

Interlocation Comparison Physicochemical Properties Of Polluted And Unpolluted Soil, Water And Sediment Ecosystems Of The Niger Delta Region

¹Antai S.P., ¹Iwatt G.D and ²Agbor R.B

¹Department of Microbiology, University of Calabar, Calabar

²Department of Genetics and Biotechnology, University of Calabar, Calabar

Abstract: These present study is an evaluation of the physicochemical properties of polluted and unpolluted soil, water and sediment ecosystems. The results indicate variations in physicochemical parameters among studied area. The pH, electrical conductivity (EC), dissolved oxygen (DO), salinity, phosphate and sulphate values were significantly lower in polluted sediment while the mean total organic carbon concentration was higher in polluted sediment. Comparison of the mean physicochemical parameters of petroleum hydrocarbon polluted and pristine soil samples showed significantly low mean pH, total nitrogen and available phosphorus values in polluted soils, whereas C:N ratio and calcium values were significantly ($p < 0.05$) higher in polluted soil. It can be concluded that the polluted soil, water and sediment ecosystem should be subjected to a suitable remediation methods, to reduce the effect of the pollutant in the environment.

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Introduction

In the past decades, there has been a great increase in industrial activities around the globe. These activities have commiserated in the introduction of vast quantities of organic and inorganic substances into the environment. Petroleum exploration, exploitation and other industrial activities result in pollution. Also gas flaring, constant oil spills and industrial effluent affect both aquatic and terrestrial ecosystems with destruction of forest and farmland (Dambo 2000; Mogo, 2002; Etesin 2002). crude oil and other petroleum products spillage occur due to a number of causes which include corrosion of pipelines and tankers, sabotage, oil production operation (normal and operational failures), inadequate or non functional production equipment (Dabbs, 1996). These petroleum contaminants contain different hydrocarbon components that may persist in the environment causing health problems to human and animals. Hydrocarbons and heavy metals have been found to accumulate in sediment and in organisms in the aquatic ecosystems over a long period of time after oil spills and related activities (Michael and Zengel, 1998; Lim et al., 1998; Etesin 2002; Chindah., 2004). Heavy metal pollution like petroleum hydrocarbon is also in the increase due to industrialization and urbanization. The use and release of heavy metals into the air, water and soils have created a significant number of contaminated sites around the globe. Thus, there has been extensive study on the effect of metal contamination of microbial community (Jones 1984). Acute effects of immediate exposure to toxic heavy

metals on microbial processes have been well studied (Ekpenyong et al., 2007). furthermore, long term effects of anthropogenic or natural metal contamination have been investigated (Kamaludeen et al., 2003). These studies have indicated that up to 100% of the bacteria in habitats contaminated for extended periods were metal resistant. Apparently, this heavy metal resistance is of great concern since studies have suggested simultaneous selection phenomena of antibiotic resistance and metal tolerance by bacteria (Mar, 1987)

Materials And Methods

Sampling locations

In the initial survey carried out 25 locations (13 soils and 12 aquatic) were identified for this study. All locations were situated in Akwa Ibom and Cross River States of Nigeria.

Sample collection

Before collecting samples GPS coordinates of each location was obtained using GPS 72H equipment (Garmin, Taiwan). Water samples were collected using sterile 250ml capacity media bottles. Sediment samples were obtained using Ponar grab sampler and aseptically transferred into 40z capacity Whirl- Pak bags (Nasco, USA). With the aid of sterile plastic hand trowel, mixed surface and subsurface soil samples were collected in duplicates and transported in ice-chest to the laboratory within six hours of collection.

Physicochemical analysis

Processing of soil and sediment samples

Soil and sediment samples for physicochemical analysis were air dried, ground, sieved and homogenized. Samples were re-bagged in Whirl-Pak bags from which portions were used for physicochemical analysis.

Determination of pH

Soil and sediment pH were determined using soil/ sediment solution ratio of 1:2 (10g of soil/ sediment in 20ml of distilled water), (McCauley et al., 2003). The pH was read with Hanna instrument pH/ conductivity/ Temperature meter HI 9811-5N (Hanna instrument, USA). The pH of water was determined directly using the same pH meter.

Determination of water temperature

Water temperature was determined onsite using the same meter mentioned above.

Determination of electrical conductivity (EC)

Sediment EC was determined in 1:5 sediment: water suspension. Ten grams (10g) of sediment was weighed into 50ml of de-ionized water and mechanically shaken at 15 rpm for 1 hour to dissolved soluble salts. The conductivity meter Model HI 9811-5N was calibrated with 0.01M KCl after which the cell constant was calculated using the formula:

$$K_c = 1412/C_{KCl} \times (0.0191 (t-25) + 1).$$

Where K_c = cell constant,

C_{KCl} = measured conductance, μS

t = observed temperature of standard KCl solution, $^{\circ}C$.

