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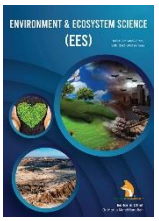

RESEARCH ARTICLE

GEOENVIRONMENTAL ASSESSMENT OF HEAVY METALS CONTAMINATION ALONG QUA IBOE TERMINAL SHORELINE, IBENO, SOUTHERN NIGERIA

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ABSTRACT

Coastal sediments and soils along Qua Iboe Terminal shoreline, Ibeno have suffered high potential of being contaminated by heavy metals leading to health risk. it is expedient to evaluate their levels in terms of contamination or /and pollution on the soils and sediments. The aim of this research was to determine the extent of contamination caused by heavy metals in the study area so as to assess its eco-toxicological risk and geochemical distribution pattern. Sediment and soil samples from Qua Iboe Terminal shoreline and its environs were collected and analyzed for Six heavy metals [Copper (Cu), Lead (Pb), Molybdenum (Mo), Zinc (Zn), Chromium (Cr), and Iron (Fe)] using Inductively Coupled Plasma- Mass Spectrometry (ICP-MS). The physicochemical parameters of sediments and soils were determined using standard methods. The results of all the physicochemical parameters determined were within maximum tolerable limits. The average heavy metals concentration in soil and sediment followed the order of Zn > Cr > Pb > Cu > Mo with corresponding values for soil and sediment of 55.60, 48.30, 21.80, 11.9, 3.4 mg/kg and 47.80, 35.00, 17.90, 11.74 and 5.4 mg/kg respectively. Statistical analysis revealed that Pearson Correlation were significant at r >0.500 between some metals. The anthropogenic influence on soil indicated low contamination by Cu, Cr, and Zn and moderate contamination by Pb and Mo, for both sediments and soils. The geo-accumulation index for most metals was of class 0 (uncontaminated) except for elements like Pb and Mo. The enrichment factor had values less than 1.5 for both soil and sediments showing deficiency to minimal enrichment. The pollution load index (PLI) for sediment were < 1 indicating low pollution status and > 1 for soil at locations 4, 6, 8, 9, 13, 14 and 15 indicating moderate pollution status in some sites. Evaluated mean contamination factor revealed moderate contamination for Pb and Mo for both soil (1.71 & 3.43) and sediment(1.09 &1.14). On the basis of the analytical data available, areas in close proximity to the offshore installations (Utana/Iwokpom/Opulum Creek) have the greatest impact on sediment and soil in the study area.

KEYWORDS

Soil, Sediment, Heavy Metals, Contamination, Assessment, Shoreline

1. INTRODUCTION

The contamination of environmental media (soil/sediments, water, and air) by hydrocarbons (mostly petroleum hydrocarbons) and heavy metals is becoming prevalent across the globe. This is might be due to heavy dependence on petroleum as a major source of energy throughout the world, rapid industrialization, population growth and complete disregard for environmental health. Chemical contaminants are sub-divided into organic and inorganic pollutants (Okori and Ekanem 2022). A lot of activities of man in recent years have increased the quantity and distribution of Heavy Metals in the atmosphere, land and water bodies (Ubong et al., 2023). Heavy metals are widespread constituent of the rocks and minerals of the earth, formed through natural processes such as weathering and volcanic activities. However, the quest for knowledge and comfort by humans has led to advances in technology and exploitation of the earth's resources, leading to a change from natural cycling of the element to anthropogenic addition of heavy metals to soils and sediments.

Consequently, these heavy metals are harmful to plants and animals when taken at excessive levels. This is the widespread problem around the world where excessive concentration of heavy metals like Pb, Zn, Cr, Cu, Cd, Hg and As from human activities, industrial effluents, waste water sludge treatment, energy, fuel production and agriculture can be found in soils/sediments (Wang et al., 2004). Heavy metals in soil subsequently enter the human food web through plants and they constitute risk to the ecosystem as they tend to bio accumulate and can be transferred from one food chain to another. Numerous studies have confirmed that the combination of polycyclic aromatic hydrocarbons and heavy metals could present a great environmental threat to all components of the ecosystem and therefore the United States Environmental Protection Agency (US EPA) has ranked them (16 PAHs and Pb, As, Cr, Cd, Zn) among the top contaminants of concern (US EPA, 2002) (Wang et al., 2004; Affian et al., 2009).

The resultant effect is the threat posed by these pollutants to the ecosystem around the world and the urgency with which this issue needs to be addressed. Heavy metals are usually present in trace amount in natural soils, sediment, and water but many of them are toxic even at very

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low concentration. Heavy metals such as Arsenic (As), Lead (Pb), Cadmium (Cd), Nickel (Ni), Mercury (Hg), Chromium (Cr), Cobalt (Co), Zinc (Zn) and Selenium (Se) are highly toxic even in minor quantity. Increasing quantity of heavy metals in our resource is currently an area of greater concern especially since many industries are discharging their metal containing effluents into fresh water without adequate treatment (Salomons et al., 1995). Heavy metals contamination in soils and sediments is dependent on their sources, redox conditions, microbial activities, and the physicochemical properties of solid and aqueous phases (Neff et al., 2005).

Owing to rapid developments along the coastline, pollutants contamination is elevated and due to their lipophilic nature and persistence in soils after deposition, they accumulate in crops and other biota and are transferred through the food chain which rises its impacts on individual wellbeing (Liu et al. 2016; Zhang et al. 2016; Bortey-Sam et al. 2014). Due to the health risk associated with heavy metals contamination, it is expedient to evaluate their levels in terms of contamination or /and pollution on the soils and sediments along Qua Iboe Terminal shoreline, Ibeno. Sediments and soils are not only basic components of our environment that provides nutrients for living organisms, but they also serve as reservoirs for deleterious chemical species which causes negative effects on aquatic system and human health (Jiang et al., 2013).

Many studies have been carried out on Qua Iboe River estuary for heavy metal trend and pollution in surface water or for sediments (Udosen et al., 2001; Udosen et al 2006; Udosen et al. 2007; Moses et al. 2015; Ntekim et al. 1992; Ekwere et al 1992; Benson et al. 2008; Uwah et al. 2013). Many research have been conducted on heavy metals in soil, sediment and water and health implications (Kolawole et al., 2018; Jia et al., 2018; Ephraim et al., 2014; Olatunji et al., 2014; Ekwere et al., 2013). But there is a knowledge gap on the comparative study of distribution and possible sources of heavy metals in soils and sediments of Ibeno and its associated creeks which this study aim to achieve.

This research is therefore focused on evaluating the concentration and distribution of heavy metals in sediments and soils along Qua Iboe Terminal (QIT) shoreline, Ibeno, Southern Nigeria. Therefore the aim of this research is to evaluate the concentration and distribution of heavy metals in sediments and soils along Qua Iboe Terminal shoreline, Ibeno in Akwa Ibom State, Southern Nigeria. So as to assess the extent of contamination caused by heavy metals, compare the levels of heavy metals in the study area; assess the eco-toxicological risk stemming from loading of it in sediments and soils and finally establishing a geochemical distribution pattern of measured heavy metals.

