Original Research Article

Analysis of Soil Quality in a Deltaic Hydrocarbon Polluted Environment Niger Delta Nigeria

Abstract

Aim: The study was aimed to ascertain the damage done by an oil spill on the soils of Ogbia area in Bayelsa State, Niger Delta, Nigeria.

Study design: The study adopted the experimental research design which entailed the use of field measurements and a control site. Three communities which are Elebele, Imiringi and Otuasega were used for the study. At each of the sample locations, three random spots were augered at two depth-levels (Top Sample (T), 0 – 15cm; Bottom Sample (B), 15- 30 cm), with the aid of an auger to collect the samples for laboratory analysis. The parameters of interest to the study are TPH, THC, Organic Matter, THF, THB, pH, sand, silt clay and soil texture and these were analysed using standard techniques as recommended by DPR.

Results: The study revealed that there is a noticeable effect of oil exploitation activities on soil quality within the study area, In the case of THC, the result revealed that the level of THC in the sampled communities was higher than that of the non spill site, hence the presence of hydrocarbon which has caused the pollution of the soil. Organic matter content of the soil also reveals that the non-polluted site has more organic content than the sampled communities.

Conclusion: The study revealed that there is a statistically significant difference in soil quality of the selected communities and that of the non-spilt site. The study, therefore, recommended complete and total remediation of the soils in the area, as this will enhance the soil for increased food production.

Keywords: soil, hydrocarbon, polluted, deltaic, environment

Introduction

Over the years there have been a rising demand for oil and the dependence on oil revenue has greatly increased. This increase has brought an increase in the economic development of Nigeria, but the situation has led to an increase in environmental, degradation, pollution and contamination of the soils in the Niger Delta. This has arisen from the breakdown of oil pipelines and wells as well as petroleum distribution processes. Oil spills on land have brought about a reduction in soil fertility which has affected food production (Sparrow & Sparrow, 1988; Racine, 1993).

While the benefit of the oil industry is not in doubt, it's explorative, developmental and production processes generate a lot of waste amongst which are of "drilling cuttings, drilling fluids, produced water, sludge, completion and workover fluids, trace metals, heat waste and oxides of carbon, Sulphur and nitrogen" (Nwilo & Badejo, 2005). Fluids and cuttings arising from oil drilling are the largest waste sources during exploration. It is speculated that at least two barrels of fluids and cuttings are generated per foot of a typical well drilled (Nwilo & Badejo, 2005).

Several studies have revealed that oil pollution affects the quality of soils; in the study conducted by Bada and Olarinre (2012), revealed that leaves had more heavy metal content in plants than stems and roots.

Furthermore, Oyem and Oyem (2013), in Ugborodo community on oil spillage impacts on the soil physico-chemical properties. Arising from oil spillage, it was observed that among the four sampled communities parameters measured indicated high amount of hydrocarbon, hence a turn out low fertility, which will bring about low food production and its attendant effects on the sources of livelihood available to the people.

Ugboma, (2014) in a separate study on showed that soil physical and chemical characteristics were affected by oil spill which resulted in soil fertility decrease and crop productivity decline as well. This, therefore, provides evidence that oil spill affects soil quality which in turn affects the quantity of food production in an area.

The record of oil exploitation activities can be likened to the record of oil poison. This is because as oil exploration and exploitation commenced the next that happened "almost immediately was the three major causes of oil pollution namely; the impact of the seismic survey, gas flaring and oil spills" (Pyagbara, 2007). The consequences of oil exploitation on the environment with an emphasis on the soil quality informed the need for this study.

Through a large number of literature research, the harm of oil-polluted soil mainly includes the following aspects: Firstly, because of the small density, higher viscosity and lower emulsifying ability of petroleum, it is easy to be absorbed in soil surface, affecting the permeability and porosity of soil (Wang, 2009; He et al, 1999); petroleum is rich in carbon and a small number of nitrogen compounds, so it can change the composition and structure of soil organic matter and impact the C/N, C/P, salinity, pH, EH and conductivity of soil (Li et al, 2009).

