ASSESSMENT OF SOIL QUALITY IN A CRUDE OIL IMPACTED SITE IN AGUOBIRI, BAYELSA STATE

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ABSTRACT

Soil quality in Aguobiri was determined to assess its suitability for agriculture. *Twelve (12) soil samples were obtained in three different locations with the help of a hand auger. The heavy metals were determined using the atomic absorption spectrophotometer (AAS) using thermo-electron AA series. Geochemical investigation involving physiochemical, heavy metals, and Total Petroleum Hydrocarbon (TPC) were analysed in the area. SPSS 16.0 version statistical software was used to analyse the soil results. ANOVA was performed at 95% 0.05 significant levels in order to check the variational trend between the impacted sites and the non- impacted area. The results indicated significant difference in the concentration of Pb^{2+}, TPC, Zn^{2+}, CEC and Cu^{2+} in the impacted area compared to non-impacted site and established standard. The results also show that most of the parameters exceeded the background values and natural concentration in the soil at the impacted sites, which implies pollution. Hence, effective bioremediation is strongly recommended for detoxification of the soil in the area.*

INTRODUCTION

Industrial contamination such as crude oil is one of the most extensive environmental pollutants in Nigeria. (IFPRI, 2008). The concentration of crude oil at the subsurface is a reflection and a function of the geologic material (soil type). Crude oil activities on the land had contributed immensely to poverty due to soil degradation that leads to low agricultural yield, Soil degradation has a significant correlation with poverty. Poverty arises when there is a decline in soil fertility which eventually leads to poor food production as a result of soil degradation caused by oil spillage and other environmental pollutants. Food security exists when all the people at all times have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. To a large extent, people of Aguobiri depend on subsistence endeavours, because they are situated at the fresh water coastlines of the Niger Delta which are criss-crossed by many creeks and rivers. The available farm lands are being threatened by crude oil activities. Notwithstanding the foregoing, there has been no attempt of soil quality assessment in the area of investigation. In the present

