

Analysis of Hydrocarbon Pollution in the Soils of Bomu and Yorla Oil Fields, Rivers State, Nigeria

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Abstract

The study investigated the dangers associated with oil exploration and exploitation in the study area. These activities have been on since 1957 in the Niger Delta region. The emphasis on the activities becomes imperative when crude oil takes the centre stage as the most essential commodity in the world. The study sites, Bomu and Yorla oil fields were chosen considering the fact that they are one of the oldest oil fields in the region. The Bomu oil field was commissioned in 1958 and the Yorla in 1973 respectively. Three sites were selected for the study. Two impacted sites (Bomu and Yorla) and a control at Igwuruta-ali in Ikwerre Local Government Area of the state. In each experimental site, soil samples were obtained along transects established from the centre of the impacted soils outwards. The direction of the transect were determined by gradients. Measurement was done in a 10m by 10m quadrat placed at regular interval of 30m along the transect. A total of six (6) quadrats were sampled along each transect of 180m in length. A total of 18 quadrats were sampled including the control. The soil samples were taken from a depth of 0 – 30cm (0 – 15cm, 15 – 30cm). The soil samples were taken to the laboratory to test for Heavy metals and Total hydrocarbon. The results revealed that there was high concentration of heavy metals (Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Copper (Cu), Iron (Fe) and Total hydrocarbon in the soils of control were relatively low compared to the oil fields. The study recommended strongly both physical method of removing petroleum hydrocarbon as well as the phyto-remediation by planting some plant species that has the potential to remediate and restore the contaminated wet-lands (e.g. *calamagrostis angustifolia*).

Keywords: Contaminated Soil, Heavy Metals, Total Hydrocarbon, Quadrats, Transect.

Introduction

Oil exploration and exploitation have been on-going in Nigeria since 1957 and oil is seen as the life blood of modern economy and has now become the most essential commodity in the world. Nigeria cannot survive without oil. Feyide (1986) aptly stated that “oil is a raw material as well as a convenient and effective source of energy. In the form of energy, it increases man’s capacity to get work done. As a raw material, it provides the feedback for the fast expanding industry in the world. All over the world the lives of people are affected and the destinies of nations are probably determined by the results of oil industry operations. Oil keeps the factories of the industrialized nations working and provides the revenue which enable oil exporters to execute ambitious national and economic development plans.

However, the exploitation of this wonderful resource in our environment has some effects.

Oil exploration and production represent prime sources of exposure to petroleum hydrocarbons. Hydrocarbon is an umbrella term used for hundreds of different organic compounds. Hydrocarbon can cause environmental pollution due to their chemical properties (e.g. toxicity) or physical properties (e.g. smothering). In the least damaging scenario, such a small of a volatile hydrocarbon on dry sand, it evaporates fast, causing no chemical or physical damage to the soil. While a spill of heavy crude oil on clay soils, the chemicals can remain within toxicity and lowering or destroying the quality of the soil (Bakpo, 2015).

Contamination of hydrocarbon occurs due to toxic organic substances, petroleum, and pesticide which is a serious concern for the environment. Contamination caused by petroleum hydrocarbon is a matter of worry because these are harmful for various life forms. Crude oil contamination is common due to its extensive use and its related dumping process and accidental discharge. The complex mixture of petroleum consists of heavy metals. Concentration of heavy metal is rising in the soil as a consequence of human action. In the soil total Hydrocarbon content is a measure of oil and grease in the soil emanating from petroleum exploration. Oil and grease are hydrocarbon component that are important environmental pollutant in both terrestrial and marine aquatic environment.

Heavy metals are high density of inorganic chemicals that are essential and toxic to both human and ecological health. Many of the heavy metals are toxic to organisms at low concentration, while some such as Copper, Zinc are essential. They are non-biodegradable. Considering the fact that oil exploration and exploitation in the Bomu and Yorla oil fields stated in 1958 and 1973 respectively, it is evident that the soils of these oil fields will experience serious degradation. It is on this strength that this paper examines hydrocarbon pollution in the soils of these oil fields.

Study Area

Rivers State is located between Latitude $4^{\circ}30'N$ - $5^{\circ}40'N$ and Longitude $6^{\circ}40'E$ - $7^{\circ}20'E$ (OSG, 2014). The state is found in the Niger Delta region of Nigeria, with a total land area of approximately 10378 square kilometers with a total population of 5,198,716 and a population density of 501 persons per square kilometer (NPC, 2006). Generally, the economically exploitable petroleum deposit being lighter and more gaseous, occur within the sandstone shale sequence of the area.

The drainage of Rivers State is synonymous with the drainage of the entire Niger Delta characterized by a maze of waterways, creeks and swamps crisscrossing the relatively low-lying plains. Water is discharged through mostly large and medium-sized natural channels, although rills, rivulet and small perennial streams may be identified. The larger rivers such as Orashi, Otamiri/Imo river system, the Sombreiro, new Calabar river and the coastal creeks often have widths above 100 metres especially at the middle of the lower courses (World Bank 1995).

