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Heavy metals and hydrocarbon status of OGBA-EGBEMA soils of Niger delta, Nigeria

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Abstract
Ogba-Egbema area has played host to oil and gas production and transportation for more than four decades with some adverse impact on the environment. This research assessed the status of seven heavy metals (Fe, Zn, Pb, Cu, Mn, Cr, and Hg) and hydrocarbon (THC, PAH and BTEX) in soils of five transects in Ogba-Egbema. A total of 120 soil samples were analyzed (45 genetic horizon samples from eight soil profiles and 75 random surface soils; 15 from each of five transects). Heavy metal status of the soils varied greatly: Zn (<0.01 – 15.10 mg/kg); Pb (<0.01 – 285.50 mg/kg); Fe (247.0 – 13128.5 mg/kg), Mn (<0.01 – 40.40 mg/kg), Cu (0.01 – 20.01 mg/kg), Cr (0.01-17.71 mg/kg) Hg was below detectable limit (<0.01mg/kg) in all the soils studied. The ranges of hydrocarbons along four transects in the un-impacted areas were: THC (0.93 – 55.8); PAH (0.01 – 0.9) and BTEX (<0.1), while in the impacted areas (along the crude oil pipeline right of way) the ranges were: THC (30.0 – 217.50); PAH (1.6 – 12.40) and BTEX (<0.1). The study revealed that in the impacted areas both heavy metals and hydrocarbons were marginally higher than in normal soils but were far below the maximum tolerable levels set by FAO and WHO for agricultural soils. There was no threat of heavy metal and hydrocarbon pollution in these soils. However, farming activities should be discouraged along the pipeline right of way given the relatively higher status of heavy metals and hydrocarbons to avoid the possibility of bio-accumulation in cultivated crops.

Keywords: Heavy Metal, Hydrocarbon, Transects, Biogenic Level, Pipeline Right Of Way

1. Introduction
Heavy metals are part of the natural composition of soils. Heavy metals are defined as that group of elements that have specific weights higher than 5 g/cm^3 (Holleman and Wiberg, 1985) [11]. All heavy metals, both essential (copper and zinc) and non-essential (Cadmium and lead) can cause toxic effects on plants and humans if found in high concentrations (Alloway, 1990) [3]. With several extraneous activities of man heavy metal build-ups beyond natural levels and tolerable limits have been known to occur (Singh, *et al.,* 2011) [22]. In the same vein petroleum related hydrocarbons are not known to occur in soils at levels of concern except if there are activities of man that necessitate it. The activities that are associated with such increase in heavy metals include the extractive industries like mining and oil and gas production. The Niger Delta area has witnessed enormous amount of oil and gas production, refining and transportation over the past four decades. These activities have led to build up of hydrocarbon levels beyond the natural or pristine status. Concawe (1972) [10] reported that levels of hydrocarbon in the soils, especially those greater than the biogenic status of 50.0µg/g are considered significant and reflective of moderate to high level of pollution of hydrocarbons. Massond *et al.* (1996) [14] stated that THC values greater than 50 µg/g in soil and sediment are possible only in moderately polluted environment while values greater than 200 µg/g signify heavy petroleum pollution.
The status of heavy metals and hydrocarbons in soils has been a major concern to researchers for several reasons. They occur usually in trace concentration in pristine ecosystems. Heavy metals have been associated with physiological defects in plants with attendant adverse impacts on the animals that depend on them. This poses a major threat to man, making the study of their status eminent. Heavy metals such as cadmium, lead and copper are potentially toxic and pose great threat to food safety and human health even in minute concentrations (Abduljaleel *et al*., 2012) [1]. When heavy metals and hydrocarbon constituents are built up beyond normal biogenic level in soils they get accumulated in time in soils and plants and would have a deleterious effect because of their toxicity and threat to human life and the environment (Singh, *et al.,* 2011; Chibuike and Obiora, 2013) [22, 9]. Heavy metals and other pollutants such as polycyclic aromatic hydrocarbons are major components of petroleum hydrocarbons (Nwaoguikpe, 2011) [17]. These metals have been implicated in environmental pollution from sources such as leaded petrol from vehicular operations, industrial effluents, and leachates from solid wastes dumps and even wash-outs from farmlands where agro-chemicals are applied.

