Evaluation of Heavy Metal Pollution Level in Soils and Plants around Ibeno Area, Akwa-Ibom State, Niger Delta, Nigeria

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ABSTRACT

Soil and plant quality around oil spill sites within Ibeno area, Akwa-Ibom, Niger Delta, Nigeria were investigated in the present study related to oil spills and gas flaring. Soil and plant samples were collected within and outside oil spill area and sent to the laboratory for analyses. Nine heavy metals were analyzed and the results of the laboratory analyses showed that the mean concentrations of cadmium, zinc, and copper were above their respective average crustal abundances thereby signifying pollution.

Environmental pollution indices were used in this study to ascertain the source and extent of pollution in the soil and plant samples in the area. It was established that both the soil and plant in Ibeno area are polluted with cadmium, zinc, and copper, while manganese, lead, nickel, cobalt, mercury, and arsenic showed no significant pollution at the time of this research. The established order of pollution starting with the highest are: Cd > Zn > Cu > Pb > Co > Ni > Hg > Mn > As.

These findings were further validated by the computed soil-plant transfer factor, as it revealed zinc, cadmium, copper and lead as the dominant metals in the soil and plant in the area. These results were also compared with the average crustal abundance (background value) postulated by Wedepohl as well as Taylor and McLennan, it also confirmed that cadmium, zinc, and copper are the dominant pollutant in soil and plant system. The pollution in the area was attributed to the age long menace of oil spill, gas flaring, dumping of non-functional equipment and machinery in the surrounding soils in the area. The use of environmentally friendly techniques such as bioremediation in the clean-up of the contaminated soil is recommended.

(Keywords: assessment, heavy metals, pollution indices, soil, plant, Niger Delta, oil spills, gas flaring)

INTRODUCTION

General Background

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Heavy metals are natural components of the Earth's crust formed by pedogenetic processes such as weathering of parent materials. They cannot be degraded or destroyed and enter into the body system via food, drinking water and air [1].

As trace elements, some heavy metals (copper, selenium, zinc) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted [2-3].

Soils are the major sink for heavy metals released into the environment. The heavy metals that are available for plant uptake are those that are present as soluble components in the soil solution [4]. Although plants acquire certain heavy metals for their growth and upkeep, excessive amount of these metals can become toxic to plants. The ability of plants to accumulate essential metals equally enables them to acquire other non-essential metals [5]. As metal cannot be broken down, when concentrations within the plant exceed optimal levels, they affect the plant both directly and indirectly.

Some of the direct toxic effects caused by high metal concentrations include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress [6]. An example of indirect toxic effects is the replacement of essential nutrients at cation exchange sites of plants [7]. In addition, the negative influence heavy metals have on the growth and activities of soils microorganisms may also indirectly affect the growth of plants. For instance, a reduction in the number of beneficial soil microorganisms due to high metal concentration may lead to a decrease in organic matter decomposition leading to a decline in soil nutrients [8].

Ibeno is the operational base of the Exxon Mobil Producing Nigeria Unlimited, an oil producing and servicing companies in Nigeria. Petroleum exploration and exploitation have triggered adverse environmental effects in Ibeno in particular, and the Niger Delta in general. In the latter, immense tracts of mangrove forests have been destroyed as a result of petroleum exploitation in the mangroves and these have not only destroyed the traditional livelihood of the region but have caused environmental pollution that has affected weather conditions, soil fertility, groundwater, surface water, aquatic creatures and wildlife [9]. If this trend is allowed to continue unabated, it is most likely that the food web complexes in this wetland might be at a higher risk of induced heavy metal contamination.

Qua Iboe River Estuary lies within the study area with Douglas Creek emptying into it. The creek is about 900 m long and 8 m deep. It is the point where petroleum exploration and production (E & P) wastes from the Exxon Mobil Qua Iboe Terminal (QIT) tank-farm are transferred to the downstream of Qua Iboe River Estuary and adjourning creeks through two 24″ diameter pipes. The Exxon Mobil oily sludge dumpsite is located adjacent to this creek and the flare-stack where gas is continuously been flared is situated few meters from the creek [10-11]. This unhealthy situation continues to attract the interest of environmental observers and calls for evaluation of the impact of exploration, exploitation, production and transportation of oil activities in the coastal areas of Ibeno, Akwa-Ibom State, Nigeria.

<u>Statement of Problem</u>

Prior to the discovery of oil in Ibeno, the people were making their living through fishing and farming. The discovery of oil and gas deposits in Ibeno area of Akwa-Ibom State, Niger Delta, Nigeria has negatively affected the environmental, socio-economic and cultural heritage of the people. The Ibeno community has been ravaged by numerous oil spills, leading to the deterioration and destruction of the serene aquatic environment (Figure 1). The oil spill menace has led to total annihilation of the ecosystem in the river-line community, thereby making life more unbearable for the people of the area. The need to ascertain the level of pollution in soils and plants in Ibeno area due to the occurrences of oil spills cannot be overemphasized, hence the need for the present study.