The conductivity of sediment suspension and water samples were measured by rinsing cell with one or more portions of sample, adjusting sample temperature to about $25^{\circ}C$.

The cell was further immersed in sample and the conductivity recorded with sample temperature. Following recording, the EC at $25^{\circ}C$ was calculated using the formula below:

$$EC (\mu S/cm) = CM \times K_c / [0.0191 (t-25) + 1]$$

Where K_c = the cell constant, $1/cm$

CM = measured conductance of the sample, μS

t = observed temperature of sample, $^{\circ}C$

(Rayment and Higginson, 1992).

Determination of dissolved oxygen

Dissolved oxygen in water samples was measured onsite with the aid of Model MW600 dissolved oxygen meter (Milwaukee instrument, USA). (APHA, 1992).

Determination of salinity

Water salinity was measured using Bench top meter Model 860033, (Sper Scientific, USA) with measurement range of 0-11.38 part per thousand (ppt).

Determination of organic carbon

Organic carbon in soil and sediment was determined colorimetrically using modified Walkley-Black method as described in methods in soil

microbiology and biochemistry (Alef and Nannipieri, 1995).

Total Nitrogen estimation

Total nitrogen was estimated by the macro-Kjeldahl digestion method as outlined by Jou (1979). Soil and sediment samples were digested with catalyst mixture and concentrated H_2SO_4 . The digest was distilled with 10N NaOH into boric indicator (H_3BO_3). The distillate was titrated with $0.01NH_2SO_4$ to a pink colour. A blank (without soil or sediment) was prepared and used. Percentage total nitrogen in the soil/sediment was calculated from the following equation:

$$\% Total N = \frac{M(T - B) \times 14 \times 100}{1000W}$$

Where M = normality of H_2SO_4 , T = ml, burette reading for the sample, B = ml, burette reading for the blank and W = weight of sample.

Available Phosphorus

Soil available phosphorus was extracted with acid fluoride using the Bray P-1 method (Bray and Kurtz, 1945). Phosphorus in the extract was determined colorimetrically by blue colour method of Murphy and Riley (1962) as outlined by Juo (1979).

Soil Potassium and sodium determination

The method of Jackson (1962) was adopted. Soil sample was extracted with 1N NH_4OAC (pH 7.0) using 1:10 soil solution ratio. Potassium and sodium in the extract were determined by flame photometry using flame photometer Model 420 (Sherwood Scientific Ltd, UK)

Nitrate, Sulphate and Phosphate determination

For extraction of nitrate and sulphate determination, 50g of each of the soil/sediment samples were weighed, transferred to 250ml stopper conical flask and agitated with exactly 50ml of distilled water (1:1 ratio) for 10 minutes using a mechanical shaker. After agitation, the samples were left for 30 minutes and filtered into Buchner funnels using Whatman No. 42 filter paper. Turbid filtrates were centrifuged at 3000rpm for 5 minutes.

The extraction for phosphate was carried out by weighing 50g of soil into 50ml of $NaHCO_3$ at pH 8.5. Agitation and filtration was performed as described above. Nitrate, sulphate and phosphate were analyzed according to the methods described by Mussa et al., (2009).

Particle size analysis

Soil and sediment particle size distribution was determined using Bouyoucos -type hydrometer method (Day, 1965).

Statistical analysis

Analytical software (SPSS version 16, quick Calcs online GraphPad and Microsoft excel) were used in analyzing the data obtained from this study. Means of soil, sediment and water physicochemical

parameters from sampled locations were compared using one way Analysis of Variance (ANOVA) and Duncan Multiple Ranged test used to test for significant difference among means.

Results

The physicochemical parameters of petroleum hydrocarbon polluted samples are presented in Table 1. The pH values of polluted water samples ranged between 5.26 ± 0.04 and 5.86 ± 0.64 and varied significantly ($p < 0.05$) among samples. The temperature of the polluted water samples was in the range of $26.3 \pm 0.5^{\circ}\text{C}$ and 27°C , and did not vary significantly ($p > 0.05$) among locations. Electrical conductivity (EC) of the polluted water samples ranged between $56.68 \pm 0.53 \mu\text{S}/\text{cm}$ and $73.01 \pm 1.75 \mu\text{S}/\text{cm}$ while dissolved oxygen (DO) was in the range of $2.61 \pm 0.01 \text{mg}/\text{l}$ to $5.17 \pm 0.01 \text{mg}/\text{l}$. Polluted water samples salinity ranged from $0.72 \pm 0.01\%$ to $2.23 \pm 0.01\%$. EC values varied significantly among locations. There was no significant variation in the DO values of samples CO6, DO6, HO6 and ZO6. Salinity values for samples AO6, CO6 and DO6 did not vary significantly. Nitrate, phosphate and sulphate levels in the polluted water samples ranged from 1.50 ± 0.01 to $2.17 \pm 0.04 \text{mg}/\text{l}$, 2.18 ± 0.04 to $4.51 \pm 0.04 \text{mg}/\text{l}$ and 6.29 ± 0.04 to $7.57 \pm 0.30 \text{mg}/\text{l}$ respectively. Significant variation ($p < 0.05$) in nitrate levels among samples was observed with the exception of the levels in samples AO6 and DO6 that showed no significant variation. Furthermore, phosphate levels vary significantly ($P < 0.05$) with the exception of the levels in samples CO6 and DO6. For samples HO6 and ZO6, there was no significant variation in sulphate levels.