report, geochemical analysis of soil was carried out to know the trend of the impacted and non-impacted area of Aguobiri in Southern Nigeria. Aguobiri Community is accessible by road and river. Moreover, it is a low land which is surrounded by tidal flats, flood plains and lagoons, forming its dominant geology. The people are mainly peasant farmers who rely on rainfall for subsistence agriculture. The area experiences alternating climatic season between wet and dry season usually from March to October.
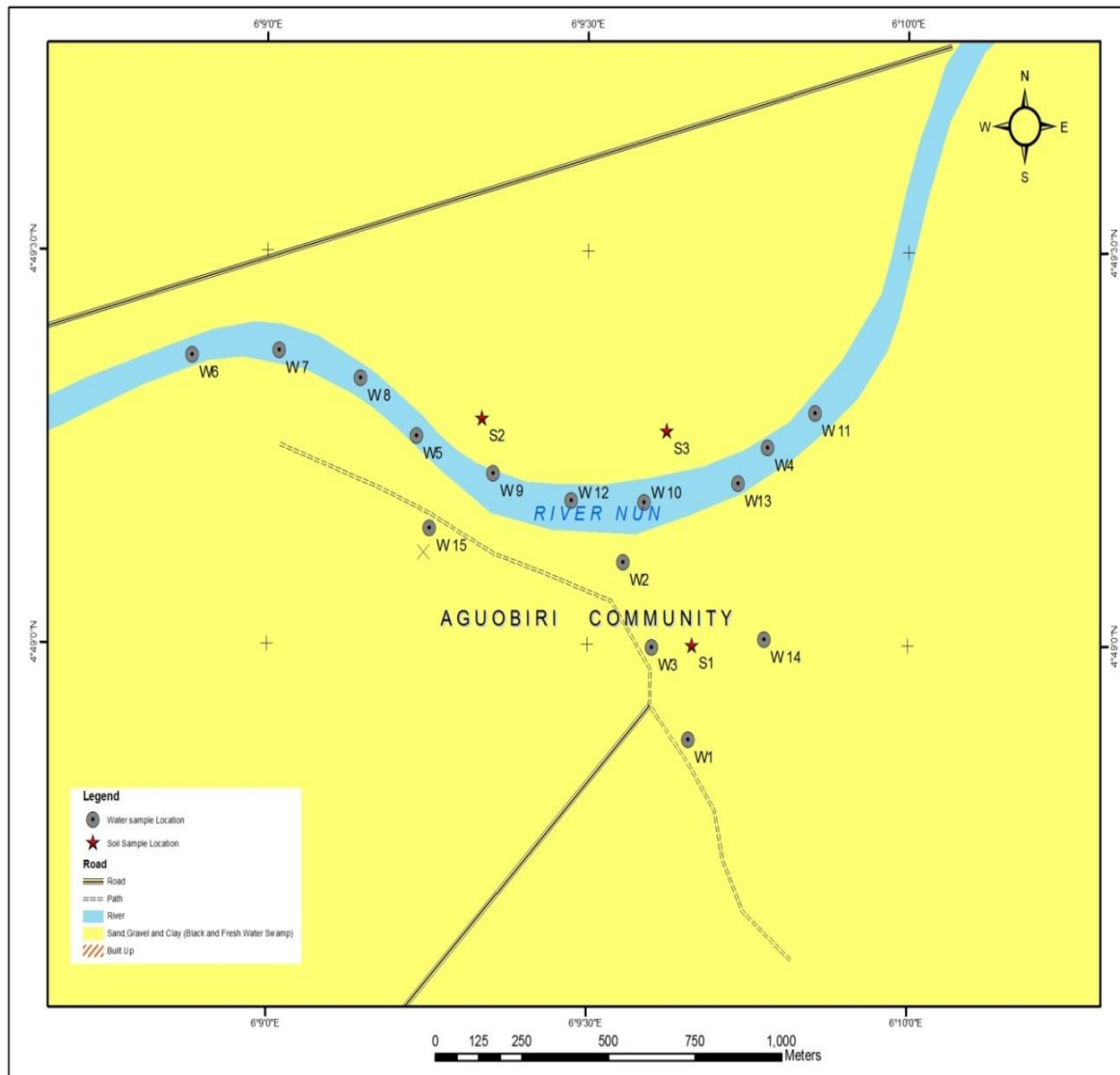
Fig 1: Geologic and Location Map of the Study Area indicating Sampling points

Sampled location showing the water sampled points and soil sampled points

MATERIAL AND METHODS

The investigated area lies within latitude 04^049' to $04^049.2$'N and longitude $006^009.1$'E. It is situated on the Nun River creek which empties into the Atlantic Ocean.

Plate 1: Showing Crude Oil Impacted site in the Study Area

Study area (Fig. 1), lies within the fresh water coastal line which cuts across creeks and rivers of the Niger Delta. The Niger Delta developed at the site of a rift triple junction related to the opening up of the Southern Atlantic starting in the late Jurassic and continuing into the Cretaceous accumulating sediment that are now over 10 kilometre thick (Short and Stauble, 1967;Doust and Omatsola, 1990). The detailed Geology of the Niger Delta has earlier been discussed by (Allen, 1965; Reyment, 1965; Etu-Efeotor, 1981; Udom*et al,* 1998; Offodile,1992).

Geochemical investigation involving twelve (12) soil samples, in order of topsoil, 30cm, 60cm, and 100cm (1m) were sampled in 3 different locations, 2 from the pipeline impacted area and one from non-impacted site as control point. Soil boring was done with a 5 metres length collapsible hand auger. Macroscopic observation of physical properties of the soil which includes the colour, particles size, and soil type were done in situ in the field. Twelve (12) samples were collected and stored in white nylon bags and properly labelled and then transported to the laboratory for analysis according to (Allen *et al* 1974; Adelekan and Abegunde, 2011).