MATERIALS AND METHODS

<u>Study Area Description</u>

The study area is Ibeno in Akwa Ibom State, Niger Delta, Nigeria. It lies between Latitudes 4˚32'54''N to 4˚34'00''N and Longitudes 7˚55'35''E to 8˚16'10''E (Figure 1). The area is underlain by sedimentary formation of Late Tertiary to Holocene belonging the coastal plain sand of southern Nigeria (Figure 1). Deposits of recent alluvium and beach ridge sands occur along the coast and estuaries of the Imo and Qua Iboe Rivers, as well as on the floodplains of creeks (Figure 2). The sands are mature, fine to coarse-grained and moderately sorted. The coastal plain sand, also known as the Benin Formation, overlies the Bende-Ameki Formation and dips south-westwards.

(a) (b) (c)

Figure 1: Ecological Disturbances at Ibeno, Akwa-Ibom State, Niger Delta Region, Nigeria. (a) Surface water contamination, (b) Land degradation, and (c) Oil spills.

Sample Collection, Preparation and Analyses

Soil and plant samples were collected in separate polythene bags for the present study (Figure 3). Control samples were collected far away from the Exxon Mobil Qua Iboe Terminal tank-farm. The soil and plant samples were air-dried under shade and ground to pass through a 0.5 mm sieve for metal determinations and analyzed using the partial digestion method. About 3.0 g of pulverized sample was put in a digestion tube of 50 cm^3 volume and 10 cm^3 of aqua regia (400 cm^3 of HCl and 133 cm^3 of HNO_3) was added and swirled. A programmable controller of digestion block was set up before the commencement of digestion at the following temperature and time ranges: temperature step up to 75 °C, held and heated for 30 minutes; temperature step up to 100 °C, held and heated to for 30 minutes; temperature step up to 110 °C, held and heated for 60 minutes and finally step up to 140 °C, and heated for 400 minutes. Within these temperature and time ranges of

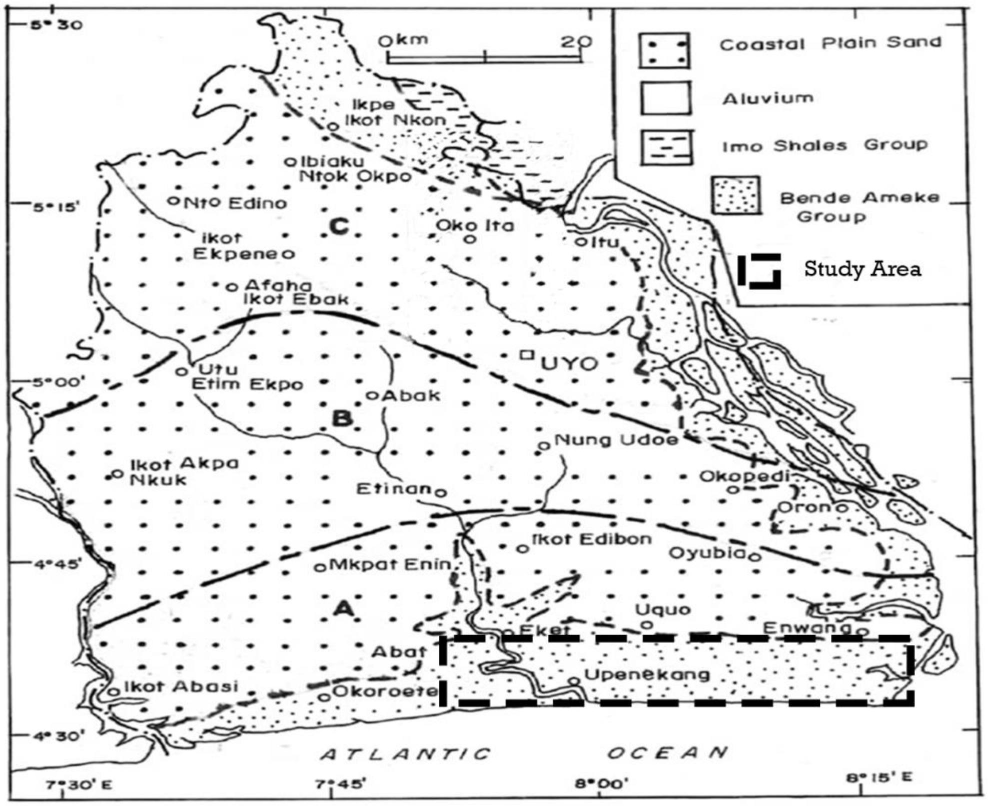

Figure 2: Geology Map of Akwa-Ibom State Showing the S Area.

