Assessment of Heavy Metal Contamination in Soils Around Burutu and Obuguru Communities in the Niger Delta

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Abstract **- This study aimed to determine the levels of heavy metals in the upper soil of Obuguru and Burutu communities in the Niger Delta. From both communities, twelve (12) composite soil samples were collected. The analysis of heavy metals {performed with an Atomic Absorption Spectrophotometer (AAS)} revealed that Fe had the highest concentration in all soil samples studied. The general order from the highest concentration of heavy metals to the lowest was Fe > Mn > Zn > Ni > Cd > Cr > Pb > Cu in Obuguru and Fe > Zn > Mn > Ni > Pb > Cd > Cu > Cr in Burutu. Cadmium (Cd) was found to be the major metal pollutant in the soil of the study area. The concentrations of copper (Cu) and chromium (Cr) were below the department of petroleum (DPR) target values for soil, while the concentrations of the other metals studied (Zn, Pb, Ni, and Co) varied between below and above the target limit. The results of the analysis of the correlation matrix show that the metals in the study area have different degrees of relationship.**

Keywords**: Anthropogenic source, Geo-accumulation index, Enrichment factor, Background concentration, Target value.**

I. INTRODUCTION

Heavy metals are chemical elements with an atomic mass greater than 20 and specific gravity greater than 5 g/cm^3 [1], [2]. These metals are typically present in trace concentrations (ppb range to less than 10 ppm) in different environmental matrices and as such, they are also regarded as trace elements [3]. Generally, the soil is regarded as the ultimate sink for these metals [4], [5]. Heavy metal concentration in soil is dependent upon the adsorption properties of soil matter. Factors such as pH, conductivity and moisture content mainly influence the solubility of heavy metal ions in soil [5], [6].

The anthropogenic sources of heavy metals in the environment mainly include industrial emissions, such as those from transportation, coal combustion, and fugitive particulate emissions [5]. Since the majority of anthropogenic pollutants are released into the atmosphere before being deposited on the soil surface [5], [7], metals such as Cadmium (Cd), Copper (Cu), Lead (Pd) and Zinc (Zn) can be good indicators of contamination in topsoils because they appear in gasoline, oil lubricants and industrial incinerator emissions [8].

Heavy metals cannot be easily degraded and may even enter the food chain due to their uptake by edible plants [5], [9], [10]. Although some heavy metals, like manganese (Mn), copper (Cu) and zinc (Zn) are vital elements needed in small quantities for metabolic and redox functions, others such as lead (Pb) and cadmium (Cd) do not have any biological function and are usually toxic to living organisms [11]. High concentrations of heavy metals are associated with increased risks for cardiovascular disease, endocrine disease, liver disease, diabetes, cancer etc. [12]. For instance, chronic exposure to Cd may have harmful effects such as kidney dysfunction, bone fractures, lung cancer, and hypertension, while exposure to lead (Pb) may lead to plumbism, anaemia, nephropathy, gastrointestinal colic, and nervous system symptoms [13]. Even the essential heavy metals at high concentrations may be deleterious to human health and the ecosystem [6].

Decades of anthropogenic activities have resulted in a widespread problem of soil pollution around the globe [14]. For some specific places, including the Niger Delta activities associated with the oil industry pose the primary sources of environmental pollution [15], [16]. High concentrations of Pb, Cu, Cd, Cr, Ni, and Zn have been reported in crude oil-contaminated soils within the Niger Delta [17], [18].

Several studies have so far explored the effects of exploration activities on the soils of the Niger Delta and these include works of [19], [20], [21], and [22] just to mention a few. However, there are not many or hardly any studies in the public domain that can provide specific details on the quality of soils in Obuguru and Burutu communities. As a result, continuous research into the effects of crude oil exploration on soil quality in this area is required. To close this knowledge gap, this study investigated the levels of Zn, Cu, Pb, Ni, Mn, Cd, Cr, Co and Fe in soils from residential areas around Obuguru and Burutu Communities of the Niger Delta.