Laboratory Analysis of Soil
A prescribed analytical format (Carter, 1993) was followed in order to obtain reliable data in line with the standard laboratory techniques (soil quality assessment procedure), In the same vein soil analysis evaluation in the laboratory encompasses the determination of Total Petroleum Content (TPC), cations , anions and Heavy metals content.

The soil samples were air dried on a wooden tray for 3 days and then ground in an agate molter with pestle and sieve with 2mm. The cations were determined as follows; five grams of soil was weighed into a flask, 100ml of neutral ammonium (NH_4) was added. It was passed through a mechanical sieve for 30 minutes. The solution was decanted into a clean container using a filter paper and a funnel. Estimation of Magnesium (Mg^{2+}) and Calcium (Ca^{2+}), was done by EDTA titration. Whereas, Sodium (Na^+), and Potassium (K^+) were analysed through flame photometer. The determination of p^H was analysed as follows; 20 grams of soil was taken, and diluted with 20ml of distilled water and weighed. This was allowed to stand for 1 hour to calibrate, using p^H 4, and 7. Thep^H was measured after calibration. The heavy metals in the soil were analysed using six grams of dissolved soil sample. While the extraction was done with 60ml double sulphur by atomic absorption. Zn, Fe, Ni, Cu, were also determined by atomic absorption while vanadium and mercury were determined by colometric method. The Total Petroleum Content (TPC) was analysed as follows; 5 grams of processed soil was weighed in glass container, and 20ml of normal enzyme was added. It was then placed in a shaker for five (5) minutes to recover (TPC) and was allowed to settle out. Decounting enzyme layer was made carefully to measure the absorbance with spectrophometer at 490nm.The concentration of crude oil was calculated using a length of 416nm.

RESULTS

Table1: Results of Soil and Statistical Analysis of soil quality in Aguobiri, Bayelsa state.

Location	Parameters	Units	Control site	Impacted site 1	Impacted site 2
Aguobiri	pH		6.81±0.09a	5.30±0.34a	5.8±0.35a
	E.C	(µs/cm)	2.47±0.34a	4.72±1.26a	4.54±0.64a
	O.C	(%)	0.03±0.07a	0.92±0.16b	4.54±0.64c
	N	%	0.31±0.01a	0.07±0.01a	0.20±0.12a
	Ca	(mg/kg)	9.54±0.58c	3.68±0.65a	2.77±0.49a
	Mg	(mg/kg)	5.67±0.29c	3.08±0.70a	2.18±0.81a
	Na	(mg/kg)	0.58±0.01c	0.31±0.02b	0.26±0.01a
	K	(mg/kg)	0.15±0.01a	0.10±0.01a	0.12±0.06a
	NO_3	(mg/kg)	0.63±0.31a	0.92±0.75a	0.59±0.36a
	SO_4	(mg/kg)	1.89±0.45a	4.03±0.97a	2.37±0.63a
	Cl	(mg/kg)	121.0±1.62a	639.0±71.0a	639±2.12a
	Salinity		4.34±0.58c	12013±1.33a	2536±9.34a
	Zn	(mg/kg)	0.00±0.00	2.10±0.52a	1.83±0.13a
	V	(mg/kg)	0.00±0.00	2.45±0.58b	4.52±0.56b
	Pb	(mg/kg)	0.73±52.30a	12.8±1.39b	12.90±1.39b
	Cu	(mg/kg)	0.00±0.00	0.79±0.14a	1.06±0.23a
	Cr	(mg/kg)	3.57±1.23a	0.00±0.00	0.00±0.00
	Mn	(mg/kg)	3.40±0.57a	7.49±1.82	6.26±0.79a
	Ni	(mg/kg)	3.40±0.57a	8.40±5.30	0.00±0.00
	Hg	(mg/kg)	0.00±0.00	0.00±0.00	0.00±0.00
	TPC	(mg/kg)	0.29±0.07a	30.12±0.00b	48.20±0.00b
	CEC	(mg/kg)	10.85±0.65b	7.17±1.20a	5.33±0.88a
	Fe	(mg/kg)	8.30±2.14a	14.53±3.02ab	20.35±0.06b

Mean values ± SEM with similar alphabelt on the same column are not significantly different from each other at p≤ 0.05.