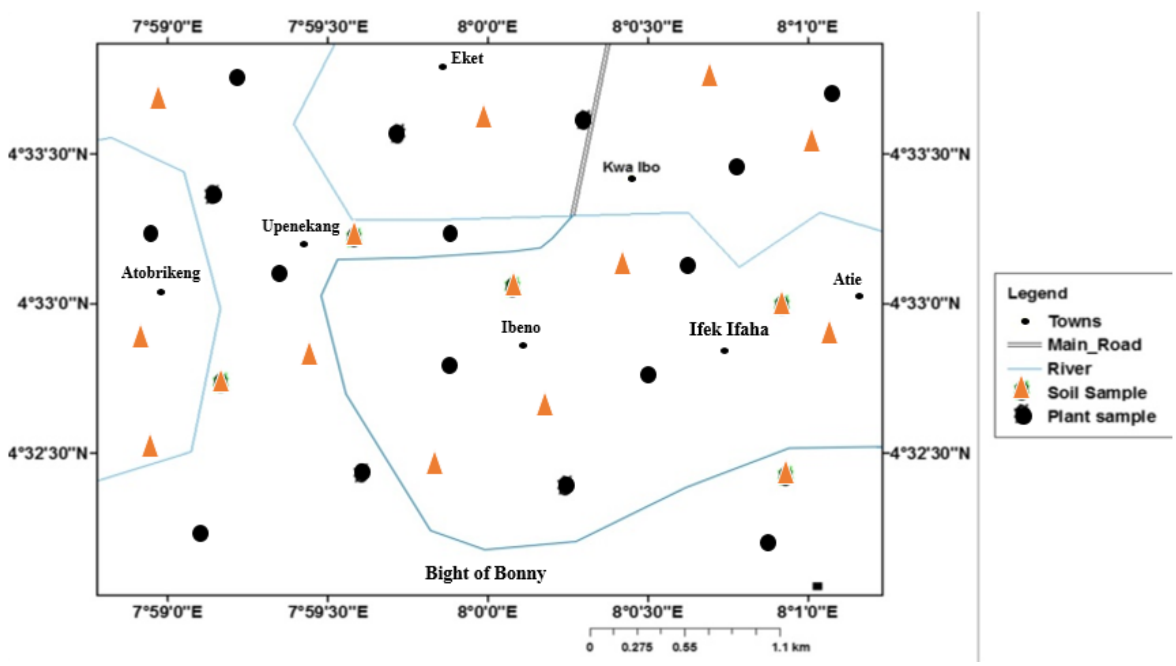

Figure 3: Map of the Study Area Showing Sample Locations.

digestion, the process was checked for 20 minutes to ensure smooth proceeding of the digestion processes.

After the digestion, tubes were removed from the block and allowed to cool at room temperature. 25 cm^3 of 0.1 % of HNO were mixed with a vortex stirrer and transferred to 50 cm^3 centrifuge tube and caped, it was centrifuged for 15 minutes at 500 revolutions per minute. 10 cm^3 of digested solution was decanted as suited for Inductively Coupled Plasma Mass Spectrometry analysis (ICP-MS). The analysis was carried out at ALS Geochemical Laboratory, Czech Republic and samples were prepared in accordance with USEPA [12] standard.

The results of the laboratory analyses of both soil and plants were compared with Wedepohl [13] as well as Taylor and McLennan [14] recommended elemental background values/crustal abundances for each trace element. The pollution levels of the analyzed heavy metals were determined using index of geo-accumulation, contamination factor, degree of contamination, metal pollution index, elemental pollution index and soil-plant transfer factor. The metals, whose concentration in soil and/or plants exceeds their natural background values, are adjudged to be high and therefore either the soil or plant is said to be contaminated with respect to the element and further confirmed by the pollution index interpretation concept.

Pollution Indices

Environmental pollution indices are useful in the evaluation of soil and plant quality by establishing their pollution status. They are used to determine the degree to which soil and plant have been negatively impacted by geogenic and/or anthropogenic factors. The different pollution indices have different but similar criteria for interpretation of the degree of pollution in rock, soil, plant or water. They include contamination factor, degree of contamination, geo-accumulation index, metal pollution index, elemental contamination and soil-plant transfer factor. Many workers have used these pollution indices to successfully unravel the extent and intensity of pollution in different locations with similar geology [9, 15-17].

RESULTS AND DISCUSSION

The statistical summary of the results for the analyzed heavy metals in soils and plants at Ibeno is shown in Table 1, while Table 2 shows the average crustal abundance of the metals according to Wedepohl [13], and Taylor and McLennan [14].

The results of the analysis revealed that the concentration of all the elements analyzed were slightly higher in soils than in in plants (Table 1). This is because the oil spills directly on the soil and the impact is expected to be high on the soil (point source). The soil serves as a potential sink for metals, and through soil-plant interactions, these metals are absorbed and/or adsorbed by the plant (Amadi et al., 2015). The mean concentrations of cadmium, zinc and copper in all the locations exceed the average crustal abundances postulated by Wedepohl [13], and Taylor and McLennan [14] as shown in Table 2.

According to Amadi *et al*. [17], heavy metals contamination of the environment has gained tremendous attention in the last two decades due to their toxicity at low concentration and accumulation effects in soils and subsequent transfer to plants there affecting the food-chain, as well as their non-biodegradable nature. Nine metals (Mn, Cd, Pb, Hg, Cu, Zn, Co, Ni, and As) were analyzed and used for this study (Table 1).

Research has shown that crude oils contain these metals, and due to incessant oil spills on the ground, they migrate through the soil/air interface thereby becoming enriched in the analyzed soils. Subsequently, as the plant roots takes up these metals via soil-plant interaction processes (e.g., by capillarity and translocation actions).

The soil slightly acidic. Unabated gas flaring in the area has led to acid rain menace, which has seriously affected both aquatic and terrestrial habitats in the area. Acid rain has also led to rusting of zinc and iron roofs and pipes in the area. Studies have revealed that low pH increases metal mobility in surficial environments such as soils [18].

Table 1: Statistical Summary of Laboratory for Soil and Plant Samples from Ibeno.