The heavy metals (nickel and vanadium) in oil mixtures (Saadat et al, 2014) and high concentrations of salt in oilfield output water can also damage the soil environment (Efsun et al, 2015). Secondly, microorganisms in the natural environment are quite abundant in healthy and clean soil. In normal situation, the microorganisms which can resist the oil pollution stress are not developed, while in contaminated soil, in order to adapt to this kind of environment, they can produce certain enzyme system and gradually form a dominant population with symbiotic or synergy effect (Chiara et al, 2009).

A number of studies have shown that the hydrocarbon pollution can change the microbial population, the composition of the community structure and the enzyme system in soil, given priority to the inhibitory action (Deng, 2014; Uzoije and Agunwamba et al, 2009). Thirdly, it can impede the normal growth of crops such as reduce the germination rate and fertility and decline the resistance to pests and diseases (Xu and Lu, 2010; Zhu, 2010; Shan et al, 2014). In addition, the oil compounds could react with inorganic nitrogen and phosphorus, limiting the nitrification and removal of phosphoric acid, so the effective nitrogen and phosphorus in the soil would decrease and the absorption of crops will be affected (Liao et al, 2015; Pinchin et al, 2013; Shen, 2011).

Moreover, the polycyclic aromatic hydrocarbons in petroleum chemicals have carcinogenic, mutagenic, teratogenic and other toxic effects. It can enter into the bodies of people and animals through breathing, skin contact and diet, degrading the normal function of livers and kidney etc, therefore causing a great threat to human's health. At last, the oil pollutants in the soil not only impact the pedosphere, but also the atmosphere and water sphere.

Materials and Method

The Study Area

The area of study is Imiringi, Otuasega and Elebele communities which are located within the Kolo Creek, which is located $4^{o}.47'0'N - 6^{o}.25'0'E$ within the lower Niger Delta. (See fig 1).

Ogbia is one amongst other local government areas in Bayelsa State, with the Head Quarters situated in the town called Ogbia which is located on the South of the area within Latitude $4^0$45'00"N $6^0$39'00"E. It covers a total area of 695 km^2. Kolo Creek oil and gas field as called by SPDC is located in Imiringi town. The name Kolo creek as called by SPDC, and is "named after Kolo Creek in Ogbia Local Government Area of Bayelsa State. The area is located about 10km North-West of Yenagoa, which is the capital city of Bayelsa State. It is characterized by tropical rain forest and fresh water swamps that are usually flooded in the raining season".

The study was conducted in the Kolo Creek area as called by Shell Development Company of Nigeria (SPDC) which is basically made up of three communities in Ogbia; there are Imiringi, Otuasega having and Elebele communities which were selected for the study because of the presence of oil wells in the communities. The study adopted the use of the experimental research design which enabled the researchers achieve the purpose of the study.

Since the interest of the study is on soil quality, soil samples were collected using a systematic sampling pattern (Tel and Hagarty, 1984). At each of the sample locations, three random spots were augered at two depth-levels (Top Sample (T), 0 – 15cm; Bottom Sample (B), 15- 30 cm), with the aid of an auger (EGASPIN, 2002). Also, at each of the sample locations and soil depth levels (T or B), the soil samples were bulked together to give a composite sample. The soil samples from different sample locations and soil depth levels were on each occasion collected in polythene bags and labeled accordingly and sent to the laboratory for analysis. Two hypotheses were also put forth to guide this study.