Table 2 is based on the physicochemical parameters of pristine water samples. The pH, temperature and electrical conductivity and dissolved oxygen values ranged from 5.57 ± 0.02 to 6.64 ± 0.2 , 25.3 ± 0.6 to $27.3 \pm 0.5^{\circ}\text{C}$, 3.36 ± 0.03 to $46.76 \pm 0.53 \mu\text{S}/\text{cm}$, and 4.25 ± 0.01 and $7.41 \pm 0.01 \text{mg}/\text{l}$ respectively. There was significant variation ($p < 0.05$) in the pH values of samples with exception of values for samples NS and EE that did not differ significantly. Water temperature varied among locations except for the values for locations CR and EE that showed no significant difference. EC values of samples- ST, NS and EE did not vary significantly whereas the DO levels varied significantly ($p < 0.05$) among all samples. Pristine water samples had salinity values of 0.01 to $0.03 \pm 0.01\%$ with nitrate, phosphate and sulphate levels varied significantly ($p < 0.05$) among samples with the exception of nitrate levels in samples CR and EE, phosphate levels in samples ST, IT and EE and sulphate levels in samples IT and EE.

Table 3 presented the mean physicochemical parameters of petroleum hydrocarbon polluted water in relation to pristine water. Comparatively, the observed mean values of some physicochemical parameters of petroleum hydrocarbon polluted water were significantly ($p < 0.05$) different from those of the pristine water. Mean EC, salinity and phosphate values were significantly higher in polluted water than in pristine water while mean pH, DO and sulphate values were significantly ($p < 0.05$) higher in pristine water than in polluted water. There was no significant difference in the mean values of pH, temperature and nitrate in both polluted and pristine water.

Physicochemical properties of underlying sediment samples

Fig. 1. presents some physicochemical properties of underlying sediment samples from polluted aquatic ecosystems. pH values varied from 4.33 ± 0.03 to 5.20 ± 0.01 while EC values ranged from 106.00 ± 4.58 to $226.67 \pm 7.02 \mu\text{S}/\text{cm}$. The pH values of samples AO6 and CO6 did not vary significantly from each other. There was no significant difference ($p = 0.320$) in the EC values of samples AO6, CO6 and DO6. In addition, the EC values of samples FO6 and HO6 did not differ significantly ($p = 0.058$), however the highest EC value of $226.67 \mu\text{S}/\text{cm}$ was obtained in samples ZO6 and this value differed significantly ($p < 0.05$) from that of other polluted sediment samples. Percentage total organic carbon (TOC) and nitrogen (N) were in the range of 5.21 ± 0.02 to $7.13 \pm 0.31\%$ and 0.14 ± 0.01 to $0.37 \pm 0.04\%$ respectively. TOC levels in samples AO6, CO6 and FO6 showed no significant difference ($p = 0.062$) while nitrogen levels in samples AO6, CO6 and DO6 did not vary significantly ($p = 0.053$). Polluted sediment nitrate level was in the range of $3.85 \pm 0.04 \text{mg}/\text{kg}$ to $4.40 \pm 0.02 \text{mg}/\text{kg}$ while sulphate level varied between 7.05 ± 0.05 and $10.12 \pm 0.02 \text{mg}/\text{kg}$. Nitrate levels in samples AO6, HO6 and ZO6. Sulphate levels were not significantly different ($p = 0.110$). Also, sulphate levels in samples FO6 and HO6 did not differ significantly ($p = 0.410$). Particle size analysis of most sediment samples (AO6, CO6, DO6 and ZO6) revealed the textural class of sandy clay loam (SCL) while samples from locations-FO6 and HO6 were classified as sandy loam (SL) and loamy sand (LS) respectively. The physicochemical properties of pristine sediment as presented in Fig. 1 shows pH values ranging from 5.16 ± 0.04 to 5.44 ± 0.02 and EC values of 107.67 ± 2.06 to $225.66 \pm 5.68 \mu\text{S}/\text{cm}$. The values varied significantly ($p < 0.05$) among all samples with the pH values of the following pairs (EE-ST, ST-NS and NS-OK) not significantly different ($p = 0.687$, $p = 0.073$ and $p = 0.483$). Though, there was significant variation ($p < 0.05$) in the EC values of all samples, the values for samples NS and EE showed no significant difference ($p = 0.193$). Total