Workers in the Niger Delta have reported fairly altered chemistry of the soils due to the several years of exploration and production of oil and gas in the Niger Delta area in addition to other industrial developmental projects (Massond et al., 1996 [14]; Adedeji *et al.*, 2013) [2].

Researchers have widely reported increasing levels of mercury, lead, and sulphur among others in the environment in general and top soils in particular through the activities of vehicular movements, urbanization, industrialization programmes and oil field operations and maintenance activities (Adedeji *et al.*, 2013) [2]. This study has assessed the status of hydrocarbons and heavy metals (Fe, Zn, Hg, Cr, Cu, Pb and Mn) in the Ogba-Egbema area. Efforts have been made to relate the hydrocarbon and heavy metals status of the soils to developmental activities in the area.

Materials and methods

The study area

The Ogba-Egbema area of the Niger Delta is part of the per-humid tropics of Nigeria. Ogba-Egbema area is located on the eastern bank of the River Niger and in the heart of the Niger Delta region. The area which lies between Latitude 4º39' and 5º33' and Longitude 6º30' and 7º00'E, is characterized by greater than 2800 mm of rain annually with over 270 rain days. The area has over 8 months of wet season (late March to early November); and even the 3 months of dry season (December, January and February) each has at least 2 rain days. The area experiences heavy rainfall from May to October with a dry season between November and February. While the monthly rainfall is 4.5 – 467.4 mm, its relative humidity is 66.0 – 87.0%. The area experiences relatively high air temperatures throughout the year with minimum and maximum levels of 23 – 30ºC and 29 – 34ºC respectively. The surface wind is 0.5 – 9.8 m/s with occasional calmness while its prevailing wind directions are the southwest and northeast.

Field investigation and sampling

A total of 120 soil samples were analyzed consisting of 45 genetic horizon samples from eight soil profiles and 75 random surface soils (15 from each of five transects). The surface soils were collected from transects in Akabuka - Obite, Obagi - Ogbogu, Omoku - Egbegoro and Ebocha - Okwuzi. The fifth transect was a crude oil pipeline Right of Way (ROW) in Obagi – Ogbogu area.

Laboratory analysis

Determination of heavy metals

1.00 gram soil sample was introduced into digesting flask and 6 ml concentrated HNO_3 and 4 ml of concentrated HCl added and the mixture heated gently (at about 75ºC) with intermittent stirring for about 1 hr till the fumes changed from dark grayish brown to light gray or white. After the digestion the samples were filtered into a 100 ml volumetric flask and made up to 100 ml mark with deionized water. The heavy metal content of the filtrates were determined by AAS. Standard solutions of each of the metals determined were used in calibrating the Atomic Absorption Spectrophotometer (AAS). The various heavy metals in the digests were read off a variant AAS.

Total Hydrocarbon Contents (THC)

THC, PAH and BTEX were analyzed in 75 surface samples (15 from each of the 5 transects). This was determined by shaking 5 gram air dried soil sample with 50 ml isopropyl alcohol. Analar grade known weight of the extract was taken and spiked with an appropriate internal standard (usually 1 chlorooctadene). A gas chromatograph, varian, coupled with a flame ionization detector was used. A 200cm-glass column packed with 3 % OV 101 chromosorb WHP ON 80-100 mesh was used to peak area analysis using the Perkin Elmer Computer.

Results and discussions

Heavy metals

The results of heavy metals in surface soils and soil profiles are presented in Tables 1, 2 respectively.

Iron (Fe)

Iron was the most prevalent heavy metal in the soils with a general range of 212.60 – 20890.00 µg/g. The three lowest values were obtained in Obite 1 0-25cm (212.6 µg/g), Ebocha 1 20-38cm (298.7 µg/g) and Aggah 2 130 – 160cm (313.7 µg/g), while the three highest values were obtained from Obite 2 80-150cm (20890.00 mg/kg), Obagi 2 105-200cm (18267.50 µg/g) and Obagi 1 150 - 200 (16212.50 µg/g). There was no definite spatial or depth trend in the iron status of the soils. The following mean values were obtained for Obagi - Ogbogu (8484.99 µg/g), Aggah - Egbema (6748.15 µg/g), Umuoru - Ndoni (11617.05 µg/g), Omoku - Egbegoro (1877.94 µg/g), Omoku - Elele (11978.10 µg/g), Obiafu (2137.11 µg/g) Akabuka - Obite (5548.80 µg/g) and Ebocha - Okwuzi (8078.44 µg/g) areas.