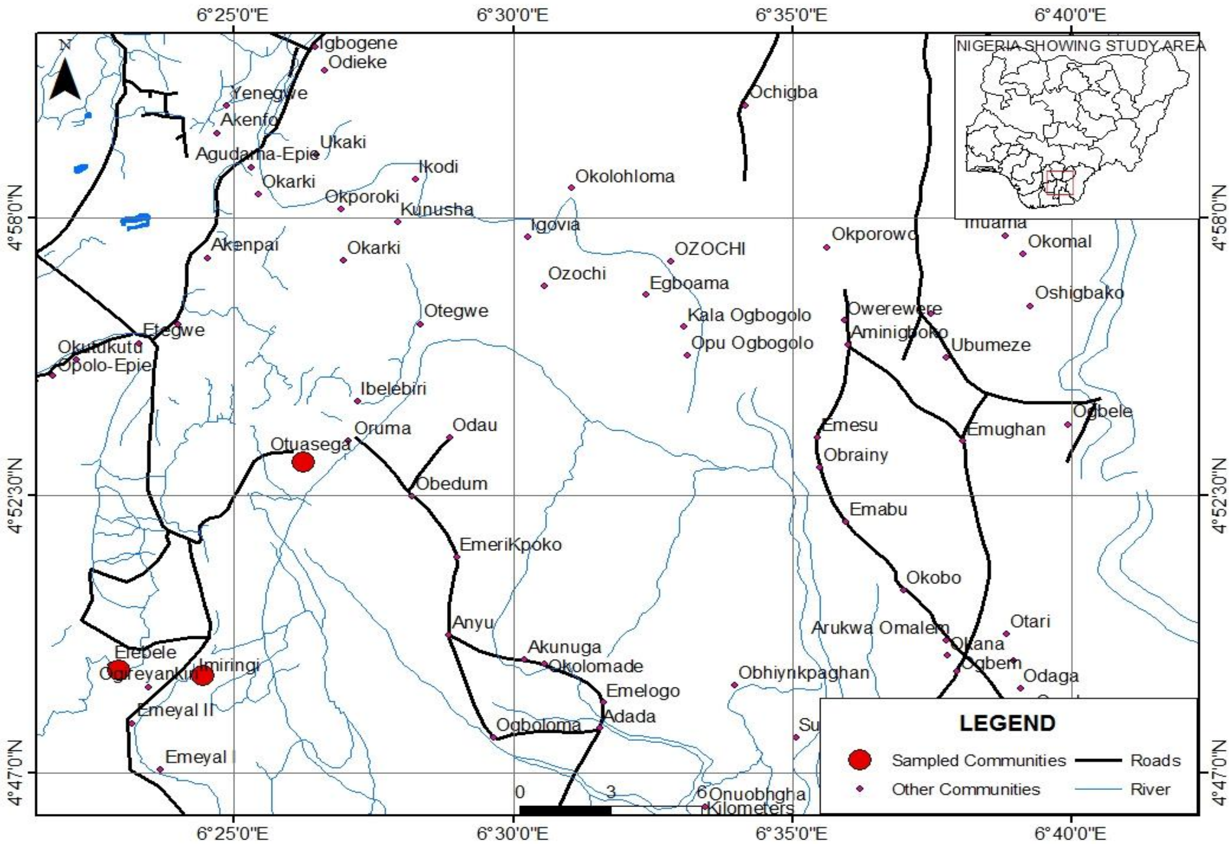

Fig 1: Ogbia Area showing sampled communities

Analytical Procedure for Soil Quality Analysis

Total Heterotrophic Bacteria

A sample of water with a mass of 1 gram is weighed into 9ml sterile diluents (0.85% NaCl) under aseptic condition. It is shaken vigorously to homogenize and serially diluted. Then 0.1ml aliquot of the inoculums is collected using a sterile pipette, inoculated on Nutrient Agar (NA) surface. The inoculums are spread evenly with sterile hockey stick (Bent rod). Plates are incubated at 28^0C for 24 hours. Thereafter, colonies are counted to obtain colony forming unit (cfu) value per ml of water sample. Distinct colonies are picked and streaked or subculture on freshly prepared Nutrient Agar medium to obtain pure culture after 24 hours incubation at 37^0C. The pure culture is gram stained for microscopic examination. It is also used to carry out biochemical tests for characterization and identification of the isolates.

