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A Study of the Effects of Petroleum Production on Selected Soil Fertility Attributes in Ogoni Land, Rivers State Nigeria

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Abstract

The physical, chemical and biological properties of soil in Khana and Gokana LGAs of Rivers State Nigeria were investigated. The main aim was to determine to what extent the soil fertility attributes in Ogoni land had been negatively affected by petroleum production in the area. Soil samples were collected from scientifically delineated spots in the study area and analyzed in the laboratory at the Institute of pollution studies, Rivers State University of Science and Technology, Port Harcourt. All the data obtained from the laboratory were analyzed statistically using one-way analysis of variance (ANOVA). Results show that soil characteristics show evidence of variation attributable to influence of petroleum production activities. It is hereby recommended that in the oil production business, government should supervise the operation of the oil companies strictly and with due regard to the welfare of the inhabitants of the communities. The oil companies should carry the host communities along in their activities. The host communities should forget the past, rely more on facts and show readiness to move forward. Oil production can still go forward to the benefit of all.

Keywords: Petroleum Production, Soil Fertility, Ogoni.

Introduction

The quality of health and life of any society is in part a function of the quality of their environment. The environment as a totality of a society's natural and artificial surrounding provides not only the essentials of life such as the air we breathe, the fluid we drink and the food we eat but also other resources needed for sustenance [1,2]. However, the relationship between any society and its environment is interactive since a society is an intricate part of the environment, and as such is influenced as well as influences its environment. This influence is delicate since non-sustainable use of any environmental resource can lead to degradation in the quality of the environment. In reports that in sub-Saharan Africa including Nigeria, the delicate balance between man and his environment appears to have been disrupted over the years due to a number of factors many of which are attributable to the activities of man [3]. Likewise, soil, air and water pollution from oil prospecting activities, industrialization, uncontrolled urbanization, deforestation and unwholesome waste handling practices have all been implicated in the loss of value of the natural environment, damage to wildlife, eco-system destruction and loss of bio-diversity. Additionally, issues of urban decay and squatter settlements arising from excessive pressure on available urban infrastructure and space escalate environmental degradation and resource depletion. These anthropogenic activities amongst others have been highlighted as major environmental challenges facing Nigeria as a country [4].

In order of importance, air, water and food are the three main necessities of life. A person can survive for about a month without food, a week without water and less than five minutes without air [5]. Air exists naturally in the environment; water also exists in nature and only needs to be made available, while food must be produced. Talking about food production, one notable environmental resource which has received very wide attention in literature is the soil [6,7,1,8]. It is a common practice to associate the importance of soils with agricultural production and forestry. In agricultural production, soils are an integral part of ecological system which produces our food and fibre. Soils are thus the most valuable natural resources of a nation [1]. Although the number of people needing food is increasing by the day, the capacity of soils to produce food in parts of the world is being degraded [1]. It will be a great challenge for the current generation to bring the global environment back into balance [6].

Africa, south of the Sahara is the only remaining region of the world where per capita food production has remained stagnant over the past 40 years. About 180 million Africans- up 100 percent since 1970- do not have access to sufficient food to lead healthy and productive lives. Africa's food insecurity is directly related to insufficient total food production, in contrast to south Asia and other regions, where food insecurity is primarily due to poor distribution and lack of purchasing power [8].

Depletion of soil fertility is a major cause of low per capita food production in Africa. According to land degradation and low soil fertility are considered the major threats to food security and natural conservation in sub-Saharan Africa (SSA) [9]. Low agricultural production has also been noted to lead to low incomes, poor nutrition, vulnerability to risks and lack of empowerment. Many of the above have been attributed to the activities involved in petroleum production. The environmental consequences of petroleum production activities in Nigeria have received the attention of several researchers in the past [10-14].

In the Niger delta region of Nigeria, oil exploration activities have been identified as key factors that bring about destruction of wildlife, loss of fertile soil, pollution of air and water and damage to ecosystem of host communities [15]. It is strongly believed that the aforementioned environmental distortions and the consequent resource depletion do have consequences such as social, economic, political and ecological, on the host society and the people of Ogoni in Rivers State are no exceptions. This research was thereby conceived to address the effects of petroleum production on selected soil fertility attributes in Ogoni land with a view of proffering solutions for sustainable living. The research therefore sought to investigate the effects of environmental degradation due mainly to petroleum production on soil fertility in Ogoni land- a very important area of Rivers State. Since there is dearth of knowledge in this area, this study is an attempt to fill this gap.