Zinc (Zn)

Zinc status was moderate to low in the soils with a general range of <0.01-15.1 µg/g in the profiles and 1.8 – 23.56 µg/g in the surface soil. However, the range on the surface soils along crude oil pipeline right of way was 1.04 - 50.44 µg/g**.** Mean values of 8.4825 µg/g 5.4981, 12.0026 µg/g, 4.0075, 9.7435 2.2646 µg/g 3.8062 µg/g and 13.828 µg/g were obtained for the Obagi-Ogbogu, Aggah-Egbema, Omoku-Egbegoro, Umuoru-Ndoni, Omoku-Elele, Obiafu, Akabuka – Obite and Ebocha-Okwuzi catchment areas respectively.

Lead (Pb)

The content of lead (Pb) in the soils varied greatly with a range of <0.01 – 285.5 µg/g for the pedons, <0.01-120.20 µg/g for the surface soils and 48.04 – 221.02 µg/g along crude oil pipeline ROW. The means in the various catchment areas were: Obagi-Ogbogu (17.65 µg/g), Aggah-Egbema (0.6075 µg/g), Omoku-Egbegoro (8.15 µg/g), Umuoru-Ndoni (0.6633), Omoku-Elele (0.5355), Obiafu (0.4926), Akabuka-Obite (4.7209) and Ebocha-Okwuzi and Obagi-Ogbogu (12.3573 µg/g). The range obtained along crude oil pipeline was 48.04 – 221.02 µg/g. Most of the lead values along crude oil pipeline (48.04 - 221.02 µg/g) exceeded the range of maximum tolerable levels proposed for agricultural soil, 90 - 400 mg/kg set by WHO (1993) [23] and NEPCA (2010) [15]. However, these values were lower than EC (1986) upper limit of 300 µg/g.

Chromium (Cr)

The range for Cr in the surface soils varied between <0.01 – 17.71 µg/g in the study area. This range was slightly higher than obtained in normal soils, but lower than the critical permissible level of 50 µg/g for soil recommended for agriculture by MAFF (1992) and EC (1986). Chromium status seemed highest on the three topmost horizons of the soils and generally declined with depth. Chromium levels in the subsoils were highest in the two pedons in Obite with ranges of 0.42 – 8.12 µg/g and 0.75 – 7.60 µg/g and lowest

in Akabuka Pedon <0.01 – 3.05 mg/kg. Relatively higher values of chromium (0.54 – 22.70 µg/g) were obtained along crude oil pipeline ROW. The Cr status for the pedons was <0.01 – 8.12 µg/g while it was <0.01- 17.7 µg/g for the surface soils.

Manganese (Mn)

Magnesium in Ogba-Egbema area varied greatly on the surface soils of the transects: Obagi (<0.01 to 40.40 µg/g), Omoku (1.25 – 14.50 µg/g), Akabuka (<0.01 – 12.08 µg/g), Obite (<0.01 – 16.65 µg/g) and Pipeline right of way (0.91 – 160.25 µg/g).

In the pedons manganese reduced with soil depths with the first two horizons being higher in most pedons and the last two horizons being lowest. Values greater than 40.00 mg/kg were only obtained for the surface soils along the pipeline right of way.

Copper (Cu)

From the study Cu has a general range of <0.01 – 46.55 µg/g in the study area with ranges of <0.01 – 13.30, <0.01 – 2.56 and 1.15 – 46.55 µg/g for surface, profiles and pipeline ROWs respectively. There was generally higher concentration on the surface and a general decline with depth.

Mercury (Hg)

Mercury was below detectable limit (<0.01 µg/g) at all depths and locations in the entire study area.

Hydrocarbons Contents

The results of hydrocarbon status of representative soils are presented in Tables 3 and 4. THC content in the soils ranged from 1.36 to 56.8 µg/g, Poly aromatic hydrocarbon ranged from 0.01 to 0.90 µg/g, while BTEX was generally less than 0.010 µg/g.