Heavy Metals	Soil (concentrations in ppm)			Plant (concentrations in ppm)		
	Minimum	Maximum	**Mean**	Minimum	Maximum	**Mean**
Cd	54.50	70.40	**61.70**	46.20	67.20	**61.40**
Zn	160.30	194.00	**177.00**	153.00	185.50	**176.80**
Mn	30.40	36.90	**32.10**	28.00	34.60	**30.74**
Pb	17.20	24.10	**19.18**	14.15	20.20	**18.64**
Co	5.10	8.70	**5.42**	3.20	6.30	**5.10**
Ni	2.18	5.91	**3.02**	0.98	3.73	**2.96**
Cu	48.11	70.36	**51.32**	36.61	60.30	**50.50**
Hg	0.00	0.04	**0.008**	0.00	0.02	**0.006**
As	0.00	0.15	**0.042**	0.00	0.96	**0.034**

Table 2: Mean Concentration of Heavy Metals in Soils and Plants from Ibeno Compared with Average Crustal Abundance/Background value by Wedepohl [13], and Taylor and Mclenan [14].

Heavy Metals	Soil Mean (ppm)	Plant Mean (ppm)	Wedepohl (1995)	Taylor and Maclean (1995)	Pollution Status
Cd	61.70	61.40	0.102	0.098	Very High
Zn	177.00	176.80	52.00	71.00	High
Mn	32.10	30.74	527.00	600.00	Very Low
Pb	19.18	18.64	17.00	20.00	Low
Co	5.42	5.10	11.60	10.00	Low
Ni	3.02	2.96	18.60	20.00	Low
Cu	51.32	50.50	14.30	25.00	High
Hg	0.008	0.006	0.056	0.040	Low
As	0.042	0.034	0.055	0.050	Low

Cadmium is one of the heavy metals with no known beneficial biological function, and it is the 67th most abundant element on the Earth's crust. The concentration values of cadmium in the investigated soils ranged from 54.50 to 70.40 ppm with an average value of 61.70 ppm, while it varied between 46.30 to 67.20 ppm with a mean value of 61.40 in plants (Table 1).

The concentrations of cadmium in both soil and plants were higher than the recommended background value of 0.102 ppm and 0.098 ppm by Wedepohl [13], and Taylor and McLennan [14], respectively. The higher concentrations of cadmium in both soils and plants in the study area can be related to the oil production activities because some of the notable uses and hence sources of cadmium include corrosion resistant coatings for vessels, disposal of industrial wastes and impurities found in petroleum products. The solubility of cadmium under low pH is high and this significantly enhances its mobility and little adsorption of by soil colloids [19].

The geospatial distribution of oil spill sites with high concentration of cadmium in Ibeno is shown in Figure 4. Zinc is one of the essential and naturally occurring trace elements with great health benefits. The concentration of zinc in soil ranged between 160.30 to 194.00 ppm with an average of 175.00 ppm while in plants, the concentration varied from 153.00 to 185.50 ppm with a mean value of 176.80 ppm (Table 1).

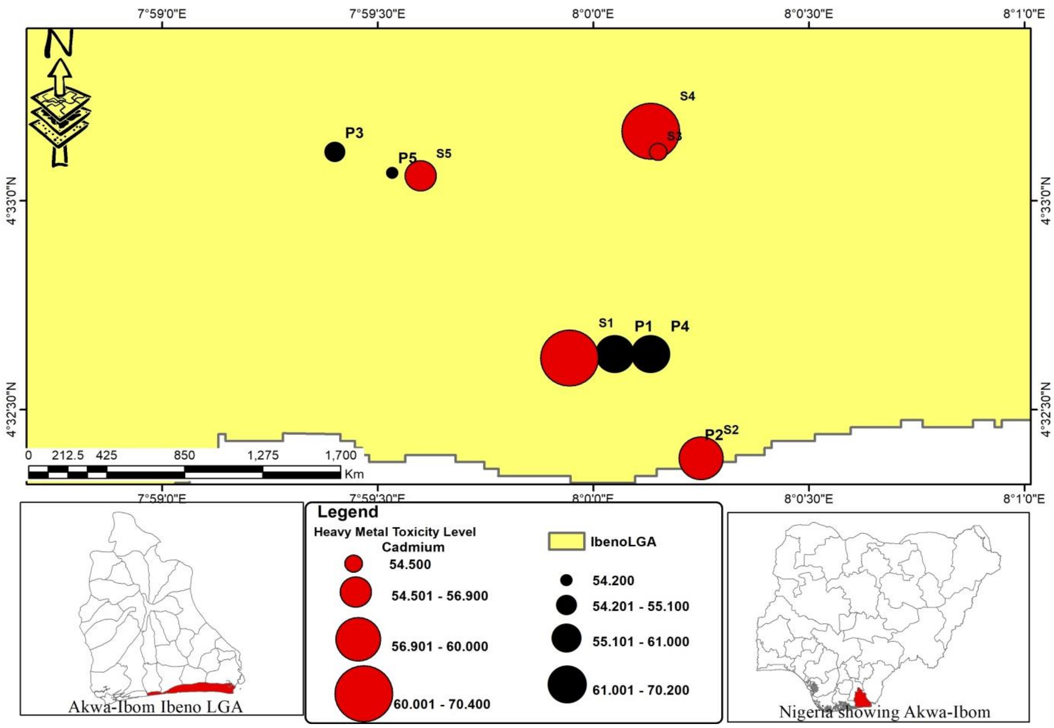

Figure 4: Spatial distribution map of cadmium in soil and plant from oil spill sites in Ibeno area.