Total Petroleum Hydrocarbon

This analysis shall be done using gas chromatography/flame ionization detector method. Methods 3580A and 3550C describe the procedure used for extracting non-volatile and semi-volatile organic compounds from solids such as soils, sludge and wastes, while method 8000 describes the determinative steps employed in the GC/FID of sample extracts obtained using the methods described above.

Soil pH Determination

The ph of soil was done with the aid of a pH meter.

Results

The results of the laboratory analysis of the soil samples collected from the selected communities are presented in the table below.

Table 1: Result of Physico-Chemical/Microbiological Analysis of Soil

Parameters	**Imiringi**	**Elebele**	**Otuasega**
TPH(mg/kg)	178.77	1,732.50	132.51
THC(mg/kg)	277.2	2246.0	223.7
Organic matter (%)	7.440	14.890	11.280
THF(cfu/g)x10^3	1.2	0.2	0.2
THB(cfu/g)x10^3	3.2	1.0	1.2
P^H	6.30	6.50	5.30
Sand (%)	11.2	12.7	11.9
Silt (%)	31.6	33.4	32.8
Clay (%)	57.2	53.9	55.3
PSD/Texture	Silty clay	Silty clay	Silty clay

Source: Researchers field work (2015)

Table 2: Comparism of soil quality Parameters of polluted sites with Non polluted soil.

Parameters	**Imiringi**	**Elebele**	**Otuasega**	**Non polluted site**
TPH(mg/kg)	178.77	1,732.50	132.51	20.18
THC(mg/kg)	277.2	2246.0	223.7	36.0
Organic matter (%)	7.440	14.890	11.280	18.20
THF(cfu/g)x10^3	1.2	0.2	0.2	0.5
THB(cfu/g)x10^3	3.2	1.0	1.2	2.2
P^H	6.30	6.50	5.30	7.10
Sand (%)	11.2	12.7	11.9	13.8
Silt (%)	31.6	33.4	32.8	35.2
Clay (%)	57.2	53.9	55.3	51
PSD/Texture	Silty clay	Silty clay	Silty clay	Silty clay

Source Researchers field work (2018)

Discussions

As seen in table 1, Total Petroleum Hydrocarbon in soils of the selected communities ranges between 132.51 and 1,732.50, with Otuasega community accounting for the lowest which is 132.51mg/kg and Elebele community accounting for 1,732.50mg/kg which is the highest, although the result shows that total petroleum hydrocarbon value differs significantly from one location to another.

Total Hydrocarbon Content in soils of the selected communities ranges between 223.7mg/kg and 2246.0mg/kg, with Otuasega community accounting for the lowest which is 223.7mg/kg and Elebele community accounting for 2246mg/kg which is the highest; although the result shows that total hydrocarbon content value in soils differs significantly from one location to another.

Organic matter in soils of the selected communities ranges between 7.440 and 14.890, with Elebele community accounting for the highest, with an organic content value of 14.890. This was followed by Otuasega community with an organic content value of 11.280 and Imiringi community with an organic content value of 7.440.

Total Heterotrophic Fungi in soils of the selected communities ranges between 0.2 and 1.2, with Imiringi community accounting for the highest, with a THF value of 1.2. The two other sampled community’s Otuasega and Elebele had the same THF value of 0.2 each.

Total Heterotrophic Bacteria in soils of the selected communities ranges between 1.0 and 3.2, with Imiringi community accounting for the highest, with a THB value of 3.2. This was followed by Otuasega community with a THB value of 1.2 and Elebele community with a THB value of 1.2.

pH in soils of the selected communities ranges between 5.30 and 6.50, with Elebele community accounting for the highest, with a pH value of 6.50. This was followed by Imiringi community with a pH value of 6.30 and Imiringi community with a pH value of 5.30.