organic carbon (TOC) values of between 2.01 ± 0.27 and $4.84 \pm 0.55\%$ were obtained in the pristine sediment while percentage nitrogen was in the range of 0.24 ± 0.02 to $0.41 \pm 0.04\%$. Nitrate and sulphate levels obtained were 10.01 ± 0.27 to $13.21 \pm 0.31 \text{ mg/kg}$ and 5.11 ± 0.39 to $26.74 \pm 1.48 \text{ mg/kg}$ respectively. There was significant variation ($p < 0.05$) in TOC, total nitrogen, nitrate and sulphate values among all samples. Duncan Multiple range test showed no significant difference ($p = 0.057$) among TOC value of samples ST, IT, NS and CR. Also TOC values of samples OK and EE were not significantly different ($p = 0.889$). Particle size analysis showed textural class of sediment samples-OK, CR and EE as sand, NS as sandy clay loam (SCL), ST as loamy sand (LS) and IT as sandy loam (SL).

Table 2 presents the t-test result of the mean of some physicochemical parameters of petroleum hydrocarbon polluted sediments in relation to pristine sediment. The observed difference in the means of pH, nitrate and sulphate were significantly ($p < 0.05$) higher in pristine sediments than in polluted sediments whereas the mean total organic carbon (TOC) was significantly ($p < 0.05$) higher in polluted sediments as compared to pristine sediments. The mean total nitrogen and electrical conductivity (EC), were not

significantly ($p > 0.05$) different in polluted and pristine sediments.

Physicochemical properties of soil samples

Some physicochemical properties of polluted soil samples are presented in Fig. 2 polluted soil samples were acidic with pH values in the range of 4.37 ± 0.01 to 5.77 ± 0.21 . The organic carbon content of the various polluted soil samples was between $7.63 \pm 1.19\%$ and $12.66 \pm 0.96\%$ while total nitrogen content was between $0.23 \pm 0.02\%$ and $0.66 \pm 0.04\%$. Consequently, the C:N ratio values ranged from 18.2 ± 1.1 to 46.5 ± 5.7 . The polluted soil levels of available phosphorus, calcium, magnesium, sodium and potassium vary from 11.82 ± 0.43 to $20.87 \pm 0.40 \text{ mg/kg}$, 4.64 ± 0.04 to $7.87 \pm 0.39 \text{ cmol/kg}$, 2.49 ± 0.06 to $4.41 \pm 0.04 \text{ cmol/kg}$, 0.20 ± 0.01 to $0.45 \pm 0.02 \text{ cmol/kg}$ and 0.07 ± 0.01 to $0.21 \pm 0.02 \text{ cmol/kg}$ respectively. Polluted soil textural classes were loamy sand (samples-A, B, D, E and G) and sandy loam (Sample-C and F) with EA, ECEC and BS values of ranging from 1.08 ± 0.01 to $1.27 \pm 0.01 \text{ cmol/kg}$, 9.09 ± 0.12 to $13.73 \pm 0.12 \text{ cmol/kg}$ and 88.0 ± 0.3 to $90.9 \pm 0.2\%$ respectively. All physico-chemical parameters from the different polluted soil samples varied significantly ($P < 0.05$).