The concentrations of zinc in both soil and plant samples were higher than the published average crustal abundances of 52.0 ppm and 71.0 ppm by Wedepohl [13], and Taylor and McLennan [14], respectively. Zinc apart from being a trace component of the crude that is spilled on the soil, other anthropogenic activities such as gas flaring domiciled in the area over the years has enhanced the rusting of zinc-coated material thereby releasing it into the surrounding soils, and which is ultimately transferred to the plants through soil-plant contact processes.

The spatial distribution map of zinc with anomalous values correspond to existing geo-referenced oil spill sites within the study area is illustrated in Figure 5. Copper is the third most used element in the world and is an essential micronutrient necessary for plant and animal growth. The concentration of copper in soils ranged from 48.11 to 70.36 ppm with an average of 51.32 ppm whereas the concentration of copper in plants ranged from 36.61 to 60.30 ppm with an average value of 50.50 ppm (Table 1). The concentrations of copper were higher than the background value of 14.3 ppm by Wedepohl [13], and 25.0 ppm by Taylor and McLennan [14], respectively.

A majority of the wastes products resulting from crude oil production are made of copper, and under the acid condition, they are released into the surrounding soils where plants later take the heavy metals (e.g., copper) up, since they obtain their food from the soil [20]. The geospatial distribution of oil spill sites where the concentrations of copper are more worrisome is shown in Figure 6. This implies that oil spill is a major source of heavy metal contamination in the area.

Manganese is a vital element for the growth and development of both plants and animals alike. The concentration values of manganese in soil ranged from 30.40 to 36.90 ppm with an average of 32.10 ppm, while the concentration values of manganese in plants varied from 28.00 to 34.60 ppm with an average of 30.74 ppm (Table 1). The concentrations of manganese in both soil and plants were lower than the recommended average crustal abundance of 527.0 ppm postulated by Wedepohl [13]), and Taylor and McLennan [14], respectively. This implies that the soil and plant at Ibeno are not contaminated with respect to manganese.

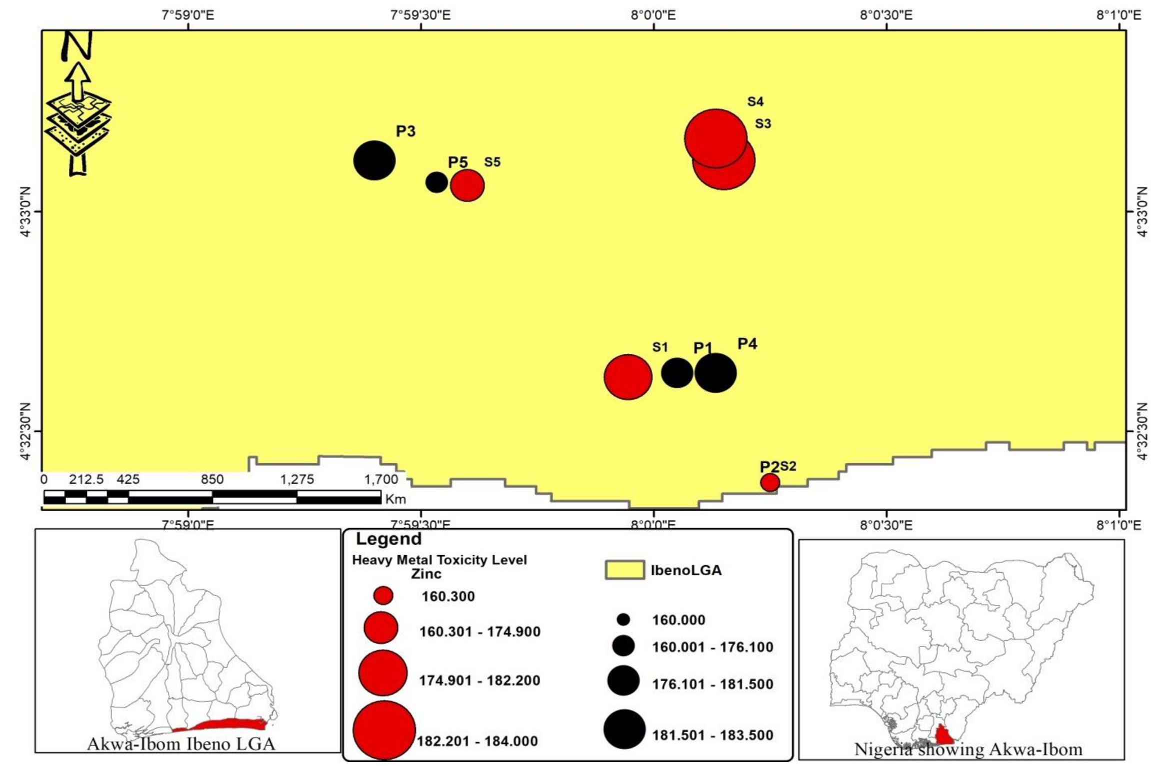

Figure 5: Concentration Map of Zinc in Soil and Plant from Oil Spill Sites in Ibeno Area.