Table 2: Result for Heavy Metals in the Soil Samples

S/N	Sample Location Description	Mn	Ni	V	Pb	Hg	TPC
				mg/kg[1]			
1	Impacted Site 1 TOP SOIL	3.16	4.98	4.04	10.21	ND	35.69
2	Impacted site 1 30CM	5.77	2.92	8.26	15.00	ND	45.33
3	Impacted 1 60CM	10.29	1.52	0.321	20.03	ND	20.81
4	Impacted 1 1M	10.75	24.18	0.011	6.01	ND	18.68
5	Control top soil	7.19	4.90	ND	ND	ND	0.39
6	Control 30cm	3.13	3.71	ND	ND	ND	0.43
7	Control 60cm	2.12	2.56	ND	0.005	ND	0.23
8	Control 1m	1.87	2.45	ND	ND	ND	0.12
9	Impacted site 2 TOP SOIL	5.98	10.24	4.01	15.0	ND	45.94
10	Impacted site 2 30CM	5.16	46.72	5.01	10.10	ND	60.90
11	Impacted site 2 60CM	8.59	47.60	6.07	18.16	ND	67.63
12	Impacted site 2 1M	5.34	11.08	8.03	8.12	ND	18.47

SPSS 16.0 version statistical software was used to analyze the physiochemical results. ANOVA was performed using Duncan Multiple Range (DMR) a software specification at 0.05 significant levels (95%). The statistical result is presented in Table (1) one which illustrates the analytical results of the soil physiochemical parameters. Significant differences did not occur in p^H, EC, O.C, N%, K^+, NO_3, SO_4, Cl^-, and Mn,between the control site and the impacted sites. But significant differences occur in Pb^{2+}, TPC, CEC, Fe^{2+}, Mg^{2+}, and salinity, between the two sites.

DISCUSSION

The soil samples from the study area are acidic in nature as recorded from analysis. The p^H values obtained from the soils are characteristics of soil of the fresh water swamp forest of Nigeria in which the research work was carried out Acidic condition is also known to contribute to corrosiveness as well as influences chemical reaction rates and speed up biological processes, (Moore et al; 1998, Imasuen and Onyeobi; 2013). Soil p^H which are between 6.0 and 7.5 are seen as normal and p^H lower than six (6) induces Phosphorus into insoluble compounds with iron and aluminium (Hue, 2008). Similarly, p^H higher than 7.5 incorporates phosphorus into insoluble compounds with calcium (Moore et al; 1998). In the investigated area, soil acidity can be classified as; Top soil-very acidic, 30cm - very acidic, 60cm- moderately acidic and 1m- slightly acidic in the impacted site 1. Whereas, the impacted site 2 was classified thus; top soil very acidic, 30cm moderately acidic, 60cm, slightly acidic, 1m slightly acidic. The control site also indicated as; top soil strongly acidic, 30cm moderately acidic, 60cm slightly acidic, and 1m slightly acidic. This shows that the concentration of soil acidity in the investigated area varies with depth; acidity reduces as the depth increases. The organic content of soil in the study area is rich in macronutrients; and hence supports healthy growth of plants. In spite of the high level of crude oil activities in the area, crop yield is still excellent. However, it is recommended that in areas where soil lacks micronutrients or is infertile, Chemical Productivity index (CPI) after (Imasuen, 1987) is advised. Result of analysis showed high values of organic content according to (Odu *et al;* 1985). The lower limit of organic content is 1% which indicated that the control site and the impacted sites had this parameter in excess. Organic content of soil may influence the degree of metal enrichment in the soil (Imasuen and Egai 2013). Higher values of sulphate in soil can induce acidity, acid sulphate soils can acidify groundwater including lakes and garden, ponds, can kill fish and other aquatic species Acidic sulphate soils can degrade steel and concrete structures, damaging buildings and highways EPHC&NRMMC,(2011). The concentration of sulphate in the area ranges from 0.94-2.89 mg/kg in the control site, whereas in the impacted sites, the sulphate value ranges from 1.31-6.36 mg/kg. Statistics revealed no significant difference within the permissible limit between the control site and the impacted sites. Cation exchange capacity (CEC) is a function of the soil type and thus expresses the organic matter present in it (Onyeobi and Imasuen, 2013); a sandy soil with a lot of organic matter will have a very low (CEC), while a clay soil with a lot of organic matter as (humus) will have a high CEC. Organic matter or humus always has a high CEC, with clay soils. It depends on the clay type. CEC in the study area ranges from 2.85-10.04mg/kg in the impacted area and varies from 4.47-10.85mg/kg in the control site. The control site has more clay content and humus than the impacted site. Statistical result indicates significant difference in soil quality between the impacted sites and the control site (Table 1). Heavy metals have the tendency to accumulate in various organs which, in turn can enter into the human metabolism through consumption of food crops grown on the soil causing serious health hazards (Peul*et al.,* 1987; USEPA, 1991; Anadim*et al;* 1984; Birge*et al.,*2000;