2. Materials and Methods

2.1 Description of study area

Table 1 shows the location and co-ordinates of the sampling sites.

Table 1: Location and co-ordinates of the sampling sites for sediment and soil

Station No. for sediment	Longitude E	Latitude N	Site Description	Designation	Station No. for soil	Longitude	Latitude
SD1	008 00.821	04 33.355	Mobil dumpsite	Douglas Creek (DC)	SS1	8° 0' 42.300"" E	4° 33' 12.660"" N
SD2	007 59.931	04 33.315	Nnitana nne akpan	DC	SS2	7° 59' 20.552"" E	4° 33' 34.322"" N
SD3	008 00.206	04 33.243	Douglas creek	DC	SS3	8° 0' 12.360"" E	4° 33' 14.580"" N
SD4	008 00.122	04 34.013	Mkpanak bridge head	DC	SS4	8° 0' 10.061"" E	4° 34' 31.275"" N
SD5	007 58.837	04 34.211	Iwokpom	DC	SS5	7° 59' 20.220"" E	4° 32' 53.100"" N
SD6	007 58.325	04 32.010	Mobil jetty	Residential and Industrial Area, (RIA)	SS6	7° 59' 20.662"" E	4° 32' 42.745"" N
SD7	007 59.201	04 32.498	Putuwa	RIA	SS7	7° 58' 54.015"" E	4° 32' 29.380"" N
SD8	007 55.548	04 34.271	Ikot Inwang	RIA	SS8	7° 57' 14.522"" E	4° 32' 54.345"" N
SD9	007 55.587	04 34.561	Upenekang	RIA	SS9	7° 58' 7.996"" E	4° 34' 8.533"" N
SD10	007 56.533	04 33.503	Okoroutip	RIA	SS10	7° 56' 25.555"" E	4° 33' 9.407"" N
SD11	007 56.136	04 34.515	Opulum	Utana/Iwokpom/Opulum Creek (UIOC)	SS11	7° 56' 8.777"" E	4° 32' 48.107"" N
SD12	007 56.914	04 34.356	Iwokpom Opulum	UIOC	SS12	7° 55' 50.492"" E	4° 32' 45.968"" N
SD13	007 56.550	04 34.173	Utana Iwokpom	UIOC	SS13	7° 55' 33.000"" E	4° 32' 7.500"" N
SD14	007 58.433	04 34.032	Mobil tank farm 103	UIOC	SS14	8° 0' 59.758"" E	4° 32' 33.929"" N
SD15	007 58.501	04 34.120	Inewa Creek	UIOC	SS15	8° 1' 53.406"" E	4° 32' 50.810"" N
SD16	008 03.429	04 32.637	Ntaikang	Fishing Settlements (FS)	SS16	8° 3' 25.740"" E	4° 32' 38.220"" N
SD17	008 05.222	04 32.733	Ndito Eka Iba	FS	SS17	8° 4' 14.214"" E	4° 32' 32.159"" N
SD18	008 06.735	04 32.717	Itak Ifaha	FS	SS18	8° 5' 13.985"" E	4° 32' 32.741"" N
SD19	008 08.472	04 32.739	Attiah	FS	SS19	8° 8' 28.320"" E	4° 32' 44.340"" N
SD20	008 09.707	04 32.707	New barracks	FS	SS20	8° 9' 42.420"" E	4° 32' 42.420"" N
Control sediment sample	007 57.823	04 35.615	Esit urua, Eket	Control sediment (CSD)	CSS control soil sample	7° 56' 33.488"" E	4° 36' 51.981"" N

2.2 Field Data Acquisition

All sampling points were appropriately located using the GARMAN III Global Positioning System (GPS) as soil and sediment samples were strategically collected from twenty (20) locations designated into four points; Douglas Creek (DC), Utana/Iwokpom /Opulum Creek (UIOC) which connects to Qua Iboe estuary and fluxes into the Atlantic ocean, Residential/Industrial Area (RIA) where various anthropogenic activities occur and along the Fishing Settlements (FS) which harbor the coastal fishing ports that are bonded by the Atlantic ocean and offshore facilities. The site for the collection of the control soil sample (CSS) and control sediment sample (CSD) were at areas of little or no activities.

2.3 Sample Collection

Forty (40) soil samples were collected using a stainless-steel handheld auger at two depths; topsoil of 0 to 15 cm deep and bottom soil of 15 to 30 cm. Replicate samples were collected at each sampling point and were thoroughly mixed to form one composite sample. The soil samples were collected in new sample bags (polyethylene) and labeled accordingly. Twenty (20) sediment samples were collected from Qua Iboe estuary, creeks, rivers, streams, and canals adjoining the industrial sites and coastal communities around the vicinity of Qua Iboe terminal tank farm. The sediment samples were collected in precleaned polyethylene bags and aluminum foil using a hand trowel in shallow water and Van Veen Grab Sampler (Surface area 0.1 m^2) in deep water at different depth ranging from 0-30 cm. In all, twenty (20) locations were sampled, and sixty (60) samples collected for both sediment and soil analysis. Representative samples were prepared by mixing four to six subsamples from an area of approximately 4 m^2. The samples were drained of water in-situ and properly packaged and transported to the laboratory. Physiochemical parameters including temperature, pH, and conductivity of water were determined at the site of the sediment collection using standard field equipment and the soil/sediment pH and electrical conductivity were determined in the laboratory (Table 2).

Table 2: Field/laboratory features and equipment

Parameters /analytes	Method/equipment	Medium	Facilities/location
Temperature (Temperature of water at the site of the sediment and soil samples collection)	WTW LF 91 meter	Water	Field (In situ)
pH	WTW- pH 90 electronic meter	Water, Sediment, Soil	Field/ Soil Science Laboratory, University of Uyo
Electrical conductivity	Tester CON -P10 series	Water, Sediment, Soil	Field/ Soil Science Laboratory, University of Uyo
Total organic content (TOC)	Titration/ wet oxidation method (After Walkey Black, 1934)	Sediment, Soil	Research Laboratory, University of Calabar
Soluble organic matter/separation technique	Soxhlet extraction/Column chromatography (After USEPA, 1996a)	Sediment, Soil	Chemistry Laboratory, Cross River State University of Science and Technology, Calabar Campus (CRUTECH)
Heavy metals	Perkin Elmer Elan 9000 Inductively Coupled Mass Spectrometer (ICP-MS)	Sediment, Soil	Geochemistry laboratory, Bureau Veritas mineral laboratories, Vancouver BC, Canada

2.4 Sample Preparation and Treatment

Prior to heavy metal detection, the soil and sediment samples were air dried at room temperature. The dried samples were then disaggregated using porcelain mortar and pestle and sieved through 2 mm mesh sized nylon sieve to remove large debris, animal shells and other waste materials. Considerable precautions were taken to avoid contamination during drying, grinding, sieving and storage. Particle size analysis was done using the sieve analysis procedure with the aid of a sieve shaker machine, the different laboratory test sieve ranged from 2 mm→1 mm→0.5 mm→0.011 mm→0.050 mm→Pan (clay). 100 g of each sample was placed on the arranged laboratory sieve and inserted into the sieve shaker machine for 10 minutes. The particles that passed through were retained on the standard set of sieves of various sizes and were measured for the weight percentage of particles. The formula for percentage of grain size was used in calculation.