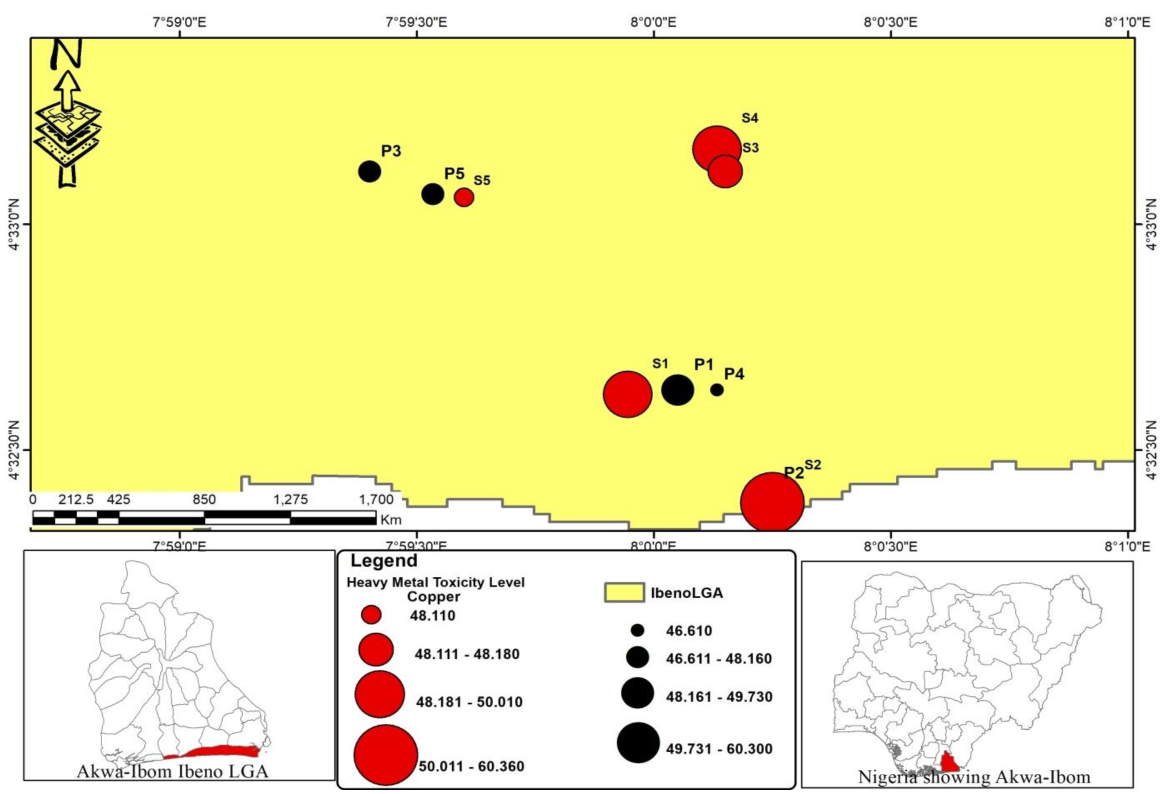

Figure 5: Concentration Map of Copper in Soil and Plant from Oil Spill Site in Ibeno Area.

A similar trend was observed for cobalt, lead, nickel, mercury and arsenic for both analyzed soil and plant samples (Tables 1 and 2). By implication, despite the occurrence of oil spills in Ibeno area, the surrounding soils and plants are currently uncontaminated with reference to manganese, lead, cobalt, nickel, mercury and arsenic as their concentrations in the all the locations falls below their corresponding elemental background values/average crustal abundances. On the contrary, in all the sampled locations, cadmium, copper and zinc showed elevated concentrations when compared with their average crustal abundances postulated by Wedepohl [13] as well as Taylor and McLennan [14]. The high values of cadmium, copper and zinc is an indication of pollution.

Environmental Pollution Indices

In order to quantitatively ascertain the level and extent of heavy metal contamination in soil and plant around the oil spill sites, pollution indices such as metal pollution index, geo-accumulation index, contamination factor, degree of contamination, elemental contamination index and soil-plant transfer factor were used.

Metal Pollution Index (MPI)

The metal pollution index (MPI) is a method of assessment that shows the combined impact of metallic parameters on the overall quality of soil, sediment, plant or water. The MPI rating is a reflection of the relative impact of individual elements on the overall quality of the analyzed media (soil, sediment, plant or water). The higher the concentration of a metal compared to its maximum allowable concentration, the poorer the quality of the soil, plants, sediment and water [15]. It is expressed in the formula below:

$$MPI = \sum_{i=1}^{n} \left[\frac{Ci}{(MAC)i}\right] \qquad \textbf{(1)}$$

where *Ci* is the mean concentration and *MAC* is the maximum allowable concentration. According to Amadi *et al.* [21], metal pollution index is an effective method of describing soil, sediment and plant quality to stakeholders in the environmental sector. About five groups of MPI exists in the following order:

MPI <1.0 = unpolluted;
1.0-4.99 = slightly polluted;
5.0-19.99 = moderately polluted;
20.0-40.0 = strongly polluted; and
MPI >40.0 = very strongly polluted.

The calculated MPI values for soil and plants are contained in Table 3. The high concentration of cadmium, copper and zinc in soil and plant samples in the area are attributed to human activities (oil production) domiciled in the area. The degree of pollution based on MPI classification indicates that both the soil and plant in Ibeno area are very strongly polluted by cadmium, slightly polluted by copper and zinc, and unpolluted by manganese, lead, cobalt, nickel, mercury and arsenic (Table 3).