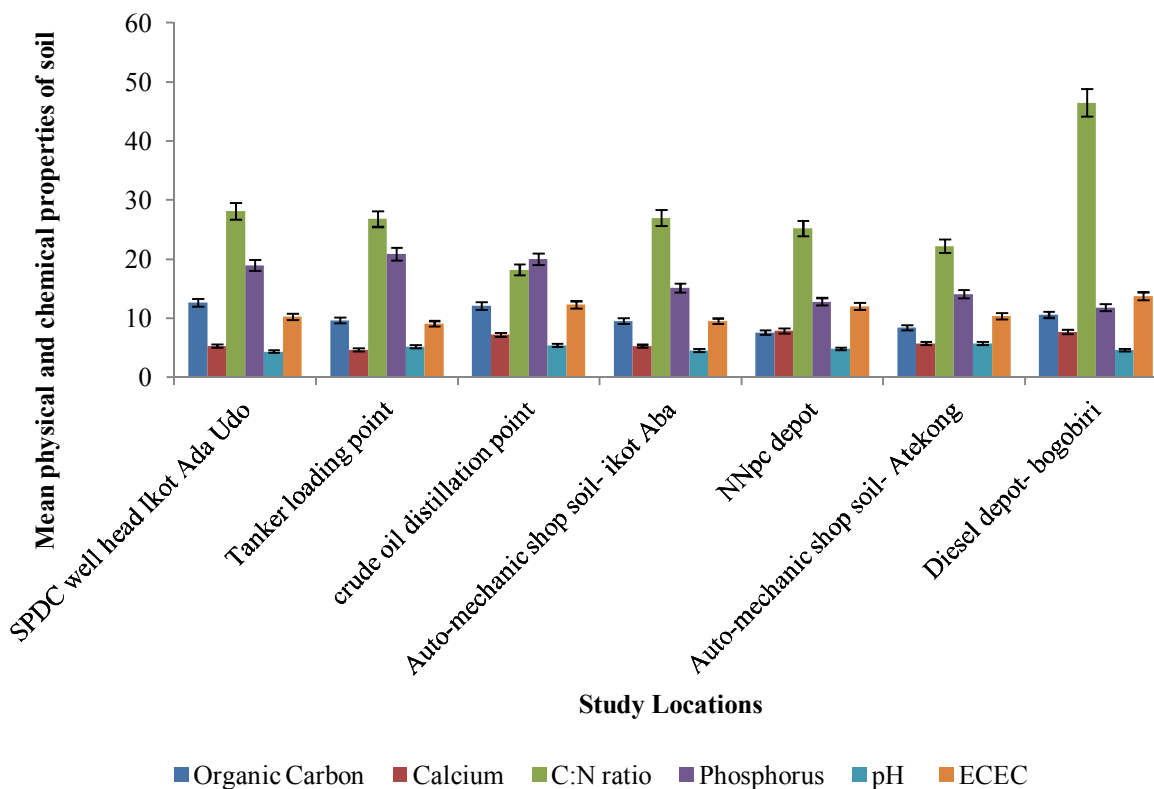


Figure 1: Inter-location comparison of physicochemical parameters from petroleum hydrocarbon polluted soil samples

Table 1: Inter-location comparison of some physicochemical parameters of petroleum hydrocarbon polluted water samples.

Physico-chemical parameters of samples	Location code					
	AO6	CO6	DO6	FO6	HO6	ZO6
pH	5.44 ^{ab} ±0.02	5.50 ^{ab} ±0.02	5.86 ^b ±0.64	5.26 ^a ±0.04	5.26 ^a ±0.09	5.60 ^{ab} ±0.01
Temp. (°C)	26.3 ^a ±0.5	26.7 ^a ±0.3	26.5 ^a ±0.5	27.6 ^a ±0.5	26.4 ^a ±0.1	27.0 ^a ±0.0
EC(μS/cm)	56.68 ^a ±0.53	60.17 ^b ±0.25	60.65 ^{bc} ±0.40	61.95 ^c ±1.27	70.79 ^d ±0.33	73.01 ^c ±1.75
DO (mg/l)	5.17 ^c ±0.01	4.00 ^b ±0.03	4.01 ^b ±0.02=1	2.61 ^a ±0.01	4.24 ^b ±1.13	4.03 ^b ±0.01
Salinity (%)	2.23 ^d ±0.01	2.21 ^d ±0.03	2.31 ^d ±0.03	0.72 ^a ±0.01	1.25 ^c ±0.02	1.16 ^b ±0.01
Nitrate (mg/l)	1.72 ^c ±0.45	1.66 ^b ±0.01	1.70 ^c ±0.01	1.50 ^a ±0.01	2.08 ^d ±0.02	2.17 ^c ±0.04
Phosphate (mg/l)	4.51 ^c ±0.04	4.21 ^d ±0.02	4.12 ^d ±0.12	3.19 ^c ±0.05	2.30 ^b ±0.02	2.18 ^a ±0.04
Sulphate (mg/l)	7.57 ^c ±0.30	6.75 ^c ±0.01	7.17 ^d ±0.01	5.84 ^a ±0.21	6.39 ^b ±0.02	6.29 ^b ±0.04

Table 2: Inter-location comparison of some physicochemical parameters of pristine water samples.

Physico-chemical parameters of samples	Location code					
	ST	OK	IT	CR	NS	EE
PH	5.81 ^b ±0.01	5.57 ^a ±0.02	6.05 ^d ±0.05	6.64 ^c ±0.02	5.98 ^c ±0.02	5.95 ^c ±0.02
Temp. (°C)	25.3 ^{ab} ±0.6	25.6 ^{bc} ±0.3	24.3 ^a ±0.5	27.6 ^a ±0.5	26.36 ^{cc} ±0.5	26.7 ^{dc} ±0.5
EC(μS/cm)	42.81 ^b ±1.33	33.36 ^a ±0.83	46.76 ^c ±0.53	50.93 ^d ±1.03	42.84 ^b ±0.73	42.74 ^b ±0.67
DO (mg/l)	7.41 ^f ±0.01	7.15 ^e ±0.01	4.25 ^a ±0.02=1	7.03 ^d ±0.03	4.63 ^b ±0.02	5.06 ^c ±0.01
Salinity (%)	0.01 ^a ±0.00	0.02 ^c ±0.01	0.03 ^c ±0.01	0.01 ^a ±0.00	0.02 ^{bc} ±0.01	0.01 ^{ab} ±0.01
Nitrate (mg/l)	7.58 ^c ±0.06	3.42 ^b ±0.28	10.61 ^d ±0.31	1.09 ^a ±0.12	27.40 ^c ±0.10	1.27 ^a ±0.24
Phosphate (mg/l)	0.04 ^a ±0.01	0.13 ^c ±0.02	0.05 ^a ±0.01	0.07 ^b ±0.01	1.15 ^d ±0.01	0.03 ^a ±0.01
Sulphate (mg/l)	2.34 ^a ±0.06	11.10 ^b ±0.28	20.80 ^d ±0.31	18.22 ^a ±0.12	24.26 ^c ±0.10	21.04 ^d ±0.24