2.5 Determination of Physicochemical Parameters

Physicochemical parameters such as temperature, pH, moisture content, bulk density, electrical conductivity, redox potential, and total organic carbon were determined using standard methods.

2.6 Determination of Heavy Metals Concentration

2.6.1 Sample Digestion and Analysis

0.5 g sample in a 100 ml digestion flask was added H_2O-HClO-HNO_3, (2:1:1) and digested to dryness. Then 50% HCl was added to the residue and heated on a hot plate. The solution was cooled and homogenized before being transferred to a 50ml volumetric flask, where it was brought to volume using 50% HCl. Sample splits of 1 µl were then analyzed for heavy metals using Inductively Coupled Plasma- Mass Spectrometry (ICP-MS). All the soil and sediment samples were analyzed for total concentrations of Pb, Zn, Cu, Cr, Mo, Fe, etc. The accuracy of the analytical procedure used was repeatedly checked by analyzing duplicate samples and repeatedly analyzing reference samples (STD QREAS25A-4A, STD QREAS45E), and comparing the obtained values with the expected values. The quality control samples represented 10% of the total analytical load. The duplicate samples were treated identically. The percentage recovery from 92% to 104% while precision is within 5%.

2.7 Statistical Analysis

To compare the heavy metal content at the different sampling site and its interpretations, the following statistical methods were applied to the data obtained.

- Correlation matrix: To determine what association exists between the listed elements or the relationship that exists between the tested heavy metals
- Contamination factor: Contamination Factor (CF) shows the level of contamination of soil sediment by a metal. It is employed to determine the extent of contamination of soil or sediment in the study area by the heavy metal.
- Enrichment factor: Enrichment Factor (EF) can be used to differentiate between metals that accumulate due to anthropogenic (human-induced) activities from those due to natural processes. The principle is to normalize a tested element against a reference one. Iron (Fe) is chosen as the element of normalization because natural sources vastly dominate its input.
- Geo-accumulation index (Igeo): The index of geo accumulation (Igeo) enables the assessment of contamination by comparing the current and pre-industrial concentrations of the metals in earth crust.
- Pollution load index (PLI): The variability in the concentration of heavy metals was plotted on the sample location map of the study area using the calculated indices of pollution.
- Bar charts: Heavy metal concentrations were analyzed using bar charts to give a pictorial representation.

3. Results and Discussion

3.1 Levels of physiochemical parameters in sediment and soil samples

The temperature of the water at the site of the collection of sediment ranged between 27.2 °C and 30.6 °C with a mean of 28.9 °C. In the soil samples, the temperature was within a range of 26.4 °C to 30.95 °C at depths 0-15 cm and 15-30 cm. Temperature is a function of incident solar radiation, rainfall seasonal swings, local vegetation cover, type of soil and depth in the earth. At soil depth greater than 30 feet below the surface, the

soil temperature is relatively constant; this corresponds roughly to the water temperature measured in ground water wells 30 to 50 feet deep. This is referred to as the mean earth temperature (Jaarveld et al., 1997). The high temperature may be attributed by the physiographic condition of the area.

pH is an index of hydrogen ion concentration and a very important environmental variable. Soil and sediment pH is a key characteristic that can be used to make informative analysis both qualitative and quantitatively regarding soil/sediment characteristics. It is an important parameter controlling the bioavailability of organic contaminants and also affects the amount of nutrients in chemicals that are soluble in the soil (USEPA, 2009). The pH levels in sediment varied between 6.58 and 7.79 with the highest value of 7.79 in station 7. The pH levels in soil samples (0-15cm depth) varied between 5.53 and 7.18 and that of soil samples (15-30cm depth) ranged between 5.4 and 7.82 with the highest value of 7.82 in station 3. The mean pH values of both sediment and soil samples were within the WHO standards of 6.5 – 8.5 permissible levels (Tables 3-5).

Table 3: Physicochemical parameters of sediment samples for the entire study area

Stations	Temperature (°C)	pH	Particle Size Analysis			Moisture Content (%)	%TOC	Electrical conductivity (mS/cm)	Redox potential (mV)
			Sand	Silt	Clay				
			(%)	(%)	(%)				
SD1	30.1	7.17	87.2	6.8	6	11.34	0.81	3.77	-33
SD2	29.9	6.95	69.2	10.8	20	26.66	0.79	0.84	-22
SD3	29.7	6.68	81.2	10.7	8.1	29.49	0.98	3.53	-3
SD4	27.9	7.62	89.2	4.6	6.2	32.29	0.85	4.42	-44
SD5	28.6	6.86	89	5	6	37.52	0.75	4.88	-17
SD6	28.1	6.87	82.2	11.2	6.6	38.9	0.73	5.11	-15
SD7	27.7	7.79	93	2	6	17.26	0.88	1.76	-27
SD8	30.2	7.65	94.2	2.1	3.7	15.68	0.71	1.13	-34
SD9	28.3	6.85	85	8.5	6.5	12.81	0.89	7.4	-42
SD10	27.5	7.37	91.2	2.5	6.3	21.68	0.67	7.5	-18
SD11	27.2	6.68	87.2	4.8	8	28.1	1.32	7.23	-9
SD12	29.2	6.58	88.3	4.8	6.9	30.52	1.45	7.07	-37
SD13	29.6	7.71	88.1	5.5	6.4	31.06	1.17	2.38	-42
SD14	30.6	7.56	90.5	3.5	6	21.4	1.21	2.17	-56
SD15	28.5	7.62	91.6	2.4	6	30.8	0.78	1.75	-46
SD16	28.3	7.72	93.2	0.7	6.1	11.3	0.56	1.84	-61
SD17	29.4	7.37	93.2	0.7	6.1	12.4	0.49	1.52	-58
SD18	30.6	7.56	93.2	0.7	6.1	10.5	0.46	2.48	-56
SD19	29.6	7.55	93.2	0.7	6.1	11.6	0.51	3.95	-62
SD20	28.8	7.68	93.2	0.7	6.1	10.2	0.52	1.06	-63
MEAN	28.99	7.29	88.65	4.44	6.96	27.7	0.83	3.59	-37.25
MIN	27.2	6.58	69.2	0.7	3.7	10.2	0.46	0.84	-63
MAX	30.6	7.79	94.2	11.2	20	38.9	1.45	7.5	-3
ST.DEV	1.04	0.41	5.92	3.55	3.18	10.61	0.28	2.28	18.85

Table 4: Physicochemical parameters of soil samples for the entire study area (0-15 cm depth)