Materials and Methods

This study was carried out in Khana and Gokana, two out of the four Local Government Areas that make up Ogoni and out of the 23 that make up Rivers State which lies within the Niger Delta region of Nigeria located between latitudes 4°33' and 4°50'N and longitude 7°20' and 7°35'E the two Local Government- the main home of the Ogonis occupy the south eastern fringe of the state and jointly cover a land area of 795km2. The other two LGAs are Tai and Eleme [16]. In 2006, there were 523,045 persons (276,273 males and 246,772 females) in Khana and Gokana [17].

The area is characterized by distinct wet and dry seasons. The dry season is however very short lasting for about three months [18]. The whole of Ogoni is located in a coastal plain forming the north-eastern part of Rivers State. They belong to the group of soils termed the "Acid Sands" in southern Nigeria [19]. The natural vegetation is tropical rain forest much of which has been destroyed or altered and replaced with secondary or tertiary vegetation which lacks the complex ecological characteristics of the original forest. The Ogoni land is purely for agricultural activities which involve farming, fishing tapping and distillation of palm wine into a local brand of dry gin, and more. The people also earn their living as civil servants and traders [20].

The people relied heavily on agriculture and crops such as cassava, yam and oil palm. This study is concerned with environmental degradation pertaining to soil environment only. The data gathering exercise was therefore limited to the effect of petroleum-related, soil degrading influences in the area. In this research the ex post facto design methodology was used. First, a reconnaissance survey of the entire study area was carried out to determine the physical characteristics of the area. The area suitable for the study was thus selected by a team of five up of the researcher and four other guides from Ogoni who took active part in the study.

A total of 10 communities, six from Khana (Baen, Buan, Kpean, Kwawa, Labara and Zaakpon), and four from Gokana (B-dere, Bomu, K-dere and Kpor) were initially selected. The reason for selecting these communities were that they have history of oil production activities and agitations arising therefrom. They were also accessible at the time of the study. Out of the six communities mapped out in Khana, 3 were selected using a simple random sampling method. These were Kpean, Kwawa, and Zaakpon. Likewise in Gokana, two out of the 4 listed were randomly selected. These were K-dere and Kpor. Next for each of the five selected communities, the points from where soil samples would be collected were identified and marked. Preference was given to areas near a flow station, a manifold or an oil spill spot. Points were thus selected for each community and marked 1, 2, 3 and so on. From these points measurements were taken at 10, 20, and 30 metres interval and marked as 1A, 1B, 1C. These were repeated in opposite direction for uniformity and marked 1D, 1E, and 1F. From the above sites 6 different samples were collected from each location, representing different space intervals from the point of interest. That is at 10, 20 and at 30 metres away from affected points. All samples on opposite direction (DEF) were consolidated with their main equivalent (ABC) to form composites. Additionally, samples were collected from same locations from entirely unaffected areas to serve as controls. Each of these samples was marked O. Samples were collected in February 2007 for the dry season and in August 2007 for the rainy season.

Same were replicated in the five locations. So in all a total of 20 soil samples were collected each at a depth of 0-30 cm. The Department of Agriculture, Madya Pradesh, recommends a soil sampling depth of 15cm for arable crops and 20-30cm for orchard crops [21]. In similar studies, collected soil samples for the A-horizon, at 0-15cm depth at distances of 60, 100, 500, and 1000m from flare stack [22]. Also Onyeike and Ogbuja (1999), collected soil samples from depth of 0-15cm for top soil and 15-30cm for subsoil. But worked on the top 30cm of the soil [23]. All the soil samples collected from already delineated areas of Ogoni land were analyzed in the laboratory at the Institute of Pollution studies, Rivers State University of Science and Technology, Port Harcourt, using standard soil laboratory techniques. These techniques have been successfully used by Onyeike and Ogbuga (1999), in several related studies of the soil [24,25].