Table 1: Heavy metals (µg/g) in the Surface Soils

(OBAGI OGBOGU CATCHMENT)

Sample identity	pH	TOC	Fe	Zn	Cu	Pb	Mn	Cr
OB OB 1	5.4	3.28	9870.8	8.37	3.70	34.0	21.00	4.12
OB OB 2	4.7	3.72	6758.6	16.45	6.00	<0.01	<0.01	<0.01
OB OB 3	5.5	2.96	10243.9	10.56	5.00	14.20	40.40	5.08
OB OB 4	6.4	0.84	7824.4	7.10	4.65	20.82	28.45	0.08
OB OB 5	6.1	1.85	9129.1	7.22	6.05	120.2	12.90	0.24
OB OB 6	5.3	0.74	8342.9	7.14	3.60	10.00	0.56	7.22
OB OB 7	4.7	2.15	8002.5	6.17	5.55	0.86	0.50	0.66
OB OB 8	5.6	1.48	6479.7	5.61	0.95	2.40	0.80	2.56
OB OB 9	5.0	5.27	8357.3	11.41	6.80	<0.01	12.32	3.00
OB OB 10	5.2	1.46	6579.0	17.80	13.30	3.20	<0.01	6.05
OB OB 11	5.3	1.66	7876.0	9.58	6.50	0.65	<0.01	<0.01
OB OB 12	5.5	1.27	6889.0	6.44	2.90	2.18	<0.01	10.54
OB OB 13	5.2	1.42	9554.4	3.03	0.75	0.98	14.45	8.05
OB OB 14	5.5	1.70	11234.0	11.07	2.32	1.66	12.10	1.22
OB OB 15	5.3	1.70	7435.8	6.87	1.28	25.89	10.03	<0.01
Range	4.7 – 6.4	0.74 – 5.27	6479.7 – 11234.0	3.03 – 17.80	0.75 – 13.30	<0.01 – 120.2	<0.01 – 40.40	<0.01 – 10.54

OMOKU EGBEGORO CATCHMENT

Sample identity	pH	TOC	Fe	Zn	Cu	Pb	Mn	Cr
OM/EGB 1	6.0	1.05	1028.4	13.50	3.36	12.36	14.50	0.08
OM/EGB 2	5.3	2.96	1505.1	3.40	3.45	<0.01	10.02	2.05
OM/EGB 3	5.2	5.42	1320.6	2.40	<0.01	9.1	11.15	0.16
OM/EGB 4	5.4	2.03	1540.0	13.85	2.5	2.32	3.45	0.55
OM/EGB 5	4.88	1.36	1999.15	14.5	<0.01	10.25	5.95	0.05
OM/EGB 6	6.28	1.28	2160.95	12.85	2.75	12.15	10.27	0.10
OM/EGB 7	5.66	1.51	2654.75	9.75	2.5	9.4	1.25	<0.01
OM/EGB 8	6.5	2.27	1996.55	16.85	4.5	12.35	1.70	0.08
OM/EGB 9	4.09	3.23	2254.5	11.85	2.45	18.35	4.15	0.25
OM/EGB 10	5.80	3.06	1328.4	23.56	3.36	12.36	12.50	2.05
OM/EGB 11	5.18	1.78	2665.1	13.4	3.45	9.9	11.55	3.36
OM/EGB 12	4.34	2.50	1866.6	11.4	1.7	<0.01	10.15	0.08
OM/EGB 13	5.83	2.22	1950.00	15.85	3.5	17.75	7.00	0.09
OM/EGB 14	5.9	2.30	2002.2	7.88	<0.01	3.20	8.65	2.20
OM/EGB 15	5.7	1.86	1896.8	9.00	0.38	5.02	4.39	0.12
Range	4.09 – 6.28	1.05 – 5.42	1028.4 – 2665.1	2.40 – 23.56	<0.01 - 4.5	<0.01 – 17.75	1.25 – 14.50	<0.01 – 3.36

AKABUKA TRANSECT

Sample identity	pH	TOC	Fe	Zn	Cu	Pb	Mn	Cr
AK 1	5.7	1.28	5432.6	2.85	0.80	2.28	10.20	0.41
AK 2	6.1	1.75	5825.0	4.10	0.60	4.38	0.56	1.02
AK 3	6.2	1.45	5230.3	2.45	0.40	4.68	0.24	0.06
AK 4	6.0	1.92	5864.0	3.20	0.30	5.16	0.39	2.10
AK 5	5.6	2.10	5657.4	4.00	0.74	3.92	8.05	0.58
AK 6	6.4	1.74	5182.2	3.54	0.55	4.18	0.81	0.10
AK 7	5.8	2.44	5486.6	2.76	0.60	4.76	12.08	0.25
AK 8	6.4	1.84	5896.0	1.80	0.68	4.56	<0.01	3.05
AK 9	6.2	2.21	5760.2	2.35	0.83	2.72	0.94	1.30