The state is in the humid tropical belt, which is designated (Af) in Koppen's system of climatic classification. The temperature averages $27^{\circ}C$. The annual range varies from $1^{\circ}C$ to

3°C. Diurnal range is between 6°C and 8°C. Rainfall in the state could be described as seasonally variable and energetic in down pour. Rain occurs every month of the year, but of varying duration (Ede, 1995).



Source: *Niger Delta Atlas*

The soil of Rivers State is formed by the accumulation of sedimentary deposits transported by the Niger Delta and Benue Rivers. By extension the soils are formed from unconsolidated younger sands, highly ferralitic in nature and experience considerable leaching and erosion respectively. Soils of the state are spatial in characters (Isichei and Sandford, 1976). The soil is strongly acidic (pH 4.1 – 4.6) with organic matter and nitrogen content except in low-lying depression which decrease rapidly below the top layer. Plants nutrients are generally low, in these soils, except for a fairly high level of available phosphate. In areas subject to

flooding, the soils are characterized by low organic matter, nitrogen and other nutrients with high potassium. The mangrove soil can be described as dark grey in colour and usually supported mangrove (*Rhizophora racemosa*) vegetation. The soil has saline sands which owe their origin as products of erosion of sand deposits. The soils consist of 75°C sand and low organic matter and nutrient content (Adoki et al 1998).

There are three principal types of vegetation, mangrove swamp forest, fresh water swamp forest and moist or low land rainforest (World Bank, 1995).

Environmental Consequences of Hydrocarbon Pollution

Looking at the environmental consequences of hydrocarbon pollution, it is important to understand that hydrocarbon is the umbrella name used for hundreds of different organic compounds. Hydrocarbon can cause environmental pollution due to their chemical properties (e.g. toxicity) or physical properties (e.g. smothering). Owing to the very large number of hydrocarbon present in crude oil, the environmental and health impacts of all the constituent parts have not yet been fully studied or understood (UNEP, 2011).

Impact on Soil: Hydrocarbon pollution of soil can occur in several ways, from natural seepage in areas where petroleum is found in shallow reservoirs, to accidental spillage of crude oil on the ground and the flaring of gas (UNEP, 2011, Deekor, 2002).

Regardless of the source of contamination, once hydrocarbon come into contact with the soil, they alter its physical and chemical properties. Although the degree of the alteration depends on the soil type, the specific composition of the hydrocarbon spilled. In other situations, for example a spill of heavy crude oil on clay soil, the chemicals can remain in the soil for decades, altering its permeability, causing toxicity and lowering or destroying the quality of the soil. In such a situation the soil itself will become a source of pollution.

According to UNEP (2011), contaminated soils can affect the health of organisms through direct contact or via ingestion or inhalation of soil contaminants which have been varporized. Soil can also act as reservoir of residual pollution, releasing contaminants into ground water or air over extended period of time, often after the original source of pollution has been removed.

Materials and Methods

Three sites were selected for the study. Two impacted sites and a control. The two impacted sites are Yorla Oil field flow station in Khana Local Government Area. The facility is owned by SPDC. The other one is Bomu oil field or flow station in Gokana Local Government Area also owned by SPDC. These sites were selected for ease of accessibility. A control site was selected at Igwuruta-ali in Ikwerre Local Government Area because there is no history of oil exploration and exploitation. All sites for data collection are in Rivers State, within the same bio-climatic zone. The Bomu oil field was commissioned in 1958. The Yorla oil field was commissioned in 1973. Both sites are located in the Ogoni Region of Rivers State. Oil exploitation has been ongoing in these fields until 1993 when the company stops the flaring of gas as a result of the protest by MOSOP (Movement of the Survival of the Ogoni People)

which became a Pan Ogoni movement in response to the environmental consequences of oil production. The action shut down major oil exploitation in the area. Nevertheless, there have been illicit activities of oil theft and the attendant spillages in the region.

Soil Sampling

In each experimental site, soil samples were obtained along transects from the epicenter of the impacted area outwards. The direction of the transects were determined by gradient. Measurement was done in a 10m by 10m quadrat placed at regular interval of 30m along the transect. A total of six (6) quadrats were sampled along each transect of 180m in length. Therefore, a total of 18 quadrats were sampled including the control. The soil samples were taken from the centre of each quadrat along the transect. A total of 18 soil samples were collected from 18 quadrats. In each quadrat, two (2) soil samples were taken from a depth of 0 - 30cm (0 - 15cm, 15 - 30cm) with an auger. The T-shaped screw auger was twisted into the soil to the required depth and then pulled soil. The soil samples that stick to the screw were collected and labeled for laboratory analysis.

Laboratory Techniques

In the laboratory, the soil samples were air-dried under room temperature, gently crushed and sieved using 2mm sieve. The sieved samples were properly stored and sub-sampled for the determination of the parameters, Heavy metals and total hydrocarbon content (THC).

Heavy Metals

Heavy metals were determined after finely grounded the soil sample to facilitate digesting 1g of the finely ground sample with per chloric acid and nitric acid, heavy metals in the digest were read using atomic absorption spectrophotometer (Model UNICAM 939).