In This Study the Idea Was to Examine

To what extent the physical, chemical, and biological characteristics of the soil have been altered by the presence of petroleum extraction activities. The basis for confirmation of degradation is identification of significant variations in concentrations of parameters studied among the different intervals and also in comparison with the control. Where the parameters remained unchanged, no effect would be suspected. Standard soil fertility attributes (soil pH, organic carbon, available N. P. and K) which are the most important factors in terms of plant growth, crop production and microbial diversity and function were investigated [26]. As we know, these parameters are generally sensitive to soil management. For polluted or degraded soils, these fertility indicators are regarded as part of a minimum data set of soil chemical indicators. Other parameters measured were soil physical parameters such as Temperature (°C), % moisture content, permeability (mm/mm), Available water capacity (cm/cm), bulk density (g/cm³) and % porosity. So many other soil parameters were tested. The soil bacterial count of total heterotrophic bacteria was also considered. All the data obtained from the laboratory analysis were subjected to statistical analysis. Initially, descriptive statistics such as percentages, mean distribution and standard deviation were employed to ascertain the mean distribution and concentration of parameters associated with different areas, measurement and space intervals under study. Inferential statistical analysis was also done using the student t-test as adopted from analysis of Variance (ANOVA) [27]. T-test of significance was done at 95 percent confidence level of probability (p=0.05) between oil contaminated samples and control.

Results and Discussions

This section is divided into three

A. Soil Physical Characteristics

The physical characteristics of the soil that were used as indicators of soil fertility depletion are presented in table 1. No significant difference was detected among the samples with reference to the texture of the soils. From the table it can be seen that variations exist among the sites attributable to location and spatial differences with respect to most soil physical parameters. Soil temperatures of all the soils studied ranged between 23.00C and 27.00C. The soil temperatures in all five locations were lower near the source of pollution compared with areas further away. The soil temperatures for the points nearest to the source of pollution ranged between 23.00C and 25.10C with a mean value of 24.20C. The average temperatures for the second farthest point from source of pollution were slightly higher with a mean value of 24.60C. These values clearly show that temperatures reduced with nearness to the source of pollution.

Table 1: Physical Characteristics of Polluted and Unpolluted Soils in Ogoni

Soil Parameters	AD 10 M	BE 20 M	CF 30 M	O' CONTROL	Sig
Temperature (0C)	24.20 ± 0.58c	24.60 ± 1.06c	25.40 ± 0.76b	26.20 ± 0.52a	*
Moisture Content (%)	10.60 ± 0.89c	9.80 ± 0.84c	11.60 ± 1.14b	13.60 ± 1.14a	*
Permeability (mm/min)	9.20 ± 1.04c	8.40 ± 1.35c	12.00 ± 2.74b	13.60 ± 3.84a	*
Available Water Capacity (cm/cm)	6.80 ± 1.60b	6.10 ± 0.59b	7.00 ± 1.54b	10.10 ± 2.94a	*
Bulk density (g/cm3)	1.61 ± 0.03a	1.61 ± 0.02a	1.56 ± 0.04b	1.50 ± 0.02b	*
Porosity (%)	39.70 ± 1.34c	39.40 ±0.87c	41.10 ± 1.53b	43.40 ± 0.63a	*

Values are means ± Standard deviations of five replicates
Values on the same row having the same superscript letters are not significantly different at 5% level
AD 10 M : Within 10m radius from source of pollution
BE 20 M : Within 20m radius from source of pollution
CF 30 M : Within 30m radius from source of pollution
O' CTL : CONTROL

The highest temperature values were obtained at the controls. The temperatures of the control samples ranged between 25.7^{0}C and 27.00C with a mean value of 26.2±0.52^{0}C. These temperatures were significantly ($P \leq 0.05$) higher than those obtained at the polluted samples. There was no significant ($P \geq 0.05$) difference between the first and second intervals of 10 metres and 20 metres distances respectively from the source of pollution. In a related study carried out in the area, Onyeike and Ogbuja (1999) had reported similar findings where slightly lower temperatures averaging 24.5±0.10C maximum, were obtained at polluted sites comparably to values averaging 25.4±0.440C recorded at the control. However, there were also areas in the cited study where higher temperature values were reported at the polluted areas than at the control, a phenomenon attributable to the presence of higher levels of biodegradable pollutants in the soil.