Contamination Factor (CF)

Contamination factor is a quantifier of the degree of contamination of soil, sediment or plant relative to the average crustal abundance of the respective metal or to measured background values from geologically similar material or area [22-23].

It is expressed as:

$$CF = Cm/Bm \qquad \textbf{(2)}$$

where *Cm* is the mean concentration of metal m in soil/plant, and *Bm* is the background value of metal m, either taken from the literature (average crustal abundance) or directly determined from a geologically similar material.

The contamination factor (CF) is used to determine the contamination status of the soil and plant around oil spill sites in the present study. The results of the CF for soil and plant are described in Table 4.

The results revealed that the soil as well as plant samples in the vicinity of the oil spill sites in Ibeno are highly contaminated with cadmium, considerably contaminated with zinc and copper, moderate contamination with lead, while mercury, arsenic, cobalt, nickel and manganese have low contamination status. The contamination of both soil and plant by these metals can directly be linked to the oil spillage, gas flaring as well as the dumping of old equipment and machinery used in oil exploitation and production on the surrounding soils of the host communities. The acidic nature of the soil creates an enabling environment for easy release and geochemical mobility of these heavy metals.

Degree of Contamination

The degree of contamination (*Cd*) is defined as the sum of all contamination factors.
It is mathematically expressed as:

$$Cd = \Sigma\ (CF) \quad \textbf{(3)}$$

where *Cd* is the degree of contamination, and *CF* is the contamination factor.

The computed degree of contamination value for soil and plant are 430.83 and 422.81, respectively. These values fall in the class of very high degree of contamination (Table 5). This implies that the soils and plants around oil spill sites in Ibeno area is highly contaminated with heavy metals due to the oil production activities going on for decades in the area.

Index of Geo-Accumulation (Igeo)

Index of geo-accumulation (Igeo) is quantifiable check used to describe concentration inclination of metals in soils, plants, sediments and rocks. Geo-accumulation index (GeoI), as proposed by Mueller [24] and cited by Lokeshwari and Chandrappa [25] and Amadi *et al*. [26], has been widely used to evaluate the degree of heavy metal contamination in terrestrial and aquatic environments. Mathematically, it is expressed as:

$$Igeo = \ln\ [Cm\ /1.5*Bm) \quad \textbf{(4)}$$

where *Cm* and *Bm* are as previously defined in contamination factor, while 1.5 is a factor for possible variation in the background concentration due to lithologic differences.

The Igeo result showed that both the soil and plant are very highly polluted with cadmium, very lightly polluted with zinc and copper, and unpolluted by manganese, lead, cobalt, nickel, mercury and arsenic (Table 6). The consistency and similarity in the computed MPI, CF and Igeo for both soil and plant is a reflection of the effectiveness of environmental pollution indices in the overall assessment of soil and plant quality status.

Table 3: Computed Metal Pollution Index for Soil and Plant in Ibeno Area.

Heavy Metals	MPI value Soil	MPI value Plant	Pollution Status
Cd	604.90	601.96	Very Strongly polluted
Zn	2.49	2.49	Slightly polluted
Mn	0.05	0.05	Unpolluted
Pb	0.96	0.93	Unpolluted
Co	0.47	0.44	Unpolluted
Ni	0.15	0.15	Unpolluted
Cu	2.05	2.02	Slightly polluted
Hg	0.14	0.15	Unpolluted
As	0.76	0.62	Unpolluted

<1.0 = unpolluted; 1.0-4.99 = slightly polluted; 5.0-19.99 = moderately polluted; 20.0-40.0 = strongly polluted; >40.0 = very strongly polluted

Table 4: Computed Contamination Factor for Soil and Plant in Ibeno Area.

Heavy Metals	CF value Soil	CF value Plant	Contamination Status
Cd	411.30	359.25	Very High Contamination
Zn	5.90	5.89	Considerable Contamination
Mn	0.11	0.11	Low Contamination
Pb	1.28	1.24	Moderate Contamination
Co	0.77	0.73	Low Contamination
Ni	0.30	0.30	Low Contamination
Cu	5.13	5.05	Considerable Contamination
Hg	0.20	0.15	Low Contamination
As	0.01	0.01	Low Contamination

CF < 1 = Low Contamination; 1 ≤ CF < 3 = Moderate Contamination; 3 ≤ CF < 6 = Considerable Contamination; CF ≥ 6 = Very High Contamination.

Table 5: Degree of Contamination.

Cd	Degree of Contamination
Cd < 6	Low degree of contamination
6 = Cd < 12	Moderate degree of contamination
12 = Cd < 24	Considerable degree of contamination
Cd ≥ 24	Very High degree of contamination

Table 6: Computed Index of Geo-Accumulation for Soil and Plant in Ibeno Area.

Heavy Metals	Igeo Soil	Igeo Plant	Igeo Rating
Cd	5.61	5.61	Very Highly polluted
Zn	1.37	1.37	Very Lightly polluted
Mn	-2.64	-1.94	Unpolluted
Pb	-0.16	-0.19	Unpolluted
Co	-0.66	0.57	Unpolluted
Ni	-1.60	-1.10	Unpolluted
Cu	1.23	1.22	Very Lightly polluted
Hg	-2.02	-2.30	Unpolluted
As	-5.35	-7.30	Unpolluted

<1 = unpolluted; 1.0-1.99 = very lightly polluted; 2.0-2.99 = lightly polluted;
3.0-3.99 = moderately polluted; 4.0-5.0 = highly polluted; >5 = Very highly Polluted

This pollution can be directly attributed to the oil spill, gas flaring and the metal pipes used in transporting the crude oil to the Qua-Ibo terminal in the study area.