Table 3 Inter-location comparison of physico-chemical parameters from petroleum hydrocarbon polluted sediments

Physico-chemical parameters of samples	Location code					
	AO6	CO6	DO6	FO6	HO6	ZO6
pH	4.63 ^b ±0.06	4.83 ^d ±0.01	4.63 ^b ±0.01	4.77 ^c ±0.03	5.20 ^c ±0.01	4.33 ^a ±0.03
EC (μS/cm)	119.67 ^b ±3.05	121.33 ^b ±1.53	123.0 ^b ±1.00	106.00 ^a ±4.58	112.41 ^a ±1.02	226.67 ^c ±7.02
TOC (%)	6.56 ^{bc} ±.31	7.26 ^c ±0.08	6.26 ^b ±0.03	7.13 ^c ±0.31	5.21 ^a ±0.02	7.96 ^b ±0.86
N (%)	0.33 ^c ±.01	0.34 ^c ±0.01	0.31 ^c ±0.02	0.37 ^d ±.04	0.18 ^b ±0.01	0.14 ^a ±0.01
Nitrate (mg/l)	4.03 ^{bb} ±.07	4.10 ^{bc} ±.01	4.40 ^d ±.02	4.24 ^{cd} ±.06	3.85 ^a ±0.04	3.90 ^a ±0.21
Sulphate(mg/l)	9.39 ^b ±.38	9.94 ^b ±0.25	10.12 ^c ±0.02	7.31 ^a ±0.77	7.05 ^a ±0.05	9.94 ^b ±0.28
Sand (%)	54.57	52.40	50.62	70.53	82.66	47.94
Silt(%)	17.06	18.72	19.16	11.63	7.30	18.13
Clay (%)	22.37	28.88	30.22	17.84	10.04	33.93
Textural class	SCL	SCL	SCL	SL	LS	SCL

EC=Electrical conductivity, TOC=Total organic carbon, N= Total nitrogen, SCL=Sandy Clay Loam, SL= Sandy Loam, LS= Loamy Sand AO6=Utaewa-Jaja creek, CO6 = Location 1-Essene creek, DO6=Location 2-Essene creek, FO6=Ukan beach-Essene creek, HO6=Imo River, ZO6=Enen Idem. Mean ±SD, Means in row with the same letter are not significantly different from each other (Duncan Multiple Range test, P<0.05).