As stated earlier, the temperature of a soil greatly affects the physical, biological and chemical processes occurring in that soil, and plants growing on it. In cold soils, rates of chemical and biological reactions are slow. Biological decompositions are near standstill, thereby limiting the rate at which nutrients such as nitrogen (N), phosphorus (P), sulphur (S), and calcium (Ca) are made available to plants. Also absorption and transport of water and nutrient ions by higher plants are inhibited by low temperatures.

Temperatures that are too high can also inhibit plant and microbial processes [6]. Temperature and moisture both influence the organic matter content of the soil through their effects on the balance between plant growth and microbial decompositions. For soil moisture content, the trend shows increase in values with distance away from the source of pollution. The soil's moisture content closest to the source of pollution ranged between 10.0 percent and 12.0 percent with a mean value of 10.6±0.89 percent. This mean value came down to 9.80±0.84 percent in the BE 20 M sample. The highest values averaging 13.60±1.1 percent were obtained at the controls. These values were significantly ($P \leq 0.05$) higher than the values obtained at the furthest point from the source of pollution which averaged 11.6±1.14 percent. All these were also found to be significantly ($P \leq 0.05$) higher than values obtained in spots closest to the source of pollution (Table 1). The implication of these results is that soil moisture content has been found to reduce with petroleum production activities. Percentage moisture content was higher at the control. Ayotamuno et al (2006a) [23], had earlier reported a similar case where a soil's moisture content prior to contamination averaging 13.0 percent was brought down to about 8.0 percent after crude oil contamination.

It has earlier been mentioned that in heavily-polluted soils, water droplets adhere to the hydrophobic layer, and this prevents the wetting of the soil aggregates [28]. Soil permeability also took exactly the same trend as moisture content with higher values recorded at the unpolluted control than at the polluted sites. The range of values averaging 13.6±3.84 mm/min obtained at the control is significantly (P≤0.05) higher than the value for the point furthest from the source of pollution (12.0±2.74) which in turn is significantly (P≤0.05) higher than the area closest to the source of pollution. However, there was no significant (P≥0.05) difference between the two areas closest to the source of pollution (AD 10 M and BE 20 M). Even though oil production activities could be implicated for variations in permeability values reported, the mean value of 13.6±3.84 mm/min recorded at the controls shows that background conditions were not even ideal with respect to this parameter. Permeabilities below 15 mm/min are very slow indeed [1].

For available water capacity, evidence is also strong that there were variations in values attributable to location and spatial differences vis-à-vis proximity to sites of oil production activities. Here again, the higher values were obtained at the controls with a mean value of 10.1±2.94 cm/cm. This figure was significantly (P≤0.05) higher than all other figures obtained at sites under the influence of oil production activities. There were however no significant (P≥0.05) differences among the other spots at different intervals from the source of pollution. In a similar study, had reported results where plant available water capacity values were brought down as a result of degradation from 10.3 cm/cm to 5.94 cm/cm, and affirmed that the lower values for the degraded soils show loss of physical fertility [29]. Are also in agreement with this finding. In the present study, oil activities reduced available water capacity significantly [30].

Available water holding capacity is very important for effective plant growth especially during periods of low rainfall. Soils with high available water holding capacity can sustain two or more crops annually with little or no irrigation, but these are common with soils having a high content of silt and clay. The soils in question with very high proportion of sand are known to be limited in moisture holding capacity particularly during the dry months. Another highlight of table 1 is that the highest porosity figures were obtained at the controls. The trend shows that percentage porosity decreased with nearness to source of pollution. The range of values at the control samples averaged 43.4±0.63 percent which was significantly (P≤0.05) higher than the mean value of 41.1±1.53 percent obtained at the point farthest from the source of pollution. These two mean values were also in turn significantly (P≤0.05) higher than the first and second points from the source of pollution. Total porosities ranging from 38 to 50 percent had been reported in some "Acid Sand" soils by [31]. Also on the basis of 50 percent Total Porosity considered as maximum for the "Acid Sands", porosity can be considered moderate to high in the soils investigated. Pollution however brought about reduced porosity.