Sand level in soils of the selected communities ranges between 11.2% and 12.7% with Elebele community accounting for the highest, with sand % value of 12.7%. This was followed by Otuasega community with sand % value of 11.9% and Imiringi community with sand % value of 11.2%.Silt as observed to range between 31.6 and 33.4. The highest was recorded in Elebele with a percentage value of 33.4% silt; Otuasega had 32.8% silt and Imiringi 31.6% silt.

Clay ranged between 53.9 and 57.2 with the highest percentage value of 57.2% recorded in Imiringi. This was followed by Otuasega with clay percentage value of 55.3% and Elebele with a clay percentage value of 53.9%.The texture of the soil as shown revealed that the three community soils are silty clay soil.

Table 2 revealed that total petroleum hydrocarbon level in the three sampled communities is above that of the non polluted site with Elebele community having more concentration of total petroleum hydrocarbon than the other communities. The result here shows that there is a noticeable effect of oil exploitation activities of soil quality within the study area.

In the case of THC, the result revealed that the level of THC in the sampled communities was higher than that of the non-spill site, hence the presence of hydrocarbon which has caused the pollution of the soil.

The organic matter content of the soil also reveals that the non-polluted site has more organic content than the selected communities. This implies that the presence of oil in the soil due to pollution has affected the organic content of the soil hence bringing a reduction in its amount when compared with the non-polluted site.

Hypothesis Testing

Table 3: Chi-Square analysis for the difference in soil quality between Imiringi (polluted site) and non-polluted site

Observed	**Expected**	**O-E**	**$(O-E)^2$**	**$\frac{(O-E)^2}{E}$**
178.77	20.18	158.9	25150.79	1246.3
277.2	36.0	241.2	58177.4	1616.0
7.440	18.20	-10.76	115.78	6.36
1.2	0.5	0.7	0.49	0.98
3.2	2.2	1	1	0.45
6.30	7.10	-0.8	0.64	0.090
11.2	13.8	-2.6	45.69	3.31
31.6	35.2	-3.6	12.96	0.368
57.2	51	8.2	67.24	1.32
				X^2 = 2875.12

df = (9-1) (2-1)

(9-1) (2-1)

8x1 =8

Therefore we conclude that X^2 calculated value is 2875.12 while the critical value at 10 degree of freedom and 95% significant level is 15.51.

The calculated X^2 calculated value 2875.12 is greater than the critical value of 15.51 we, therefore, reject the null hypothesis which states that there is no statistically significant difference in soil quality of Imiringi and that of the non polluted site and accepts the alternate hypothesis which states that there is a statistically significant difference in soil quality in Imiringi and that of the non polluted site.

Table 4:Chi-Square analysis for difference in soil quality between Elebele (polluted site) and non-polluted site

Observed	**Expected**	**O-E**	**$(O-E)^2$**	**$\frac{(O-E)^2}{E}$**
1,732.50	20.18	1712.32	2932.01	145.3
2246.0	36.0	2210	4884100	135669.4
14.890	18.20	-3.31	10.96	0.602
0.2	0.5	-0.3	0.09	0.18
1.0	2.2	-1.2	1.44	0.65
6.50	7.10	-0.6	0.36	0.05
12.7	13.8	-1.1	1.21	0.088
33.4	35.2	-1.8	3.24	0.092
53.9	51	2.9	8.41	0.165
				X^2 = 135,816.5

df = (9-1) (2-1)

(9-1) (2-1)

8x1 =8

Therefore we conclude that X^2 calculated value is 135,816.5while the critical value at 10 degree of freedom and 95% significant level is 15.51.

The calculated X^2 calculated value 135,816.5is greater than the critical value of 15.51 we therefore reject the null hypothesis which states that there is no statistically significant difference in soil quality of Elebele and that of the non polluted site and accept the alternate hypothesis which states that there is a statistically significant difference in soil quality in Elebele and that of the non polluted site.