Elemental Contamination Index (ECI)

Elemental contamination index is calculated for the expression of a single metal contamination within a sample or combined metal contamination for a sample comparative to the background values of the individual metal and it is expressed as:

$$ECI = (Cn - Bn)/Bn \qquad \textbf{(5)}$$

where *Cn* is the concentration of metal in sample, *Bn* is the background value of the metal.

The result of the computed elemental contamination index (ECI) for soil and plant are contained in Table 7. Interestingly, similar classification pattern was observed for both soil and plants in the determined pollution indices (metal pollution index, contamination factor, Index of geo-accumulation index and elemental contamination index). This is a clear indication that the sources of contamination for both the soil and plant in the area are the same or very similar.

Table 7: Computed Elemental Contamination Index for Soil and Plant in Ibeno Area.

Heavy Metals	ECI Soil	ECI Plant	ECI Classification
Cd	410.33	408.33	Extremely high contamination
Zn	4.9	4.89	Very Low contamination
Mn	-0.90	-0.89	Very Low contamination
Pb	0.30	0.24	Very Low contamination
Co	-0.23	-0.27	Very Low contamination
Ni	-0.70	-0.70	Very Low contamination
Cu	4.13	4.06	Very Low contamination
Hg	-0.8	-0.85	Very Low contamination
As	-0.99	-0.99	Very Low contamination

<5.0 = very low contamination; 5.0 – 9.99 = low contamination; 10.0 – 24.99 = medium contamination; 25.0 – 49.99 = high contamination; 50.0 – 100.0 = very high contamination; >100 = extremely high contamination

Soil - Plant Transfer Factor

Transfer factor (TF) of a metal is given by the formula:

$$TF = \frac{[M]Plant}{[M]Soil} \qquad \textbf{(6)}$$

Where *[M]*plant is the concentration of a metal in the test plant tissues, and *[M]*soil is the concentration of the same metal in the soil where the plant was grown.

The TF values give an indication of the mobility of the metals in the soil. Heavy metals, when present in plant tissues can cause toxic effects to plants. Cadmium and lead can change the permeability of cell membranes. Lead causes the development of dark green leaves, stunted foliage and brown short roots.

Cadmium when excess, can cause brown margins on leaves, chlorosis, reddish petioles, curled and brown stunted shoots. In rice, severe reduction of root and shoot growth have been reported due to enrichment by either lead or cadmium. Cadmium also inhibits photosynthesis and carbon dioxide fixation. Zinc depresses nutrient uptake when in excess, and thus reduces plant growth.

It also causes chlorosis to new leaves. All heavy metals have an ability to react with phosphatic groups in plant cell and change their activity. However, the toxicity symptoms of heavy metals in plant tissues depend on many other factors, such as plant genotype. The computed TF of the heavy metals in their ascending order are: Zn (0.998), Cd (0.995), Cu (0.984), Ni (0.980), Pb (0.972), Mn (0.957), Co (0.941), As (0.809) and Hg (0.750).

Interestingly, the first three metals (Zn, Cd and Cu) were still the three metals adjudged by the pollution indices are being responsible for the pollution of both soil and plant in Ibeno area. By implication, soil-plant transfer factor has validated the results of the laboratory analyses of soil and plant samples as well as the findings of the pollution indices. The higher the TF value, the more polluted the soil and plant, and it can constitute a health risk in the food chain [27-30].

CONCLUSIONS

The study has shown that crude production constitutes a major source of soil and plant pollution in Ibeno area. Environmental quality indices are great tools used in quantifying the pollution level of an area. The pollution indices clearly revealed that the soil and plant in the Ibeno area are highly polluted with cadmium, considerably polluted with zinc and copper, slightly polluted by lead, while the pollution level by manganese, nickel, cobalt, mercury and arsenic does not constitute an environmental hazard at the moment.

The pollution level was higher in soil than that in plant. The high concentration of cadmium, copper and zinc can be directly attributed to the oil spill, gas flaring, dumping of used equipment and machinery in soils of the communities and pipes used in transporting petroleum to the terminal at Ibeno area are rusted due to the impact of acid rain in the area. The soil pH is below 7.0, signifying acidic soil. Natural attenuation mechanisms in soils such as adsorption, absorption, ionic exchange can aid in pollutant reduction.

The pollution indices revealed similar pattern of pollution for both soil and plant in the area, signifying similar source of pollution. The present study has established soil and plant pollution by heavy metals in the order of: Cd > Zn > Cu > Pb > Co > Ni > Hg > Mn > As. The mean concentration of the first three metals (Cd, Zn and Cu) exceeds their average crustal abundances which is an indication of pollution.

These findings were validated by the soil-plant transfer factor computations, hence the efficacy of pollution indices in unraveling the source and level of soil and plant pollution demonstrated in this study. In order to achieve sustainable development, the government and the oil companies need to adopt environmentally friendly and blue-green technology approach in exploitation of crude oil in the area. The use of bioremediation and phytoremediation in the clean-up of soils polluted by oil spills in Ibeno area is strongly advocated.

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