Soil bulk density was the only case where nearness to the source of pollution was associated with higher values comparably to the other spots and to the control. The observed mean values were 1.61±0.03g/cm3, 1.61±0.02g/cm3 and 1.56±0.04g/cm3, for the nearest (AD 10 M), second nearest (BE 20 M), and farthest (CF 30 M) points to the source of pollution respectively. The points closer to the source of pollution recorded significantly (P≤0.05) higher mean values than the points further away. There was however no significant (P≥0.05) mean difference between the first two sampling points, Just as the last sampling point (CF 30 M) did not differ significantly (P≥0.05) from the control. From the above results, soil bulk density increased with oil production activities. These results are in agreement with the findings of, who in a similar study had reported higher bulk density value of 1.50g/cm3 for degraded as against 1.45g/cm3 for undegraded "acid sands" [29].

B. Soil Chemical Characteristics

The results in table 2 show the effect of petroleum production on soil chemical parameters in Ogoni. The soil characteristics that were used as indicators of levels of chemical soil degradation are presented in table 2. The results of the analysis indicated that the soils investigated were within the acidic range. Soil pH values did not show any marked variation except that it increased slightly with nearness to the source of pollution. The results show pH values ranging from 5.7 to 6.5 with a mean value of 6.06±0.29 in the sample from the spot closest to the source of pollution. This value dropped to 5.56±0.26 in the next closest point and went up again to 6.10±0.53 at the farthest point (table 2).

From the table, the control had the least values averaging 5.5±0.65. There were however no significant (P≥0.05) mean differences among the sites.

Soil pH is the most commonly used of all soil properties. Regarded as a useful indicator of other soil parameters, the main value of its measurement is that it shows a soil to be acid, neutral or alkaline, and yields useful information about the availabilities of exchangeable cations such as calcium (Ca^{2+}), magnesium(Mg^{2+}), and potassium(K+) in the soil. Certain elements such as zinc (Zn), copper (Cu), manganese (Mn), iron (Fe) and aluminium (Al) are more available in very acid soils, and for Mn and Al more toxicity may result [6].

The pH values of all the soils investigated were within the acidic range and may not support the growth of most crops that thrive on alkaline soils. This is because acidic conditions would adversely affect soil chemistry with respect to plant nutrient availability and trace metal toxicity [22]. A high pH on the other hand can induce trace element deficiency. Microbial activity is also strongly pH dependent. Some plants are sensitive to acidity and some to alkalinity. Soils that are about neutral (7.0) or on the acid side of neutrality (6-7) are best suited for agriculture [1]. Electrical Conductivity figures ranged between 3 and 27µS/cm with a mean value of 16.4±11.90µS/cm in the area nearest to the source of pollution.

Table 2: Chemical Characteristics of Polluted and Unpolluted Soils in Ogoni

Soil Parameters	AD 10 M	BE 20 M	CF 30 M	O' CONTROL	Sig
pH	6.06±0.29	5.56±0.26	6.10±0.53	5.50±0.65	
Elect. Cond. (µS/cm)	16.40±11.90	20.0±6.70	73.00±13.71	10.20±6.00	
Organic Carbon (%)	1.39±0.55b	1.87±0.25a	1.22±0.19b	0.74±0.22c	*
Total Nitrogen (%)	0.04±0.01b	0.05±0.01b	0.04±0.01b	0.08±0.03a	*
C/N Ratio	33.0±13.20a	38.4±8.50a	31.80±10.70a	10.20±3.56b	*
Potassium (Cmol/kg)	0.18±0.03	0.17±0.03	0.18±0.05	0.21±0.03	
Sodium (Cmol/kg)	0.10±0.03a	0.06±0.02b	0.06±0.02b	0.04±0.02b	*
Calcium (Cmol/kg)	0.59±0.39	0.27±0.14	0.38±0.05	0.61±0.10	
Magnesium (Cmol/kg)	0.28±0.09b	0.36±0.06b	0.30±0.07b	0.48±0.06a	*
Cation Exchange Capacity (Cmol/kg)	1.12±0.33b	0.92±0.11b	0.90±0.08b	1.36±0.06a	*
Available Phosphorus (mg/kg)	15.9±14.80	13.40±11.90	12.10±7.98	18.15±4.19	
Nitrate(mg/kg)	1.29±0.59a	1.67±0.37a	1.00±0.61b	0.71±0.18c	*