Imasuen and Omorogieva, 2013a). The results of the heavy metal contents in soil are shown in (Table 2) above. The results reflect that the heavy metals were present in considerable amount in the soil. Iron concentration in the impacted site 1, ranges from 7.83mg/kg to 20.46 mg/kg and in the .impacted site 2, ranges from 20.24mg/kg to 20.46 mg/kg. But the concentration of Iron at the control site ranges from 2 mg/kg to 12.08mg/kg. The elevated concentration of Iron in the impacted site particularly impacted site 2 is an indication of topography, metal immobility and contributions from activities and untreated wastes from the artisanal refineries in the area and marshy environment (Ukpebor and Unuigbe, 2003; Imasuen and Omorogieva, 2013). Statistical result indicates significant difference for Iron in the impacted site 2. Iron is an essential element to the human body but excess concentration induces rusting and corrosion of the soil which can damage pipes. The amount of lead (Pb) in the soil of the sampled area varies from 0.005mg/kg to 20.03mg/kg. These values are higher than the control site and the toxicity characteristic leachate limit (TCL) of 5.00mg/kg for lead, (Bowen, 1979). Lead is toxic to many plant species, although a few are relatively tolerant. When ingested, lead can cause a disease called plumbism; lead also is known to damage the brain, the central nervous system, kidney, liver and the reproductive system (Ademoroti, 1996; NRC, 1999). Natural occurring concentration of lead in soil ranges from 2 to 20.00 mg/kg (Bowen, 1979). Statistical results also reflect significant difference of lead from the impacted site in comparison with the control site. The concentration level of copper ranges from 0.39 to 4.92mg/kg; these values are relatively lower compared to the normal range of 5.00-20.00mg/kg required by plants (Bowen,