Total Hydrocarbon Content (THC)

Total Hydrocarbon content of the soil was determined by shaking the 2g of representative of soil sample with 10ml of toluene and the soil extracted measured at 240nm using spectrophotometer (Model Spectromic 20D) after which hydrocarbon content was calculated.

Discussion of Findings

Table 1 showed mean heavy metal and total hydrocarbon content of the soils. The results of the heavy metal showed that there was a variation between control and the impacted sites. The concentration lead of (Pb) in the soil was higher in Yorla and Bomu oil fields than control. This result was above permissible range of 2 – 200 mg/kg but within the range for natural soils for control. The cadmium (Cd) content of the soil of Bomu and Yorla oils were higher than the control above the permissible range of cadmium for natural soils (0.01 – 7.0 mg/kg). Chromium (Cr) also showed the same variation between control and the oil fields.

Chromium (Cr) content of the soil of the oil impacted sites above the permissible range for natural soils (5-1000 mg/kg). Nickel (Ni) followed the same trend with a variation between control and the oil fields but was within the permissible range of natural soils (10 – 100 mg/kg). Copper (Cu) and Iron (Fe) were also higher in the soils of the oil field than the control. The total hydrocarbon in the oil field were far higher than the THC of the control.

Table 1: Mean heavy metal and Total hydrocarbon Content in the Soils of the study Area.

Soil depth	Study site	Lead (Pb) mg/kg	Cadmium (Cd) mg/kg	Chromium (Cr) mg/kg	Nickel (Ni) mg/kg	Copper (Cu) mg/kg	Iron (Fe) mg/kg	THC mg/kg
0 – 30cm	Bomu	6.90 ± 2.65	8.37 ± 2.12	12.6 ± 1.75	3.45 ± 0.61	13.61 ± 3.56	661.57 ± 172.19	276.66 ± 53.31
0 – 30cm	Yorla	3.35 ± 2.40	6.13 ± 2.22	9.7 ± 3.26	2.46 ± 0.44	14.85 ± 3.03	603.04 ± 198.67	346.25 ± 52.75
0 – 30cm	Control	1.74 ± 0.29	3.29 ± 0.48	4.61 ± 0.48	2.43 ± 1.05	12.74 ± 1.77	318.57 ± 66.01	24.60 ± 21.46

Source: Field Work 2021

From the analysis in table 1, it is very clear that the result of the impacted sites and the control are at variance. This means that soil contaminated by petroleum hydrocarbon can affect soil health. They can harm soil micro-organism thereby reducing their number and activity. Soil microbes help to make nutrients available to plants. With the presence of THC in the soil it will led to lack of oxygen, decrease in crop yield, and effects on aquatic plants.

Conclusion

The soil samples from the oil field appeared to have a high level of concentration of heavy metals and Total Hydrocarbon in the two oil fields (Bomu and Yorla Oil Fields). The concentration of heavy metals and THC is a clear indication that they constitute non-biodegradable pollutants. These metals are above permissible range. This situation has risen as a result of industrial activities, exploration and exploitation of natural resources and poor handling of equipments.

The presence of these trace metals in the soils of Bomu and Yorla oil fields has affected the soil quality and components that has led to the accumulation of irons at the soil surface. Iron retention in soils can cause nutrient deficiencies. It also prevents excess or toxic concentration in most soil solution.

Recommendations

Considering the negative impact of heavy metals in soils, and the environment, its toxic nature to man and animals when they are at sufficiently high level or dosages, the study strongly recommends the following:

1. Regular soil/sediment monitoring where transects should be set in affected areas. Soil samples should be collected at intervals of two years for laboratory analysis to ascertain the presence of pollutants in the soil.
2. Phyto-remediation by planting *clamagrostis angustifolia* which has the potential to simultaneously restore and remediate the petroleum hydrocarbon-contaminated wetlands.
3. Developing an effective restoration programme in the oil field is necessary.
4. Physical method of removing Petroleum hydrocarbon include method of recycling i.e. soil flushing, soil washing, solidification, vitrification, stabilization, thermal absorption, incineration and vapour extraction (Raja et al, 2022).
5. The soils can be reclaimed and decontaminated by widely used (i) in-situ and (ii) ex-situ methods. In this case, in-situ means in the original place while ex-situ means outside the original place. To remove lighter molecules, polluted soil air extraction, air sparging, ignition or combinations of the methods are used. Ex-situ soil cleaning treatment methods are carried out off-site by excavation. Detoxification, destruction technology can be applied to remove the petroleum hydrocarbons from soil and ground water (Abdelhafeez et al 2022).
6. Surface capping of the contaminated soil. This is a physical barrier between the polluted media and the surface. It helps to isolate petroleum hydrocarbon polluted soil from potential receptors. It also helps to prevent water pollution from rainfall water infiltration due to scientific surface soil capping. Contaminated media is covered with sufficiently thick and impenetrable barriers that minimize the transport of toxic petroleum hydrocarbons.

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