amount of nutrients and soil additives such as bulking agents (Lodolo *et al*., 2001). Compost bioremediation refers to the use of a biological system of microorganisms in a mature, cured compost to sequester or break down contaminants in water or soil.

Bioremediation has the advantage that polluted soil can be treated at the site without having to move them somewhere else. Bioremediation is a site-specific process and therefore feasibility studies are required before full-scale remediation can be successfully applied (Balba *et al*. 1998).

4.5: Phytoremediation

Phytoremediation refers to the use of vegetative species for *in situ* treatment of land areas polluted by a variety of hazardous substances (Sykes *et al*., 1999). Different types of phytoremediation have been developed. These include: phytoextraction relies on plants natural ability to take up certain substances (such as heavy metals) from the environment and sequester them in their cells until the plant can be harvested. Phytodegradation is a means by which plants convert organic pollutants into a non-toxic form. Phytostabilization is a situation where plants release certain chemicals that make the contaminant less bioavailable and less mobile in the surrounding environment. And phytovolitization is a process through which plants extract pollutants from the soil and then convert them into a gas that can be safely released into the atmosphere (Bentjen, 2002). Attempts have been made to improve the efficacy of phytoremediators through genetic modification. Genes from different sources, including mammals and microorganisms are being introduced into plant species, resulting in the creation of novel classes of phytoremediators that have the ability to extract harmful heavy metals from contaminated soil (Gleba *et al*., 1999).

Phytoremediation is environmentally friendly, visually attractive and more cost effective than conventional remediation methods (US EPA 2001). Moreover, the structure of the soil is highly maintained (Khan *et al*. 2000). A number of studies on the use of vegetation in the treatment of oil contaminated soil have been documented (Lee and Banks, 1993; Shimp *et al*., 1993).

CONCLUSION

Oil pollution is not environmental friendly at all, especially in a fragile humid environment like Niger Delta. The environment is such that the effect of pollution is far felt as a result of the terrain and climate.

Since lot of things can lead to oil pollution in the area, it is important that elementary and cheap means of oil pollution remediation be known and practice. The application of nutrients has widened our knowledge on biological indicators assessment for bioremediation of crude oil contaminated soils/sediments. Bioremediation has long been applied as a remedial technology that is cost effective, ecologically friendly and efficient for the decontamination of crude oil-polluted sediments and soils (Kaplan and Kitts, 2004). It is believed that organic treatment is more cost effective compared to inorganic treatment. However, for foreseeable future, long term tolerance studies are needed before being recommended for large scale use.

It is also evident that a mixture of nutrient sources to form an improved 'diet' source for microorganisms and induced optimum microbial proliferation conferred high biodegradation potential in soils and sediments with high pollutant concentration and also reduced the duration of degradation.

Conclusively, the presence of nutrients in the right quantities is necessary in TPH degradation in contaminated soil/sediment. Also the rate of degradation depended on the concentration of contaminants and the nutrient availability. This can further be improved by exploiting consortia of nutrient sources.

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