Values are means ± Standard deviations of five replicates
Values on the same row having the same superscript letters are not significantly different at 5% level
AD 10 M : Within 10m radius from source of pollution
BE 20 M : Within 20m radius from source of pollution
CF 30 M : Within 30m radius from source of pollution
O' CTL : CONTROL

This increased with movement away from the pollution source to mean value of 20.0±6.7µS/cm and to a further 73.0±13.71. The control was the least with an average value of 10.20±6.0µS/cm. Although figures for Electrical conductivity indicated higher values for polluted sites comparably to the control, the noted differences were not significant (P≥0.05) at 5 percent level of significance. made similar observation where Electrical Conductivities of soils were increased with hydrocarbon contamination [23].

Electrical Conductivity is the estimate of the amount of Total Dissolved Salts (TDS) or the total amount of dissolved ions in salt water. However, the levels of contamination in all the soils were within acceptable limits for agriculture. Electrical Conductivity values of 4000µS/cm (4Ns/cm) which correspond to an osmotic pressure of 3.5 atmosphere in the soils solution at field capacity is generally accepted as the limit above which the yield of most sensitive crops starts to be affected [1]. It therefore follows that soils in the study area even with the contamination do not in their present state contain excess dissolved salts. No salinity problems. Some parameters which did not show clearly marked trends in their concentration among the sites were potassium (K) calcium(Ca), cation exchange capacity(CEC), and available phosphorus (P). All these parameters had higher concentrations obtained at their controls. The range of values for K for the point closest to the source of pollution (AD 10 M) was 0.13 -0.21 with a mean value of 0.18±0.03 Cmol/kg. This mean value dropped slightly 0.17±0.03 Cmol/kg in the sample next to the closest (BE 20 M), and then went up again to 0.18±0.05 in the last (CF 30 M). The control had the highest mean value of 0.21±0.03 Cmol/kg. Even though these results tend to suggest that potassium concentration decreased with nearness to source of pollution, these differences were not significant at 5 percent significant level. K range of between 0.18 and 0.50 Cmol/kg has been described as medium [29]. K level below 0.18 Cmol/kg is said to be low. The results show higher values for calcium averaging 0.61±0.10 Cmol/kg at the controls. This is higher than figures obtained at the spot closest to the source of pollution which averaged 0.59±0.39 Cmol/kg. The second and the last points (BE 20 M) and (CF 30 M) had figures averaging 0.27±0.14 and 0.38±0.05 Cmol/kg respectively. None of these differences was significant at 5 percent level. With these results, no trend was visible except for the slightly higher value at the control.

Cation Exchange Capacity and Available Phosphorus showed similar trends having the highest average values at the control, followed by the sample closest to the source of pollution. CEC showed significantly (P≤0.05) higher mean value at the control comparably to the sites under the influence of oil production activities. Values for all the other sites were not significantly different. The control had a mean value of 1.36±0.06 Cmol/kg. Further highlights of Table 2 show that for Nitrate, the sample from spots closest to the source of pollution had a set of values ranging from 0.65 to 2.18 with a mean value of 1.29±0.59 mg/kg. This rose to a mean of 1.67±0.37 in the second nearest sample but came down to a mean of 1.00±0.61. All these averages were significantly (P≤0.05) higher than that obtained at the control 0.71±0.18. These results indicate an increase in concentration of nitrate with oil production activities. Onyeike et al (2000) reported similar findings in a related study where higher concentrations of nitrate were observed in polluted soil samples comparably to the unpolluted soil samples. The data for organic carbon content was higher averaging 1.49 percent in the area closest to the source of pollution. In fact while mean values for the polluted area ranged between 1.22 and 1.87 percent, that for the control was 0.74±0.22. The differences were all significant at 5 percent level. These results clearly show increase in carbon content with nearness to sites of contamination. Soil organic matter contains about 60 percent by weight of carbon and 5 percent by weight of nitrogen [32]. The organic carbon content of soils is therefore widely used as a measure of its organic matter level by multiplying with a factor of 1.8 approximately [24]. Soils containing less than 1 percent organic carbon are considered low in organic matter [1]. By these estimations, soils in the area of study are deficient in organic carbon, a condition that received improvement with contamination.