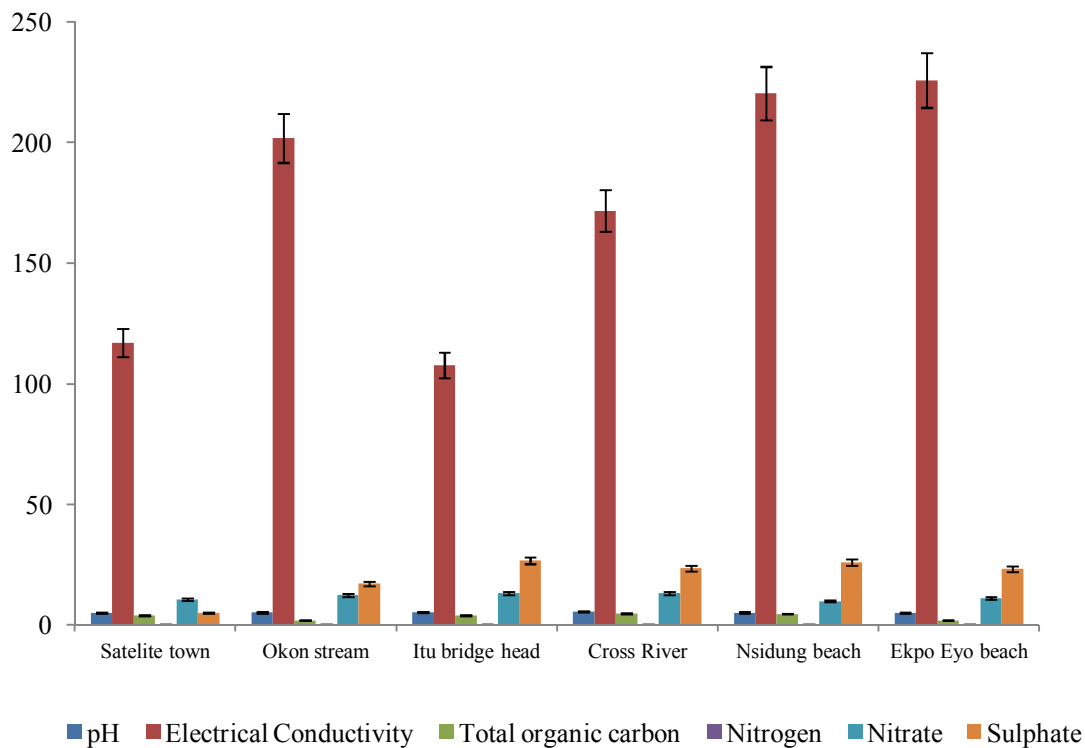


Figure 2: Inter-location comparison of physicochemical parameters from pristine sediments

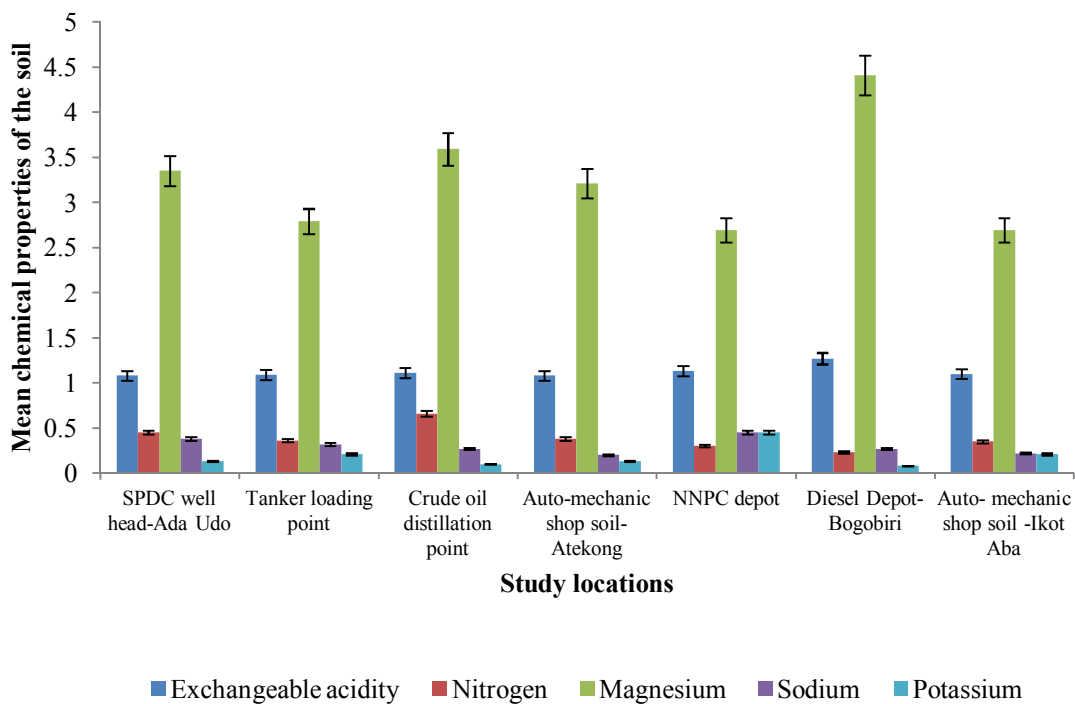


Figure 3: Inter-location comparison of physicochemical parameters from petroleum hydrocarbon polluted soil samples

Discussion

The physicochemical properties of any ecosystem in the event of pollution with organic or chemical compounds are bound to alter. In this study, changes in some physicochemical parameters of the petroleum hydrocarbon polluted ecosystems were observed in relation to the background pristine ecosystems. In the aquatic ecosystems, the mean pH values for polluted water samples (5.48 ± 0.22) was significantly ($p < 0.05$) lower than the mean value for pristine water samples (6.00 ± 0.35). Also, the mean pH value for the underlying polluted sediment samples was significantly lower ($p < 0.05$) than that of the pristine sediment samples. This difference could be attributed to the presence of acidic components resulting from the microbial utilization of hydrocarbon pollutants in the ecosystem studied. Swingle (2000) reported that organic waste reduces the pH of water and sediment to acidic level. The pH values recorded for petroleum hydrocarbon polluted water samples were below the pH range of between 6 and 9 regarded as optimum for fish and aquatic life in the freshwater ecosystems (Chapman and Kimstach, 1992).