Stations	Temperature (°C)	pH	Particle Size Analysis			Electrical conductivity (mS/cm)	Redox Potential (mV)	Moisture Content (%)	Bulk Density g/cm³	(%) TOC
			Sand	Silt	Clay					
			(%)	(%)	(%)					
SS1	30.8	6.9	85.86	9.58	4.56	0.53	8.5	13.2	1.51	1.25
SS2	30.35	6.37	65.86	21.58	12.56	5.37	18	24.25	1.61	1.34
SS3	29.85	6.95	75.86	17.58	6.56	3.48	13	21.05	1.25	0.93
SS4	28.6	7.14	95.86	0.42	3.66	4.78	22	15.75	0.87	0.92
SS5	28.8	6.97	85.92	9.66	4.42	3.69	7	16.7	1.25	1.09
SS6	29.7	7.05	65.92	17.66	16.42	6.3	1.5	30.1	1.68	1.19
SS7	29.5	5.53	91.92	3.42	4.66	2.66	6.9	18.05	0.61	0.82
SS8	26.65	5.61	85.72	3.42	10.6	6.34	5.6	21.6	0.62	0.97
SS9	26.4	6.13	67.08	18.26	14.6	2.35	24	23.8	1.57	1.34
SS10	26.8	6	85.88	10.26	8.1	5.46	3.5	16.25	1.25	0.96
SS11	30.95	6.67	87.04	6	6.3	0.9	6.5	22.85	1.55	1.23
SS12	29.75	6.31	90.24	2.8	6.3	1.49	19	20.5	0.83	1.17
SS13	28.85	7.15	94.24	0.48	6.3	2.27	24	33	0.79	1.09

Table 4: Physicochemical parameters of soil samples for the entire study area (0-15 cm depth)										
SS14	27.6	6.45	94.24	0.48	6.3	0.37	18	13.85	0.56	0.79
SS15	29.8	6.51	90.24	2.8	6.3	1.95	26.5	17.5	0.61	0.93
SS16	30.75	7.18	95.02	0.42	4.58	6.21	4.1	7.3	0.45	0.74
SS17	30.35	5.96	95.02	0.42	4.58	0.48	24	8.52	0.7	0.53
SS18	29.5	6.62	95.02	0.42	4.58	1.1	17	8.7	0.5	0.55
SS19	30.15	6.48	95.02	0.42	4.58	0.44	20	6.2	0.74	0.45
SS20	30.75	5.7	95.02	0.42	4.58	1.57	-25.5	7.8	0.99	0.37
MEAN	29.3	6.48	86.9	6.33	7.03	2.887	12.18	17.9	0.997	0.93
MIN	26.4	5.53	65.86	0.42	3.66	0.37	-25.5	6.2	0.45	0.37
MAX	30.95	7.18	95.86	21.58	16.42	6.34	26.5	33	1.68	1.34
ST. DEV	1.43	0.53	10.18	7.21	3.65	2.15	19.81	6.84	0.42	0.29

Table 5: Physicochemical parameters of soil samples for the entire study area (15-30cm)

Stations	Particle size analysis			Temperature (°C)	pH	Electrical conductivity (mS/cm)	Redox Potential (mV)	Moisture content (%)	Bulk density g/cm^3	(%) TOC
	Sand (%)	Silt (%)	Clay (%)							
SS1	85.6	6.1	8.2	31.1	6.27	0.7	5	14.6	1.62	1.24
SS2	84.3	8.5	8.6	30.4	6.2	5.52	15	20.4	1.62	1.33
SS3	83.3	8.5	8.2	30.2	7.82	3.4	35	19.9	1.3	0.94
SS4	85.4	6.24	5.43	29.1	6.89	4.33	13	16.3	0.8	0.93
SS5	89.92	5.66	5.44	29.3	6.72	6.18	8	17.1	1.3	1.08
SS6	69.92	17.66	12.42	30.2	7.09	5.82	2	29.8	1.66	1.18
SS7	91.92	3.42	4.66	29.6	5.4	2.8	75	18.1	0.62	0.83
SS8	85.2	2.4	12.6	27.2	5.4	6.6	67	21.6	1.52	0.96
SS9	75.8	14.26	10.16	26.5	6.2	2.48	20	19.3	1.46	0.96
SS10	85.28	10.26	4.6	27.4	5.82	6.39	35	11.8	1.4	0.97
SS11	80.04	7	12.96	31.2	6.98	1.18	8	31.1	1.6	1.23
SS12	94.24	0.48	5.96	30.1	6.46	1.55	20	20.4	0.86	1.16
SS13	93.24	0.42	6.5	28.9	7.39	2.58	26	38.1	0.79	1.09
SS14	94.24	0.48	5.4	28.7	6.41	0.39	21	12.8	0.57	0.8
SS15	80.04	13.06	6.9	30.3	7	1.8	27	9.49	0.62	0.93
SS16	95.2	0.4	4.58	31.1	7.16	2.25	42	8.1	0.5	0.74
SS17	95.02	0.4	4.58	30.5	5.89	0.56	22	8.77	0.7	0.53
SS18	95.02	0.4	4.58	30.2	7	1.18	16	7.43	0.5	0.54
SS19	95.02	0.4	4.58	30.4	6.92	0.29	19	8.6	0.71	0.44
SS20	95.02	0.4	4.58	31.1	6	1.66	-25	6.9	0.96	0.38
MEAN	87.7	5.32	7.05	29.7	6.55	2.88	22.5	18.1	1.06	0.91
MIN	69.92	0.4	4.58	26.5	5.4	0.29	-25	6.9	0.5	0.38
MAX	95.2	17.66	12.96	31.2	7.82	6.6	75	38.1	1.66	1.33
ST.DEV	7.39	5.36	2.91	1.36	0.65	2.16	21.86	9.31	0.43	0.27

Conductivity ranged from 0.29 mS/cm to 6.60 mS/cm with a mean 2.89 mS/ cm for soil samples for the entire study area and 0.84 and 7.5 mS/cm with a mean of 3.59 mS/cm for sediment samples. In soil, electrical conductivity is a measure of the ability of the soil to conduct an electrical current. It is also an indication of the availability of nutrient in the soil (Miroslav et al., 2006). The mean values for the study area indicate low values of electrical conductivity which indicate low available nutrients and is a function of sandy soils with low organic matter levels.

Moisture content shows the amount of water in soil or sediment, it plays an important role in understanding the behavior of soil and also shows the degree of compaction of soil in the field. It varied significantly with its location. As presented in Tables 4 and 5, it is found that the soil at the residential/industrial area had the highest moisture content of 33% at depth 0-15cm and 38.1% at depth 15-30 cm both at location 13. Sediment moisture content ranged from 10.2% to 38.9% with a mean of 27.7% (Table 3).

Bulk density is the dry weight of a unit volume of soil expressed in g/cm3. It has very important influence on the root penetration and soil permeability which in turn can affect the flow of pollutants such as water within a soil. It is generally between 0.8 and 1.7 g/cm3. Bulk density of the soil was carried out and the values ranged between 0.45 g/cm3 and 1.68 g/cm3. The particle size analysis showed that the soil is characterized by mostly sand. This is in line with the work of (Akpan et al., 2016).

Redox potential determines the geochemical mobility of pollutants in various compartments of the environment and consequently their influence on ecosystems. Oxidation and reduction reactions are especially important in soils. The redox potential of sediment ranged from -63.0 mV at station 20 to -3.0 mV at station 3 (Tables 3). The redox potential of soil ranged from -25.5 mV at station 20 to 75.0 mV at station 7 (Tables 4 and 5).