AK 10	6.4	2.38	6025.5	2.57	0.71	4.16	<0.01	0.12
AK 11	6.3	1.92	6120.7	6.45	0.49	4.88	0.55	0.12
AK 12	6.3	1.84	5980.4	4.40	0.60	4.56	0.42	2.20
AK 13	6.2	1.91	623.0	3.08	0.62	4.68	1.18	<0.01
AK 14	6.0	1.84	5643.4	2.91	0.44	4.65	0.50	0.06
AK 15	6.0	1.92	5960.9	3.55	0.38	4.71	<0.01	0.83
Range	5.6 – 6.4	1.28 – 2.44	623.0 – 6120.7	1.80 – 6.45	0.30-0.80	2.28 – 5.16	<0.01 – 12.08	<0.01 – 3.05

OBITE (OB) TRANSECT

Sample identity	pH	TOC	Fe	Zn	Cu	Pb	Mn	Cr
OB 1	5.2	2.63	11678.1	5.60	3.05	6.20	13.15	10.40
OB 2	4.7	0.53	7274.9	6.23	2.35	2.67	<0.01	6.15
OB 3	6.4	1.15	12160.1	5.91	3.15	1.25	<0.01	0.12
OB 4	5.5	1.03	7602.0	12.12	0.34	<0.01	12.18	2.06
OB 5	6.0	1.92	4588.0	2.41	2.69	0.82	10.20	<0.01
OB 6	6.1	1.70	1023.0	6.50	1.87	<0.01	14.44	3.01
OB 7	6.0	1.84	5896.0	1.80	0.68	4.56	<0.01	8.12
OB 8	5.9	1.91	2623.0	3.08	0.62	4.68	1.18	6.66
OB 9	5.5	2.66	9028.2	4.01	3.74	0.28	2.75	2.65
OB 10	5.7	1.25	10866.4	5.34	0.06	4.38	1.70	0.50
OB 11	6.2	2.82	6605.5	8.06	0.74	4.68	<0.01	1.25
OB 12	6.5	0.75	3387.0	3.50	0.03	5.16	16.65	10.40
OB 13	6.2	2.38	10232.7	1.92	0.47	4.92	6.85	14.50
OB 14	5.9	1.77	3585.2	3.22	0.05	4.18	8.80	17.71
OB 15	6.2	1.40	7627.7	7.05	2.06	4.76	2.01	1.10
Range	4.7 – 6.5	0.53 – 2.82	2623.0 – 12160.1	1.80 – 12.12	0.03 - 3.74	0.01 – 6.20	<0.01 – 16.65	<0.01 – 17.71