II. MATERIALS AND METHODS

A. Description of the Study Area

The research area is the Obuguru and Burutu settlements in Delta State, Nigeria. Obuguru lies between Latitude 5˚ 21.21′ N and Longitude 5˚ 22.29′ E. It is a small community located on the bank of a minor tidal inlet of the Forcados River estuary. It is host to an oil company and is one of the major towns/villages nearest to the Forcados Oil Terminal. The community is about 15km from Burutu community (an island), the headquarters of Burutu Local Government Area in Delta State, Nigeria. This community lies between latitude 5˚ 21′ – 5˚

35′ N and longitude 5° 31′ – 5° 51′ E and on the coast of the Niger Delta on two sides of the Forcados River. The study area has a tropical climate condition consisting of two distinct seasons: rainy (from April to November) and dry (from November to March) seasons. The indigenes of the area are mainly the Ijaw ethnic group and the inhabitants of both communities are mainly fishermen, hunters, business owners, oil company workers and civil servants. The study area is accessible by air (Helicopter and/or Seaplane) and water transport (Boat).

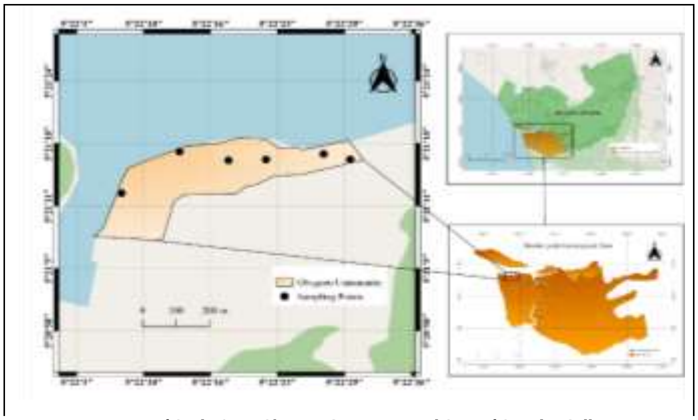

Figure 1: Map of Study Area: Obuguru Community and Sites of Samples Collections.

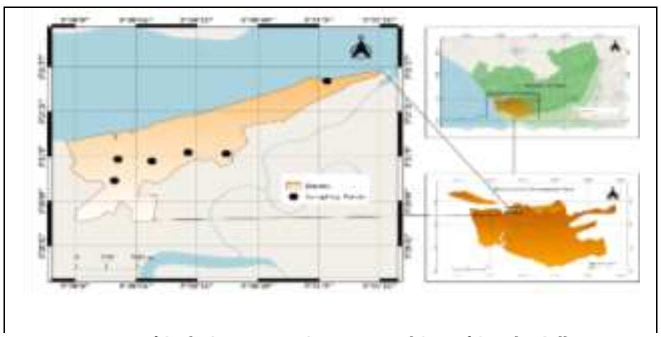

Figure 2: Map of Study Area: Burutu Community and Sites of Samples Collections.

B. Sampling and Analysis

Soil samples were collected from twelve locations in the study area. At least 2-3 samples were collected randomly from every location at a depth of 0-15 cm using a soil auger. Samples collected within a given cell were mixed to give a homogenous sample, after which it was packaged in a tagged polythene bag. The samples were air-dried, sieved to pass through 2 mm mesh and stored at 4 ℃ in the refrigerator before chemical analysis.