Significant variations were also observed among sites with respect to Total Nitrogen and C/N ratio.
For Total Nitrogen the mean value at the control 0.08±0.03 percent was significantly (P≤0.05) higher than the mean values obtained in each of the three samples of the polluted area among which there was no significant difference observed. Total Nitrogen value below 0.1 percent is considered low for soils [1]. On the basis of this, soils in the area even without oil production activities are deficient in this resource. Values for Carbon-Nitrogen Ratio showed that significant variations existed between polluted and unpolluted sites. The control representing areas of non oil activity had significantly (P≤0.05) lower values than the areas under oil production activities. The range of figures for the spots closest to the source of pollution is 19 to 46 percent with a mean value of 33.0±13.20 percent. This mean value increased to 38.40±8.50 percent in the next closest and later came down to 31.80±10.70 percent in the last spot. There was no significant difference observed among the values. But they were all found to be significantly (P≤0.05) higher than the control with a range of value between 7 and 15 and averaging 10.20±3.56 percent. [33] reported C/N ratios for several locations in the South eastern region as Ikenanzizi (11.7), Owerri (13.0), Ikot-Ekpene (11.9), Elele (11.2), Ogoni (8.9), Umuagwo (10.0), Rumuokrushe (11.8), Uyo (11.5), and Abak (12.6). While a C/N ratio around 10 suggests satisfactory conditions for normal microbial activities and humus formation [34], a C/N ratio of between 10 and 12 is considered ideal, while higher values are considered not good [1]. Based on these results, oil production activities have affected this soil characteristic adversely.

Soil Bacterial Count

The data for Total heterotrophic bacteria (THB), the soil biological characteristic used to measure the level of soil pollution are shown in table 3.

Table 3: THB Count of Polluted and Unpolluted Soils in Ogoni

Sampling Points	THB Count of Soils in Ogoni (105 Cfu/ml)					
	Kpean	Kwawa	Zaakpon	K-Dere	Kpor	Mean ± SD
AD 10 M	4.9	6.4	5.1	5.0	4.4	5.16±0.74b
BE 20 M	4.8	4.2	3.8	3.6	3.6	4.00±0.51c
CF 30 M	6.2	8.1	6.5	6.4	7.3	6.90±0.79a
O' CTL	3.3	3.6	3.7	3.4	3.0	3.40±0.27c

Source: Results of Analysis

Values in the same column having same superscript letters are not significantly different at 5 percent level.

Although the precise relationship between variations in concentration and location and spatial variability is uncertain, it is clear that THB count reduced significantly at the control sites. Values obtained at the polluted sites are higher. The increase in carbon content in the contaminated sites would have been responsible for higher microbial activities as carbon could form feed stock for bacteria [23].

Conclusion

This study has shown that petroleum production activities affected the physical conditions of the soil in Ogoni by reducing soil temperature, moisture content, permeability, available water capacity and porosity while increasing soil bulk density. All these could affect physical fertility of the soil. Petroleum production activities also affected soil chemical characteristics by increasing some while reducing others significantly. All these show that the productivity of the soil could be negatively affected

Recommendations

This paper hereby recommends that in the oil production business, government should supervise the operation of the oil companies strictly and with due regard to the welfare of the inhabitants of the communities. Oil production should follow well acclaimed, scientifically proven standard practice. The oil companies should carry the host communities along in their activities. The host communities should forget the past, rely more on facts and show readiness to move forward. Soil test should precede crop farming activities. Wherever necessary, soil liming should be practiced before planting. Oil production can still go forward to the benefit of all [36].

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