1979). Copper is generally higher in soil derived from igneous rocks and tends to be lower in extreme acid and alkaline soil. Copper in excess amount can be harmful and pollution occurs in areas where copper is found and worked. Statistical result indicated significant difference between control site and the impacted sites. Concentration level of Nickel/Chromium vary from 2.45-47.60mg/kg, it falls within the normal range of 2.00 to 750.00mg/g in natural soil concentration (Bowen, 1979). Chromium was not detected in any of the samples. Statistical analysis for Nickel reveals significant difference between control site, and impacted site (2), the difference is due to the waste generated from the artisanal refineries in the area. The concentration of Zinc in the soils of the study area ranges from 0.39 to 4.92mg/kg; these levels are within the natural range of 1.00 t0 900mg/kg in soil (Bowen, 1979). Zinc is an essential element in our diet. Too little Zinc can cause problems, but too much Zinc is also harmful. Statistical result indicated significant difference of Zinc between control site and the impacted sites. The concentration of Vanadium ranges from 4.01- 8.26mg/kg in the two locations of the impacted sites. Vanadium was not detected in the control site. The concentration of Vanadium in the study area is within the allowable limit of crude oil and petroleum (1-150mg/g) of soil. Vanadium is a ubiquitous metal. The average concentration of Vanadium in the earth crust is 150µg/g; (0.15mg/kg) concentration in soil varies in the range 3-310µg/g (031mg/kg) and may reach high values of up to 400µg/g in areas polluted by fly ash. The concentration of Vanadium in water is largely dependent on geographical location and ranges from 0.2 to more than 100 main long term sink of Vanadium in the global circulation. The concentration of Vanadium in coals and

crude petroleum oils vary widely (1-1500 mg/kg). Vanadium is an essential element for soil nitrogen fixing microorganism. It plays a significant role in human nutrition. Vanadium has been recognized as an essential element for certain species of green algae, (Arnon and Wessel, 1953) but claims supporting its essentiality in higher plants are inconclusive, (Welch and Huffman, 1973) higher concentration of Vanadium is injurious to public health, Vanadium is a potent respirable irritant (NRC, 1999). It affects the lungs, liver, kidney, spleen, and bones of human. The concentration of manganese in soil of the study area ranges from 3.16mg/kg of the top soil to 5.98mg/kg to about a depth of 1 metre. But the control site values of Manganese range from 1.87mg/g to 7.19mg/kg. Manganese concentration is higher in the soil but the concentration declined with depth in the study area.

Manganese occurs in natural soil from weathering of rockscontaining manganese during the process of pedogenesis. There is no significant difference of manganese between the impacted site and the control site. The concentration of total petroleum content ranges from 18.68mg/kg to 67.63mg/g. The results show elevated values of total petroleum content (TPC) when compared with the control site. The findings reveal the need for wholistic and constant monitoring and remediation of the environment. The public health of the area is threatened as man can absorb these contaminants through the food chain. Statistical analysis reveals significant difference between the impacted sites and the control site.

It is imperative to state that the standard used in this work was that of Canadian environmental quality criteria. Table (3) three below show a summary of the environmental quality standard in Canada after (CCME, 1991). In comparing the results obtained from the study area with this, it can be concluded that the area is not contaminated or polluted.

Table 3: Environmental Quality Criteria Canada (CCME, 1991)

Environmental Quality Criteria Canada (CCME, 1991)

Element (mg/kg)	Agriculture	Residential	Commercial/Industrial
Cd	3	5	20
Cr	750	250	800
Cu	150	100	500
Pb	375	500	1000
Ni	150	100	500

Considering the geochemical studies carried out in the area and after subjecting the physico-chemical soil result to statistical analysis using SPSS 16.0 version; there are higher concentrations of Pb^{2+}, TPC, CEC, Zn^{2+}, Cu^{2+} .These show significant differences in comparison with the control site but less than the permissible limit for agriculture, residendial and commercial purposes when compared to environmental quality criteria in Canada (CCME, 1991). Pb^{2+}, TPC are very poisonous and were

above the natural concentration in soil.Significant differences do not occur in other parameters with the control site and are within the natural concentration of the soil .The Study also reveals that the control site does not constitute higher concentration of most toxic substances, an indication that the concentration of these toxic substances are from the artisanal crude oil refineries waste products in the area which were probably drained into the soil.This is, threatening to the growth of food crops in the area and can be absorbed in man through biomagnification. Consequently, there is an urgent need for effective bioremediation in the area to bring back the lost soil fertility as the people of Aguobiri depend largely on local produce. In the interin, while chemical productivity index (CPI) after (Imasuen, 1987) is recommended, remediation studies have to be carried out and government should enforce existing environmental laws.

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