Total organic carbon (TOC) refers to the amount of organic carbon in a geological formation particularly the source rock for a petroleum play. TOC of sediments or soils can be used as biomarkers to distinguish the marine or terrestrial sources of organic matter as well as aerobic and anoxic

conditions. The TOC obtained varied between the sampling sites ranging from 0.46% to 1.45% with a mean value of 0.83% for sediment and the TOC content in the soil samples ranged from 0.37% to 1.34% with a mean value of 0.93%. The maximum TOC concentration of 1.45% was recorded for sediment at station 12 which is within the residential and industrial area (RIA) and minimum TOC concentration of 0.46% was recorded at station 18 for sediment samples which is within the fishing settlements (FS) (Table 3). This result is similar to those reported by (Sojinu et al., 2010; Uwah et al., 2013). The maximum TOC concentration of 1.34% was recorded for soils (0-15cm depth) at station 2 which is within the Douglas creek (DC) and station 9 which is within the residential and industrial area (RIA) and 1.33% was recorded at the same station 2 for soil samples (15-30cm depth). The minimum TOC concentration of 0.37% was recorded at station 20 for soil samples (0-15cm depth) and 0.38 % for soil from 15-30cm depth at the same station 20 which is within the fishing settlements (FS).

3.2 Heavy metal concentrations

The total analysis of heavy metals Cu, Pb, Mo, Zn, Cr and Fe in sediments and soils was carried out to evaluate the degree of contamination of the aquatic and terrestrial environments along Ibeno shoreline and its environs.

3.2.1 Heavy metals in sediment and soil

The concentration of all heavy metals in sediments and soils showed a relatively wide range of values. The geochemical results of sediments and soils in the study area are presented in Tables 6 and 8. The concentration of sediment shows Cu (2.9-17.8 mg/kg); Pb (7.5-24.6 mg/kg); Mo (0.71-11.12 mg/kg); Zn (12.3-89.6 mg/kg); Cr (7.0-67 mg/kg) and Fe (1.16-4.16%). The mean values for sediment were Cu (11.74); Pb (17.9); Mo (5.41); Zn (47.8); Cr (35) and Fe (1.838). The concentration for soil at two depths (0-15 cm) and (15-30 cm) show a range of values as Cu (2.1-24.2 mg/kg); Pb (6.59-31.01 mg/kg); Mo (1.02-5.39 mg/kg); Zn (11.1-111.9 mg/kg); Cr (7-86 mg/kg) and Fe (0.96-5.14%). The corresponding mean are Cu (11.9); Pb (21.8); Mo (3.41); Zn (56.6); Cr (48.3) and Fe (1.66) respectively. These concentrations are above the values at the control points. The statistical summary of the metal contents including the mean value, standard deviation, range, and background value are presented in Table 7 for sediment and Table 9 for soil respectively. A comparison of the metal concentration in both media with the control sample showed traces of the heavy metals in sediments and soils.

The spatial variation of heavy metals was lower in the sediment samples from SD1-SD2 upstream of the Douglas Creek (DC) and increased from (SD4-SD5) the river entrance into the Residential/Industrial Area (RIA) (SD6-SD10) reaching maximum peak values along the Utana/Iwokpom/Opulum Creek (UIOC) (SD11-SD15) where most of industrial effluents are discharged directly into the river body. The Fishing Settlements (FS) had slightly lower values because of its low human activities. This was a similar trend for the soil samples because of similar pollution sources. This implies that the sediment and soil samples were enriched by industrial effluents and other anthropogenic activities which leached heavy metals into the environmental media. This summation is consistent with the study reported by a group researcher on heavy metal contamination and ecological risk assessment in soils and sediments of an industrial area in Southwestern Nigeria, where activities in the industrial areas had affected the quality of the analyzed environmental media (Kolawole et al., 2018). The graphical illustration of comparison of average concentration of element in soils with those of sediments is presented in Figure 1.

Table 6: Results of heavy metals concentration in sediment samples from the study area

Location		Element					
		Cu	Pb	Mo	Zn	Cr	Fe %
Douglas Creek (DC)	SD1	4.3	7.5	0.89	13.5	10	1.16
	SD2	7.3	17.64	1.41	35	27	2.14
	SD3	7.8	16.58	1.09	41.8	26	2.02
	SD4	15.2	20.6	2.3	56.9	47	1.18
	SD5	17.8	24.6	1.7	71.5	67	4.16
	MEAN	10.48	17.38	1.478	43.74	35.4	2.132
Residential/Industrial Area (RIA)	SD6	14.2	22.07	1.37	58.2	52	3.51
	SD7	2.9	8.35	0.96	12.3	7	1.26
	SD8	15.7	23.51	8.7	64.5	58	1.62
	SD9	17.6	22.4	10.8	70.9	60	2.21
	SD10	6	13.45	0.85	25.3	20	1.54
	MEAN	11.28	17.96	4.536	46.24	39.4	2.028
Utana-Iwokpom-Opulum Creek (UIOC)	SD11	15.3	22.32	11.12	89.6	58	3.44
	SD12	17.6	9.81	0.71	16.2	8	1.4
	SD13	16.7	21.8	9.6	78.2	57	1.43
	SD14	17	20.9	10.9	81.5	64	1.22
	SD15	16.5	22.42	10.7	69.8	55	2.14
	MEAN	16.62	19.45	8.606	67.06	48.4	1.926
Fishing Settlements (FS)	SD16	5.2	10.5	0.91	26.7	22	1.62
	SD17	6.4	17.8	8.15	39.2	10	1.18
	SD18	10.5	21.6	10.2	72.8	29	1.21
	SD19	11.2	18.9	9.5	15.7	7	1.17
	SD20	9.6	15.4	6.3	16.4	16	1.16
	MEAN	8.58	16.84	7.012	34.16	16.8	1.268
	CSD	4.1	6.82	1.33	9.2	11	0.94

Table 7: Descriptive statistics for heavy metals (mg/kg) in sediment from the study area

Element	Min	Max	Mean value	Standard deviation	Average shale value
Cu	2.9	17.8	11.74	5.16	45
Pb	7.5	24.6	17.9	5.4	20
Mo	0.71	11.12	5.41	4.4	3
Zn	12.3	89.6	47.8	26.3	95
Cr	7	67	35	22.18	90
Fe %	1.16	4.16	1.838	0.888	4.72

Table 8: Result of heavy metals concentration (mg/kg) in soil samples from the study area (A: depth 0-15 cm; B: 15-30 cm)