Table 2: Heavy Metals (µg/g) in the Soil Profiles

Soil Depth (cm)	Fe	Zn	Cu	Pb	Mn	Cr	Hg
Akabuka 1 0-22	7355.0	13.3	0.4	37.0	7.10	1.65	<0.01
22-50	2761.2	<0.01	0.6	25.5	7.80	1.30	<0.01
50-70	3693.7	<0.01	0.2	26.0	3.92	0.64	<0.01
70-93	1888.7	<0.01	1.2	22.0	4.00	0.72	<0.01
93-125	6187.5	4.09	0.7	13.6	2.05	0.81	<0.01
125-158	1945.0	<0.01	<0.01	<0.01	0.68	0.23	<0.01
158-200	6887.5	<0.01	<0.01	<0.01	0.12	<0.01	<0.01
Akabuka 2 0-23	4761.2	4.21	0.3	1.5	5.01	2.42	<0.01
23-60	3234.0	0.68	0.7	3.4	3.90	1.58	<0.01
60-97	6016.2	<0.01	1.1	<0.01	3.60	0.70	<0.01
97-105	2370.3	<0.01	0.9	<0.01	0.71	0.82	<0.01
105-125	3767.5	<0.01	0.7	<0.01	<0.01	0.22	<0.01
Obagi 1 0-20	3050.0	<0.01	0.5	78.5	16.57	2.68	<0.01
20-39	2345.8	<0.01	1.12	2.98	12.66	1.71	<0.01
39-47	10120.0	<0.01	0.5	<0.01	7.03	2.42	<0.01
47-120	11268.7	<0.01	1.0	27.0	5.21	0.88	<0.01
120-150	14001.2	<0.01	<0.01	27.0	1.20	1.02	<0.01
150-200	16212.5	<0.01	0.3	64.0	<0.01	0.54	<0.01
Obagi 2 0-20	6008.6	1.60	0.70	77.6	13.90	4.63	<0.01
20-40	2863.7	<0.01	0.7	61.5	11.56	3.25	<0.01
40-57	3017.5	9.3	0.7	62.5	7.85	1.22	<0.01
57-85	8760.0	0.3	0.1	85.0	3.14	0.65	<0.01
85-105	8908.7	7.7	<0.01	80.0	1.39	1.43	<0.01
105-200	18267.5	4.6	1.9	69.5	2.20	<0.01	<0.01
Obite 1 0-25	212.6	0.7	1.4	15.5	12.92	8.12	<0.01
25-40	3613.7	<0.01	<0.01	24.5	10.07	3.35	<0.01
40-63	8817.5	<0.01	1.1	55.5	8.24	3.80	<0.01
63-110	14176.2	1.3	1.6	35.0	1.40	2.05	<0.01
110-200	10373.7	2.8	1.2	13.5	<0.01	0.42	<0.01
Obite 2 0-20	16000.3	5.60	2.56	32.78	11.21	4.88	<0.01

20-36	14675.1	4.92	1.02	28.02	12.54	7.60	<0.01
36-86	11997.5	8.15	1.40	36.56	8.00	2.92	<0.01
86-150	20890.0	8.95	1.32	44.52	2.47	0.75	<0.01
Omoku1 0-20	2781.35	11.7	0.76	103.5	6.79	3.05	<0.01
20-58	9156.33	15.1	1.70	175.0	8.62	1.20	<0.01
58-88	8681.30	3.29	1.93	71.5	10.25	0.48	<0.01
88-158	13610.07	1.94	1.50	171.0	4.75	0.05	<0.01
158-200	12869.12	3.42	1.15	153.0	1.45	<0.01	<0.01
Omoku 2 0-20	8724.05	5.62	0.43	5.35	9.08	2.18	<0.01
20-45	8601.30	2.37	<0.01	<0.01	8.40	0.82	<0.01
45-84	6425.00	4.15	0.63	<0.01	3.00	0.42	<0.01
84-180	6042.58	7.40	0.70	16.0	1.52	0.75	<0.01
180-200	13968.71	6.72	0.38	<0.01	1.04	<0.01	<0.01

Table 3: Hydrocarbons and Heavy metals *(μg/g)* in soils along crude oil pipelines ROW in Obagi-Ogbogu Area

Sample Code	THC	BTEX	PAH	Fe	Zn	Cu	Pb	Mn	Cr	Hg
PP ROW 1	27.6	<0.10	2.4	10508.2	38.37	24.4	105.56	2.88	4.67	<0.01
PP ROW 2	60.0	<0.10	5.8	9865.5	26.45	9.48	81.00	66.02	7.79	<0.01
PP ROW 3	175.8	<0.10	10.1	2717.9	20.56	2.22	126.44	0.91	3.58	<0.01
PP ROW 4	72.6	<0.10	3.6	4430.0	17.10	6.01	130.90	25.50	0.54	<0.01
PP ROW 5	217.5	<0.10	12.4	7908.7	9.22	4.13	172.25	105.55	2.12	<0.01
PP ROW 6	110.2	<0.10	4.6	2267.0	7.14	4.87	77.05	41.47	1.25	<0.01
PP ROW 7	95.8	<0.10	7.2	14324.6	36.17	46.55	182.87	160.25	19.50	<0.01
PP ROW 8	119.6	<0.10	8.5	8613.7	25.61	13.33	73.30	82.23	0.94	<0.01
PP ROW 9	49.1	<0.10	3.1	8286.5	1.04	1.15	48.04	6.32	5.65	<0.01
PP ROW 10	102.5	<0.10	8.2	10870.1	17.80	8.82	121.75	12.90	14.42	<0.01
PP ROW 11	246.2	<0.10	5.6	7190.4	29.58	17.17	145.00	7.80	22.70	<0.01
PP ROW 12	165.7	<0.10	2.3	18068.0	50.44	32/60	200.34	145.02	20.00	<0.01
PP ROW 13	88.1	<0.10	15.0	12860.4	32.73	16.06	221.02	21.21	17.04	<0.01
PP ROW 14	79.7	<0.10	1.48	12577.5	21.25	7.12	165.80	9.00	12.23	<0.01
PP ROW 15	55.1	<0.10	7.9	16243.2	6.87	2.09	67.25	5.03	0.71	<0.01
RANGE	27.6 – 246.2	< 0.10	1.48 – 15.0	2267.0 - 18068.0	1.04 - 50.44	1.15 – 46.55	48.04 - 221.02	0.91 - 160.25	0.54 – 22.70	<0.01