Dissolved ions are responsible for electrical conductivity. In this study, EC values of pristine and polluted water samples varied among locations with the EC value for polluted water ($63.87 \pm 6.49 \mu\text{S/cm}$) significantly ($p < 0.05$) greater than the mean EC values ($43.24 \pm 5.82 \mu\text{S/cm}$) for pristine water. Also, the EC values for underlying sediment samples from the same locations as the water samples showed great variability with no significant difference between the mean EC values of polluted and pristine sediments. Though, the EC values of the study locations were within the range for a freshwater ecosystem and low as reported by Ezekiel et al. (2011) for freshwater zones of the Niger delta region of Nigeria. Nevertheless, the significant high mean EC values for the polluted water may possibly be attributed to the illegal crude oil distillation activities at the polluted locations. These anthropogenic activities could increase the concentration of ions in the water ecosystem.

One of the generally accepted indicator for water quality is the dissolved oxygen. DO concentrations below 5mg/l adversely affect the functioning and survival of biological communities and below 2 mg/l may lead to the death of most fishes (Chapman and Kimstach, 1992). The mean dissolved oxygen (DO) values for petroleum hydrocarbon polluted waters was less than 5mg/l and significantly ($p < 0.05$) lower than the mean value for the pristine waters. This low DO values may be due to the depletion of oxygen resulting from possible aerobic biodegradation of the petroleum

hydrocarbon pollutants by water microorganisms. In terms of salinity, the ecosystems studied were characterized by low salinity typical of freshwater ecosystems. There was variability in salinity levels in both polluted and pristine waters but the mean salinity level was significantly ($p < 0.05$) higher in polluted than in pristine water samples. The significant difference in salinity could not be linked to the petroleum hydrocarbon pollution; however, there are several other factors that could have brought about variability and salinity alterations in aquatic ecosystems. According to the Orlando et al. (1994), the frequency and magnitude of this variability differs in each estuary, largely as a result of fresh water inflow, astronomical tides, wind and coastal shelf processes.

In aquatic ecosystem, the concentration of nutrients is a strong indicator of the health of the ecosystem. Nitrate, phosphate and sulphate are classified as pollutants when found in excess in aquatic systems. Excess of nitrate and phosphate can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that lives in the aquatic system. This, in turn, affects dissolved oxygen, temperature and other indicators. Nitrate levels in the studied aquatic systems varied significantly ($p < 0.05$) with the highest nitrate level recorded in water sample from Nsidung beach (NS). However, the mean nitrate level of petroleum hydrocarbon polluted water samples was not statistically different from that of the pristine water samples. On the other hand, the observed variability in phosphate and sulphate levels among petroleum hydrocarbon polluted and pristine water samples respectively, was accompanied by significant differences ($p < 0.05$) in their mean levels between the petroleum hydrocarbon polluted and pristine aquatic ecosystems. In spite of these differences, the nutrient levels in both petroleum hydrocarbons polluted and pristine aquatic ecosystems were low suggesting no nutrient pollution of the studied aquatic system by runoff from fertilized agricultural land, animal and human wastes. The low nutrient levels observed in this study corroborates the report of Chinda et al. (1999) and Chinda and Braide (2003) who observed low nutrient level for Niger Delta river system. The polluted soil in this study was characterized by significant low pH, total nitrogen, available phosphorus and high C:N ratio in relation to the pristine soil. Other physicochemical parameters showed no significant difference between the polluted and pristine soil ecosystem. Changes in soil properties during hydrocarbon pollution have always been reported but the effect on some soil physicochemical

parameters always seem to be outstanding. Soil pH is the most commonly measured parameters and it yields useful information on the availability of nutrient element and also affects the abundance of microorganisms. It is well known that in the event of petroleum spill on soil, the activities of microbes that are able to degrade petroleum hydrocarbon alter the soil pH due to the accumulation of acidic metabolites. In this study, the pH values of both polluted and pristine soils were acidic, thus corroborating the result of Puyate and Rim-Rukeh (2008) who reported pH values of 5.2 to 6.2 for soil in the Niger Delat area. However, the increased acidic levels in petroleum hydrocarbon polluted soils could be attributed to the microbial breakdown of this pollutant to yield acidic metabolites. This observation agrees with that of UJowundu et al (2011) who reported low pH value in diesel contaminated soil compared to uncontaminated soil. Soil total nitrogen and available phosphorus have been reported to be reduced as a consequence of petroleum pollution (Deni and Peninckx, 1999; Okolo et al., 2005). This study is in line with that report as petroleum polluted soil had significant ($p < 0.05$) low total nitrogen and available phosphorus as compared to the pristine soil. This low values especially that of nitrogen may be due to the proliferation of total heterotrophic bacteria and hydrocarbon degraders that make use of the nutrients leading to depletion. This is also reflected in the high C:N ratio as seen in the polluted soil samples. There was no remarkable difference in other soil physicochemical parameters in this study.

Reference

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