	Location	Element					
		Cu	Pb	Mo	Zn	Cr	Fe %
Douglas Creek (DC)	SS1A	5.6	11.33	1.38	19.5	19	1.19
	SS1B	13.5	20.17	3.74	53.2	41	4.1
	SS2A	13.6	30.7	4.81	40.7	25	2.12
	SS2B	14.5	29.1	3.55	52.2	43	1.16
	SS3A	9.7	16.99	2.33	45.9	35	2.37
	SS3B	5.9	13.59	1.58	37	20	1.47
	SS4A	19.8	29.8	5.01	98.7	83	1.32
	SS4B	18.2	28.6	4.99	97.8	76	1.56
	SS5A	17.4	26.7	4.42	79.7	66	2.13
	SS5B	16.2	25.6	3.87	68.9	54	1.47
Residential/Industrial Area (RIA)	SS6A	24.2	30.91	5.21	101.3	84	2.45
	SS6B	23.1	28.91	4.41	99.8	79	1.35
	SS7A	2.9	6.59	1.63	11.1	11	1.17
	SS7B	2.6	6.91	1.33	16	13	1.2
	SS8A	21.2	30.11	5.21	102.2	85	1.15
	SS8B	21.1	29.98	4.11	100.9	82	1.17
	SS9A	24.2	31.01	5.39	105.1	86	5.14
	SS9B	24	30.17	3.66	111.9	83	4.99
	SS10A	4	9.66	1.22	15.9	10	0.96
	SS10B	10.7	10.58	2.03	49.4	40	3.19
Utana-Iwokpom Opolom Creek (UIOC)	SS11A	7	10.62	1.64	25.7	21	1.51
	SS11B	7.2	11.05	1.54	17.2	23	1.57
	SS12A	3	9.47	1.13	21.8	8	1.35
	SS12B	3.3	9.53	1.02	20.2	7	1.27
	SS13A	21.4	30.22	5.19	97.8	85	1.18
	SS13B	20.2	29.81	3.93	96.9	84	1.16
	SS14A	23.3	28.91	5.36	101.8	79	1.13
	SS14B	22.8	28.62	5.28	99.1	76	1.12
	SS15A	19.8	30.51	4.91	102.8	83	1.17
	SS15B	19.7	29.81	3.81	98.4	81	1.19
Fishing Settlement (FS)	SS16A	2.6	12.5	3.1	16.1	33	1.28
	SS16B	2.1	14.7	2.8	18.2	38	1.26
	SS17A	3.4	22.6	4.3	20.6	22	1.21
	SS17B	2.8	28.2	3.2	23.5	36	1.22
	SS18A	4.6	29.4	5.1	39.3	42	1.13
	SS18B	3.8	27.4	3.7	27.4	36	1.13
	SS19A	3.2	16.2	2.7	28.7	28	1.23
	SS19B	4.3	17.8	2.1	22.2	26	1.25
	SS20A	5.7	18.3	3.4	18.8	42	1.11
	SS20B	7.3	19.5	2.6	20.7	48	1.14
	CSSA	1.4	7.34	1.26	6.8	16	1.11
	CSSB	1.2	7.38	1.18	7.2	17	1.15

A: topsoil 0-15cm, B: bottom soil 15-30cm

Table 9: Descriptive statistics for heavy metals (mg/kg) in soils from the study area					
Element	Min	Max	Mean	Standard deviation	Average shale value
Cu	2.1	24.2	11.9	8.16	45
Pb	6.59	31.01	21.8	8.6	20
Mo	1.02	5.39	3.41	1.44	3
Zn	11.1	111.9	55.6	36.67	95
Cr	7	86	48.3	27.7	90
Fe %	0.96	5.14	1.66	1.003	4.72

Zn and Mo; Cr and Mo respectively constitute the highest and lowest abundance in terms of concentrations in both sediments and soils of Ibeno shoreline and its environs.

3.3 Correlation Coefficient Analysis

Pearson's correlation coefficient matrixes among the selected heavy metals summarize the strength of the relationship between each pair of variables. All the metal pairs in the sediment samples exhibited positive relationship and some of them were significant at the 95% and 99% confidence levels. Correlation greater than 0.500 were considered significant, the following positive correlations were observed for sediment. As seen in table 10, in sediments the ranges of correlation values were from 0.909 between Zn and Cr to –0.087 between Mo and Fe. Correlation greater than 0.500 were considered significant, the following positive correlations were observed for sediment. (1) Cu: Pb(r=0.715) Zn (r=0.703) Cr(r=0.767) (2) Pb: Mo(r=0.623) Zn(r=0.852) Cr(r=0.816) (3) Mo: Zn(r=0.614) (4) Zn: Cr(r=0.909) (5) Cr: Fe(r=0.575). In soils, the ranges of correlation values were from 0.971 between Cu and Zn to 0.152 between Pb and Fe as presented in Table 11. This suggests that similar geochemical factors influenced their concentration with a similar terrigenous source or a similar mechanism of transport and accumulation within the soil matrix. The following positive correlations were observed for soil: 1) Cu: Pb (r=0.769), Mo (r=0.748), Zn (r=0.971), Cr (r=0.917), 2) Pb: Mo(r=0.912) Zn(r=0.791) Cr(r=0.832) 3) Mo: Zn(r=0.768) Cr (r=0.822) 3) Zn: Cr(r=0.947).

Table 10: Correlation constant, r between concentrations of heavy metals in the study area for sediment samples						
	Correlations for sediments					
	Cu	Pb	Mo	Zn	Cr	Fe
Cu	1					
Pb	.715**	1				
Mo	.478*	.623**	1			
Zn	.703**	.852**	.614**	1		
Cr	.767**	.816**	0.432	.909**	1	
Fe	.389**	.482*	-0.087	.469*	.575**	1

Table 11: Correlation constant, r between concentrations of heavy metals in the study area for soil samples						
	Correlation for soil					
	Cu	Pb	Mo	Zn	Cr	Fe
Cu	1					
Pb	.769**	1				
Mo	.748**	.912**	1			
Zn	.971**	.791**	.768**	1		
Cr	.917**	.832**	.822**	.947**	1	
Fe	.351*	.152	.154	.303	.231	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

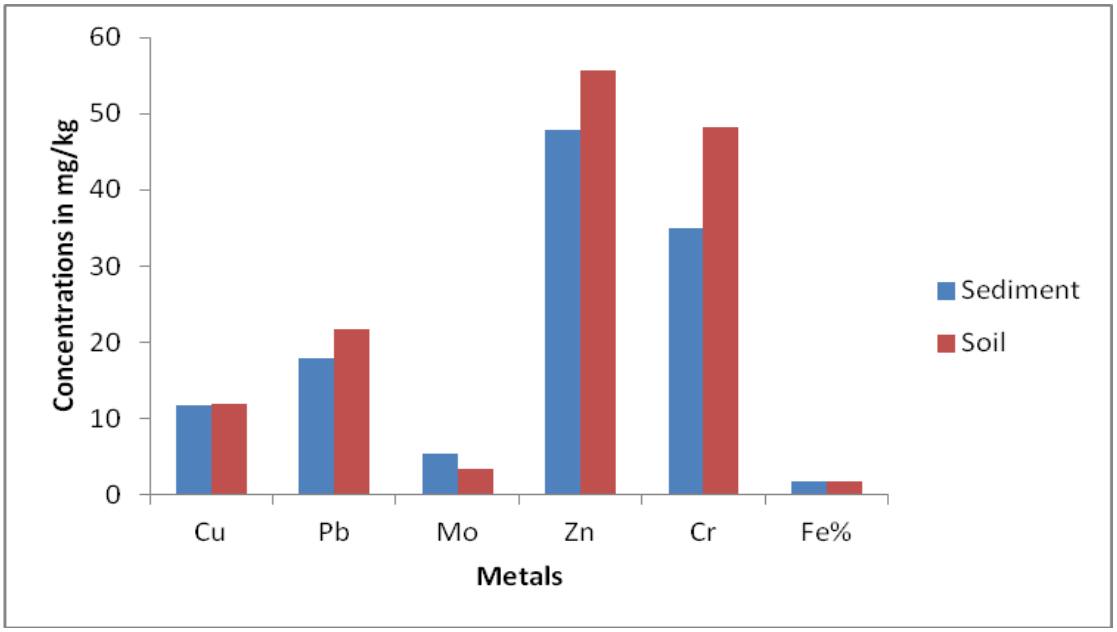

Figure 1: Comparison of average concentration of heavy metals in soils with those of sediments

3.4 Assessment of anthropogenic influence

It is often beneficial to involve various indices in geo-environmental assessments. Some of the indices employed in the present study include Contamination Factor (CF), Enrichment Factor (EF), Geo-accumulation Index (Igeo) and Pollution Load Index (PLI).