PP ROW: Pipeline Right of Way

Table 4: Hydrocarbon Status (μg/g) of Selected Surface Soils along Representative Transects in Ogba Area

Sample Identity	THC	PAH	BTEX
Transect 1 Omoku – Egbegoro Area			
SS 1	1.36	0.1	<0.10
SS 2	0.93	0.03	<0.10
SS 3	8.87	0.6	<0.10
SS 4	4.97	0.04	<0.10
SS 5	10.78	0.5	<0.10
SS 6	4.72	0.02	<0.10
SS 7	8.92	0.8	<0.10
SS 8	3.86	0.01	<0.10
SS 9	18.90	0.4	<0.10
SS 10	8.98	0.06	<0.10
SS 11	8.92	0.6	<0.10
SS 12	4.07	0.02	<0.10
SS 13	10.82	0.9	<0.10
SS 14	4.98	0.04	<0.10
SS 15	11.05	0.7	<0.10
Range in TR 1	**0.93 – 18.9**	**0.01 – 0.9**	**<0.10**
Transect 2 Obagi Area			
SS 1	5.86	0.07	<0.10
SS 2	39.60	0.2	<0.10
SS 3	19.97	0.02	<0.10
SS 4	10.85	0.4	<0.10
SS 5	5.96	0.01	<0.10
SS 6	8.92	0.6	<0.10
SS 7	3.98	0.02	<0.10
SS 8	9.26	0.8	<0.10

SS 9	6.87	0.04	<0.10
SS 10	8.55	0.5	<0.10
SS 11	5.75	0.02	<0.10
SS 12	50.8	0.4	<0.10
SS 13	33.98	0.05	<0.10
SS 14	6.29	0.7	<0.10
SS 15	2.18	0.02	<0.10
Range in TR 2	**2.18 – 50.80**	**0.02 – 0.80**	**<0.10**
Transect 3 Ebocha – Okwuzi Area			
SS 1	10.92	0.8	<0.10
SS 2	41.29	0.9	<0.10
SS 3	28.5	0.3	<0.10
SS 4	19.58	0.06	<0.10
SS 5	10.69	0.9	<0.10
SS 6	6.59	0.01	<0.10
SS 7	15.8	0.4	<0.10
SS 8	9.49	0.02	<0.10
SS 9	10.39	0.7	<0.10
SS 10	10.32	0.05	<0.10
SS 11	8.97	0.3	<0.10
SS 12	6.31	0.03	<0.10
SS 13	12.38	0.2	<0.10
SS 14	4.72	0.04	<0.10
SS 15	10.61	0.4	<0.10
Range in TR 3	**4.772 – 41.29**	**0.02 – 0.90**	**<0.10**

Transect 4 Akabuka-Obite Area			
SS 1	37.63	0.05	<0.10
SS 2	8.95	0.7	<0.10
SS 3	3.98	0.03	<0.10
SS 4	11.12	0.4	<0.10
SS 5	6.37	0.03	<0.10
SS 6	10.72	0.5	<0.10
SS 7	4.78	0.04	<0.10
SS 8	6.37	0.8	<0.10
SS 9	2.89	0.04	<0.10
SS 10	10.92	0.8	<0.10
SS 11	39.84	0.04	<0.10
SS 12	55.8	0.9	<0.10
SS 13	37.91	0.05	<0.10
SS 14	43.8	0.9	<0.10
SS 15	19.71	0.03	<0.10
Range in TR 4	**2.89 – 55.80**	**0.03 – 0.90**	**<0.10**
General Range	**0.93 – 55.8**	**0.01 – 0.9**	**< 0.10**