The hydrometer method (Bouyoucous, 1962) was used to determine the size distribution of soil particles, as described by Emoyan *et al*. (2018). The pH of the soil was measured in a separate 1:2 slurry of 10 g soil sample in 20 ml deionised water using Hanna multi-parameter kit (Model Hi98194) already pre-calibrated by using standard buffer solutions of pH 4.0, 7.0, and 9.0 [23]. Determination of the conductivity of water extract of soil samples was done using Hanna multi-parameter kit (Model Hi98194). Total organic carbon was determined by the rapid wet oxidation method based on Walkley and Black (1934) as described by Emoyan et al., (2018). Determination of heavy metal was done according to the standard method described by Chaoua et al. (2019). 0.5 g of each of the air-dried, ground, and sieved soil samples were accurately weighed into a digestion tube, and separately subjected to acid digestion using aqua regia (HNO_3: HCl, 3:1 ratio). After cooling, the digested samples were filtered using No. 42. Whatman filter paper and the filtrate was diluted to 50 ml with deionized water and kept at room temperature for further analysis. An atomic absorption spectrophotometer (AAS) (Perkin Elmer AA200, Waltham, USA) was used to determine the concentrations of the metals. The standard solutions for the heavy metals were used to construct the calibration curves with the help of AAS

C. Assessment of heavy metal pollution

The Geo-accumulation Index (I_{geo})

This index compares heavy metal concentrations in soils to pre-industrial levels to determine the extent of heavy metal pollution [26]. The *Igeo* values are calculated using the following equation.

$$Igeo = \left(\frac{Cm}{1.5Cb}\right)$$

Where:

- Cm is the concentration of the metal in the sample,
- Cb is the background value of the metal, and
- 1.5 is the background matrix correction factor due to lithogenic effects.

The seven classes in this classification are Class 0 - 6 as shown in Table 1 [27]:

Table 1: I_{geo} Classes

Class	Value	Soil quality
0	$I_{geo} \leq 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately to heavily contaminated
4	$3 < I_{geo} < 4$	Heavily contaminated
5	$4 < I_{geo} < 5$	Heavily to extremely contaminated
6	$I_{geo} \geq 5$	Extremely contaminated

Enrichment factor (EF)

EF is an effective tool used to ascertain the level of pollution and likely anthropogenic impact in the soil [26].

$$EF = \frac{\left(\frac{Metal}{Fe}\right) sample}{\left(\frac{Metal}{Fe}\right) background}$$

Where:

(Metal/Fe) sample is the ratio of metal and Fe concentration of the sample and

(Metal/Fe) background is the ratio of metal and Fe concentration of the background.

Table 2: Level of Contaminant Based on Ef Value.

Enrichment Factor (EF) Value	Contamination Degree
< 2	Deficiency to minimal enrichment
2 – 5	Moderate enrichment
5 – 20	Significant enrichment
20 – 40	Very high enrichment
> 40	Extremely high enrichment

D. Data Analysis

All statistical analysis was carried out with the aid of Data Analysis Toolpak in Microsoft Office Excel 2007.

III. RESULTS AND DISCUSSION

The result for the particle size distribution of the soil shows that the soil contained a higher composition of sand than silt and clay in all the sampling sites. In Obuguru the result was 95.31, 1.14, and 3.59 per cent for sand, silts, and clay respectively, while in Burutu it was 93.7, 1.26 and 5.04 per cent respectively. Trace metals have preferential accumulation in the clay and silt fraction of soil. Generally, the concentration of heavy metals in soil increases as the sizes of the soil particles decrease [28]. The pH values recorded ranged from 6.60 to 6.90 with a mean of 6.73±0.10 and 6.40 to 8.50 with a mean of 7.02±0.75 in Obuguru and Burutu, respectively. In other words, the pH values for all the sights were slightly acidic to moderately alkaline (Soil Science Division Staff, 1993). Similar pH values have been reported for oil-polluted sites in Odimodi (6.9), Okuntu (7.1) Ogulagha (7.3), and Effurun (6.80), Warri, Delta state [21], [30]. The pH of a soil incorporates a major impact on metal dynamics because it controls surface assimilation and precipitation, which are the main mechanisms of metal retention in soils. As pH decreases, the solubility of cationic types of metal within the soil solution will increase and so become readily accessible to plants [31]. Soil Organic Carbon (SOC) ranged from 0.09 to 0.88 % in Obuguru and 0.15 to 1.675 % in Burutu. The mean values of OC in samples from OB (0.55±0.29), and BT (0.71±0.54) is low but relatively higher than 0.36 % recorded in a similar work in the Niger Delta [21]. The effect on soil quality is the existence of degraded or severely eroded topsoil with poor structural condition and stability [32]. The low organic carbon contents values could be ascribed to the sandy nature of most of the soils [33]

Table 3: Mean Concentrations of Heavy Metals (Mg/Kg) in the Study Area.