3.4.1 Contamination Factor (CF)

The level of contamination of soil/sediment by a metal is often expressed in terms of contamination factor. The contamination factors were calculated using the formula in equation 1:

$$\mathbf{CF} = \frac{\mathbf{Cm}}{\mathbf{Bm}} \quad (1)$$

Table 12: Summary of contamination factor (CF) for sediment and soil from the study area

Sediment				Soil			
Element	**Mean**	**Min**	**Max**	**Element**	**Mean**	**Min**	**Max**
Cu	0.50	0.06	5.22	Cu	0.27	0.05	0.54
Pb	1.71	0.38	17.91	Pb	1.09	0.33	1.55
Mo	3.43	0.24	36.05	Mo	1.14	0.34	1.80
Zn	0.96	0.13	10.06	Zn	0.59	0.12	1.18
Cr	0.74	0.08	7.78	Cr	0.54	0.08	0.96

Table 13: Summary of geo-accumulation index (Igeo) for sediment and soil from the study area

Sediment				**Soil**			
Element	**Mean**	**Min**	**Max**	**Element**	**Mean**	**Min**	**Max**
Cu	-2.70	-4.54	-1.92	Cu	-2.92	-5.01	-1.48
Pb	-0.82	-2.00	-0.29	Pb	-0.60	-2.19	0.05
Mo	-0.45	-2.66	1.31	Mo	-0.56	-2.14	0.26
Zn	-1.85	-3.53	-0.67	Zn	-1.72	-3.68	-0.35
Cr	-2.33	-4.27	-1.01	Cr	-1.79	-4.27	-0.65

3.4.2 Geo-accumulation index

The geo-accumulation index (Igeo) shows the degree of anthropogenic pollution in soil samples by comparing soil metal concentrations to average shale values. It is expressed using equation 2.

$$\mathbf{Igeo} = \mathbf{log_2(C_n/1.5B_n)} \quad (2)$$

C_n is the measured concentration of the metals in the sediment/soil samples and B_n is the geochemical background value in average shale of element (Turekian and Wedepohl 1961). 1.5 is the background matrix correction in factor due to lithogenic effects Igeo scale proposed by Muller consists of seven grades (0-6) ranging from uncontaminated to highly contaminated as Class 0 (uncontaminated): Igeo ≤ 0; Class 1 (uncontaminated to moderately contaminated): 0 < Igeo < 1; Class 2 (moderately contaminated sediment): 1<Igeo<2; Class 3 (moderately to strongly contaminated): 2 < Igeo < 3; Class 4 (strongly contaminated): 3 < Igeo < 4; Class 5 (strongly to extremely contaminated): 4 < Igeo < 5; Class 6 (extremely contaminated): 5 < Igeo. Class 6 is an open class and comprises all values of the index higher than class 5 (Muller, 1969).

Where, CF = Contamination Factor, Cm = Concentration of element in sample, Bm = Background concentration of the element considered. The average shale composition of each element published by Wedepohl was taken as the background composition of the elements during the computation of contamination factor (Wedepohl, 1971). According to a study, where CF < 1 refers to low contamination, 1 ≤ CF ≤ 3 refers to moderate contamination 3 ≤ CF ≤ 6 indicates considerable contamination and CF ≥ 6 indicates very high contamination (Vineethkumar et al., 2020). From the results, the anthropogenic influence on soil indicates low contamination from Cu, Cr, and moderate contamination by Pb, Mo, and Zn for both sediments and soils (Table 12).

The Igeo values and their corresponding contamination intensity for heavy metals in sediments and soils from Ibeno are presented as a summary of its basic statistics in Table 13. It is evident from the table that the Igeo values for most of the metals fall in class "0" except for some elements like Pb and Mo where their sediment quality is in the class of uncontamination to moderate contamination.

3.4.3 Enrichment factor (EF)

EF can be used to differentiate between metals that accumulate due to human activities from those due to natural processes. The principle is to normalize a tested element against a reference one. Iron (Fe) is chosen here as the element of normalization because natural sources vastly dominate it input. The Enrichment Factor (EF) for the heavy metals was calculated using the formula in equation 8:

$$\mathbf{EF} = \frac{\mathbf{M_{sample}/Fe_{sample}}}{\mathbf{M_{ref}/Fe_{ref}}} \quad \mathbf{(3)}$$

Where, EF is the enrichment factor of the heavy metals M. M_{sample} is the concentration of heavy metal M in sample. Fe_{sample} is the concentration of iron in sample. M_{ref} is the background concentration of heavy metals M. Fe_{ref} is the background concentration of iron.

According to Sutherland, five (5) contamination categories are recognized on the basis of contamination factor (Sutherland, 2000). They are EF > 2 = Deficiency to minimal enrichment, EF 2-5 = Moderate enrichment, EF 5-20 = Significant enrichment, EF 20-40 = Very high enrichment and EF > 40 = Extremely high enrichment

Basically, as enrichment factor value increases, the contributions from anthropogenic activities are also increased (Sutherland 2000). An enrichment factor less than 1.5 suggest that the trace metal concentration may be due to natural weathering. Also, enrichment factor greater than 5 is considered to be contaminated with that particular heavy metal (Harikumar et al., 2010). From the results, it is obvious that the investigated sediments and soils can generally be classified as reflecting deficiency to minimal enrichment or trace metal concentration may be due to natural weathering with regards to the measured heavy metals (Table 14).