Discussion

The study revealed two very sharp ranges for both heavy metals and hydrocarbons. The first range representing the entire area devoid of direct impact of oil and gas was relatively low while the areas impacted by oil and gas activities, especially along crude oil pipeline right of way where very high values were obtained. The consistent high values of heavy metals and hydrocarbons along the pipelines are clearly attributable to several years of oil and gas operations in the areas. There had also been some restricted cases of oil and gas leakages and spills within and along the pipeline right of ways. After more than four decades of routine activities and operations of pipeline transportation of crude oil and gas, it is not a surprise to note that there had been occasional ruptures and vandalisation of the facilities which had resulted in higher concentrations of hydrocarbons and heavy metals in the soils, especially along oil and gas pipelines right of ways. Generally, the concentration of the heavy metals was relatively higher in the topsoil and lower in the subsoil. The results showed that there was no consistent spatial variation in the heavy metal levels between the various locations. The heavy metal concentrations obtained in this study were below critical levels.

However, the inherent potential of heavy metals to persist in the environment over a long time and the ability of plants to absorb and bio-accumulate them in their tissues portends some health and environmental concerns in the study area. This possibility of bio-accumulation that could lead to toxicity makes the present level of some heavy metals in Ogba-Egbema area an issue for consideration. Singh *et al.* (2011) [22] hold the view that prolonged exposure of plants and soil organisms to heavy metals such as cadmium, copper, lead, nickel, and zinc can cause deleterious health effects in humans who consume plant products grown on such environment. This should be of concern as farmers in the area generally do not observe safe distances from pipeline right of ways in their efforts to crop the land. However, the values of the heavy metal concentrations obtained in this study are generally far below the maximum tolerable or allowable levels for many countries (Table 5).

The levels of hydrocarbon in the soils, especially those greater than 50.0 µg/g are considered reflective of moderate level of impact (pollution) of hydrocarbons. This concentration is higher than the recognized biogenic status of 50 µg/g reported by Concawe (1972) [10]. According to Massond *et al.* (1996) [14] THC values greater than 50 µg/g in soil and sediment are possible only in moderately polluted environment while values greater than 200 µg/g signify heavy petroleum pollution.

Table 5: Values of Maximum Allowable Limits (M. A. L.) for Heavy Metals in Soil (μg/g) for Different Countries

Chemical element	Austria	Canada	Poland	Japan	Great Britain	Germany
	2	3	4	5	6	7
Cd	5	8	3	-	3	2
Co	50	25	50	50	-	-
Cr	100	75	100	-	50	200
Cu	100	100	100	125	100	50
Ni	100	100	100	100	50	100
Pb	100	200	100	400	100	500
Zn	300	400	300	250	300	300

Ref: Lacatusu, R., 2000 [12]

Conclusion

Heavy metal contents of Ogba-Egbema soils varied greatly: Zinc (<0.01 – 15.10 μg/g); lead (<0.01 – 285.50 μg/g); iron (247.0 – 13128.5 μg/g), Manganese (<0.01 – 40.40 μg/g), Copper (0.01 – 20.01 μg/g), Chromium (0.01-13.30 μg/g). Mercury was below detectable limit (<0.01 μg/g) in the surface soils of the study area. The status of the hydrocarbons along the four transects in the un-impacted areas were: THC (0.93 – 55.8 μg/g); PAH (0.01 – 0.9) and BTEX (<0.1), while in the impacted crude oil pipeline right of way the ranges were: THC (30.0 – 217.50); PAH (1.6 – 12.40) and BTEX (<0.1). This study has revealed that outside the crude oil pipeline right of way concession area, both heavy metals and hydrocarbons were only relatively higher than normal soils but were far below the maximum tolerable levels set by FAO and WHO for agricultural soil. The results obtained indicate that there is no threat of heavy metal and hydrocarbon contamination to agricultural crops in the area. Nevertheless, farming activities should be restricted along the PROW concessions. However, the situation along the PROW was slightly different as more than 65 % of the sampled stations had higher than biogenic levels of total hydrocarbons (> 50 μg/g).

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