Table 5: Chi-Square analysis for the difference in soil quality between Otuasega (polluted site) and non-polluted site

Observed	Expected	O-E	$(O-E)^2$	$\frac{(O-E)^2}{E}$
132.51	20.18	112.33	12618.03	625.3
223.7	36.0	187.7	35231.3	978.65
11.280	18.20	-6.92	47.89	2.63
0.2	0.5	-0.3	0.09	0.18
1.2	2.2	-1	1	0.45
5.30	7.10	-1.8	3.24	0.456
11.9	13.8	-1.9	3.61	0.263
32.8	35.2	-2.4	5.76	0.164
55.3	51	4.3	18.49	0.363
				X^2 = 1608.456

df = (9-1) (2-1)

(9-1) (2-1)

8x1 =8

Therefore we conclude that X^2 calculated value is 1608.456while the critical value at 10 degree of freedom and 95% significant level is 15.51.

The calculated X^2 calculated value 1608.456is greater than the critical value of 15.51 we therefore reject the null hypothesis which states that there is no statistically significant difference in soil quality of Otuasega and that of the non polluted site and accept the alternate hypothesis which states that there is a statistically significant difference in soil quality in Otuasega and that of the non polluted site.

Hypothesis Two

The second hypothesis of the study, states that there is no statistically significant variation in the extent of soil damage amongst sampled communities in Ogbia.

The table below shows the variation in the extent of soil damage amongst sampled communities in Ogbia.

Table 6: One way (ANOVA) for variation in soil quality in sampled communities in Ogbia

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	948295.4	2	474147.7	1.804708	0.186144	3.402826
Within Groups	6305476	24	262728.2			
Total	7253771	26				

From the table above, it is revealed that calculated F value for the analysis is 1.804708 while the critical value is 3.402826. Since the calculated F value of 1.804708 is less than the critical value of 3.402826 at F^{2}_{26} degree of freedom, the implication of this is that the null hypothesis H_0 of no significant difference is accepted while rejecting the alternate H_1 which states that there is a statistically significant variation in the extent of soil damage amongst selected communities. Arising from the above it is pertinent to state that the study has revealed that there is no statistically significant variation in soil quality of the selected communities.

Conclusion

The study concludes that the level of damage done by oil spill on the soils and its spatial variation in Ogbia, the study therefore revealed that total petroleum hydrocarbon level in the three sampled communities is above that of the non polluted site with Elebele community having more concentration of total petroleum hydrocarbon than the other communities. The result here shows that there is a noticeable effect of oil exploitation activities on soil quality within the study area. For THC, the result revealed that the level of THC in the sampled communities was higher than that of the non spill site, hence the presence of hydrocarbon which have caused the pollution of the soil. The organic matter content of the soil also reveals that the non polluted site has more organic content than the sampled communities. This implies that the presence of oil in the soil due to pollution has affected the organic content of the soil hence bringing a reduction in its amount when compared with the no polluted site.

Statistically, the study revealed that there is a statistically significant difference in soil quality of the sampled communities and that of the non spilled site, but on specific parameter, it was found that total petroleum hydrocarbon and total hydrocarbon content were higher in the selected communities than the non oil spilled site. The study further revealed that;

1. There is a noticeable effect of oil exploitation activities on soil quality within the study area.
2. There is also a noticeable decline in the crop production arising from soil pollution occasioned by oil exploitation.
3. There is a clear cut evidence of the state of the soil in the polluted sites as compared to the non polluted which is an indication of the state of the soil having been ravaged by the detrimental effect of oil exploratory activities in the area.
4. Total petroleum hydrocarbon level in the three sampled communities is above that of the non polluted site with Elebele community having more concentration of total petroleum hydrocarbon than the other communities.
5. The study revealed that there is a statistically significant difference in soil quality of the selected communities and that of the non spilled site

On the basis of the above, the study recommended a complete and total remediation of the soils in the area, as this will enhance the soil for increased food production.

Informed consent: Before the commencement of the research the communities were duly informed of the research which the obliged and provided a guard to assist the researchers during the period

Ethical: NA

Competing interests: there are no conflicting interests in this work

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