Table 14: Enrichment factor (EF) for sediment

Location	**Sediment**					**Soil**				
	Cu	**Pb**	**Mo**	**Zn**	**Cr**	**Cu**	**Pb**	**Mo**	**Zn**	**Cr**
1	0.00004	0.000154	0.00012	0.00006	0.00005	0.00005	0.00022	0.00018	0.00008	0.00008
2	0.00007	0.000359	0.00019	0.00015	0.00012	0.00003	0.00012	0.00014	0.00006	0.00005
3	0.00004	0.000183	0.00008	0.00010	0.00006	0.00010	0.00053	0.00056	0.00015	0.00010
4	0.00014	0.000416	0.00031	0.00024	0.00021	0.00006	0.00026	0.00021	0.00010	0.00009
5	0.00009	0.000287	0.00013	0.00018	0.00017	0.00004	0.00017	0.00015	0.00010	0.00008
6	0.00004	0.000125	0.00005	0.00007	0.00007	0.00004	0.00021	0.00016	0.00012	0.00007
7	0.00001	0.000056	0.00004	0.00002	0.00001	0.00007	0.00022	0.00025	0.00015	0.00014
8	0.00008	0.000272	0.00067	0.00016	0.00015	0.00009	0.00031	0.00037	0.00023	0.00019
9	0.00008	0.000224	0.00072	0.00015	0.00013	0.00007	0.00023	0.00025	0.00014	0.00012
10	0.00005	0.000252	0.00011	0.00010	0.00008	0.00016	0.00057	0.00057	0.00032	0.00027
11	0.00010	0.000342	0.00114	0.00029	0.00020	0.00014	0.00039	0.00044	0.00027	0.00023

Table 14: Enrichment factor (EF) for sediment										
12	0.00005	0.000067	0.00003	0.00002	0.00001	0.00013	0.00036	0.00037	0.00026	0.00022
13	0.00006	0.000166	0.00049	0.00013	0.00010	0.00002	0.00011	0.00017	0.00004	0.00004
14	0.00007	0.00019	0.00066	0.00016	0.00013	0.00002	0.00014	0.00018	0.00007	0.00006
15	0.00015	0.00046	0.00146	0.00030	0.00025	0.00018	0.00056	0.00065	0.00040	0.00035
16	0.00004	0.000185	0.00011	0.00010	0.00009	0.00019	0.00062	0.00056	0.00044	0.00037
17	0.00004	0.000223	0.00068	0.00010	0.00003	0.00021	0.00061	0.00071	0.00044	0.00038
18	0.00007	0.000302	0.00095	0.00021	0.00009	0.00005	0.00014	0.00011	0.00011	0.00008
19	0.00004	0.000142	0.00048	0.00002	0.00001	0.00001	0.00005	0.00004	0.00002	0.00001
20	0.00005	0.000174	0.00047	0.00004	0.00004	0.00012	0.00026	0.00033	0.00026	0.00022

3.4.4 Pollution load index

Pollution load index (PLI) was used to assess the metal accumulation and multielement contamination resulting in increased overall metal toxicity. The higher the pollution load index, the more serious the heavy metal accumulation in the sample.

PLI is determined using the formula in equation 4:

$$\mathbf{PLI} = \sqrt[n]{\mathbf{CF_1} \times \mathbf{CF_2} \times \ldots\ldots\ldots\ldots \mathbf{CF_n}} \quad (4)$$

Where n is the number of metals and CF is the contamination factor.

The pollution load index provides a simple, comparative means for assessing a site or estuarine quality: a value of zero (0.0) indicates perfection, a value of one (1.0) indicates only baseline levels of pollutants present and values above one (> 1.0) indicate progressive deterioration of the site and estuarine quality (Tomlinson et al., 1980).

Computed Pollution Load Index (PLI) values for sediments and soils of QIT Ibeno shoreline is presented as a summary in Table 15. PLI values of sediments of Ibeno ranged from 0.166 to 0.868 with an average of 0.516, while that of soils vary between 0.161 and 1.053 with an average of 0.580 for 0-15cm depth; and between 0.172 to 0.985 with an average of 0.581. Indication from both dataset is that PLI values for sediments is less than 1 indicating low pollution and that of soil varies from low pollution to progressive deterioration of the site and estuarine quality (Tomlinson et al., 1980).

From table 15, it is seen that there was high metal accumulation at varying degrees with communities within the Utana/Iwokpom/Opulum Creek having the highest concentration and contamination and communities within the Fishing Settlements having the least metal accumulation.

Table 15: Summary of PLI for sediment and soil					
Sediment		**A: Soil 0-15cm depth**		**B: Soil 15-30cm depth**	
Location	**PLI**	**Location**	**PLI**	**Location**	**PLI**
SD1	0.177	SS1A	0.269	SS1B	0.626
SD2	0.374	SS2A	0.616	SS2B	0.680
SD3	0.365	SS3A	0.485	SS3B	0.332
SD4	0.610	SS4A	1.010	SS4B	0.965
SD5	0.689	SS5A	0.859	SS5B	0.763
SD6	0.564	SS6A	1.075	SS6B	1.001
SD7	0.153	SS7A	0.175	SS7B	0.185
SD8	0.878	SS8A	1.046	SS8B	0.986
SD9	0.954	SS9A	1.096	SS9B	1.013
SD10	0.271	SS10A	0.201	SS10B	0.456
SD11	0.968	SS11A	0.310	SS11B	0.291
SD12	0.234	SS12A	0.189	SS12B	0.181
SD13	0.922	SS13A	1.039	SS13B	0.964
SD14	0.976	SS14A	1.047	SS14B	1.024
SD15	0.920	SS15A	1.019	SS15B	0.950
SD16	0.264	SS16A	0.297	SS16B	0.304
SD17	0.433	SS17A	0.365	SS17B	0.392
SD18	0.731	SS18A	0.548	SS18B	0.440
SD19	0.400	SS19A	0.345	SS19B	0.332
SD20	0.401	SS20A	0.414	SS20B	0.437
MEAN	0.564	MEAN	0.620	MEAN	0.616

4. Conclusion

This study examined the contamination of heavy metals in sediments and soils along the Qua Iboe Terminal shoreline, Ibeno and its environment. The interest in the study was due to the several industries and oil exploration /oil servicing company's activities in the area. These activities are capable of impacting on the quality of the different environmental media of the oil-bearing communities. Unfortunately, limited data are available on the concentration of Heavy metals in this area, therefore, the present study was carried out to examine the distribution and possible

origins of heavy metals in sediments and soils.

The results indicate that the physicochemical parameters of sediments and soils such as temperature, pH, moisture content, electrical conductivity and redox potential were within the World Health Organization (WHO) standards. The concentration of trace metals for sediments and soils were in order of Zn > Cr > Pb > Cu > Mo. Though having elevated levels compared to the control samples, comparison of the values of heavy metals with WHO permissible levels shows that their values were within limits except for Zn in sediment and in soil samples which values were higher. Statistical analysis applied to the elements via correlation matrix exhibited strong positive relationship between metal pairs Cr in sediment and Cu in soil, this suggest that similar geochemical factors influenced their concentrations. Evaluated contamination factor revealed low contamination status for Cu and Cr, moderate contamination by Pb, Mo and Zn from different sampling sites.

Geo-accumulation index indicated uncontamination to moderate contamination for both soil and sediment quality. From the calculated pollution load index, the Utana/Iwokpom/Opulum Creek had the highest concentration and contamination of heavy metals, and the Fishing settlements has the least metal accumulation. This research allowed us to conclude that due to magnifying concentrations of heavy metals, there is a possibility of bioaccumulation and their entry into the food chain. Therefore, proper sediment/soil quality monitoring is a prerequisite to curb these pollutants and prevent health hazards in the area.

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Competing Interests

Authors have declared that no competing interests exist.

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