	OBUGURU							BURUTU						
Metals	Mean	SD	Median	Range				Mean	SD	Median	Range			DPR
Zn (mg kg^{-1})	80.0	28.6	77.2	48.6	-	114		177	136	161	43.4	-	354	140
Cd (mg kg^{-1})	29.6	5.95	28.3	22.9	-	37.9		19.0	14.5	25.0	0.40	-	32.9	0.8
Fe (mg kg^{-1})	157158	77872	170470	65050	-	243900		238392	85732	197250	156200	-	373150	--
Cu (mg kg^{-1})	3.76	1.80	3.20	2.30	-	7.15		14.7	11.8	11.7	2.35	-	30.0	36
Ni (mg kg^{-1})	40.8	50.1	14.5	0.29	-	109		96.0	84.2	87.4	10.9	-	194	35
Co (mg kg^{-1})	27.1	35.6	17.1	3.00	-	98.6		32.5	60.8	8.55	1.30	-	156	20
Pb (mg kg^{-1})	7.30	4.18	3.30	0	-	10.7		67.8	95.4	27.1	ND	-	245	85
Mn (mg kg^{-1})	86.1	92.3	48.2	24.3	-	265		127	85.8	130	24.3	-	221	-
Cr (mg kg^{-1})	9.80	4.92	9.10	4.92	-	18.0		9.61	4.68	9.30	3.95	-	15.4	100

A. Heavy metals results

1) Zinc

Zinc was detected in all sample locations with mean concentrations of 80.0±28.6 mg kg^{-1} and a range of 48.6 to 114 mg kg^{-1} in Obuguru and a mean concentration of 177±136 mg kg^{-1} with a range of 43.4 to 354 mg kg^{-1} in Burutu (Table 3). In OB soils, Zn concentration was found to be below DPR (2018) target values, but in BT soils only BTL7, BTL8 and BTL9 had values higher than the target limit. Similar values of Zn concentration have been recorded for topsoil in Elebele community, Bayelsa State [34]. However, the Zinc levels observed in this study are significantly higher than those reported by [35]. Zn may well be emanating from phosphate fertilizers, organic waste dumping, wastewater disposal, and burning of fossil fuels within the study area [36].

2) Cadmium

The average concentration of Cd in OB soil samples was 29.6±5.95 mg kg^{-1}, and it varied between 22.85 and 37.9 mg kg^{-1}. Whereas it was in the range of 0.40 to 32.9 mg kg^{-1} with a mean concentration of 19.0±14.5 mg kg^{-1} in BTL/BTS samples (Table 3). Overall, the highest concentration was recorded in OBL3, while the lowest was measured in BTS12. The recorded concentrations for Cd in all samples were above the target value (0.8 mg kg^{-1}) set by DPR (2018). In all the sampling points except in BTS11 & BTS12, the concentrations were also remarkably higher than the intervention value (12 mg kg^{-1})

(DPR, 2018). The elevated level of cadmium could probably be a result of anthropogenic activities in the study area such as fossil fuel burning, application of phosphate fertilizers, sewage sludge, as well as waste batteries and plastic disposal [3], [38].

3) Iron

In all the sampling sites, BTL8 had the highest concentration (373150 mg/kg) followed by BTL9, OBL2, OBS4 and OBS5 respectively. Iron concentrations varied between 65050 to 243900 mg kg^{-1} in Obuguru and between 156200 to 373150 mg kg^{-1} in Burutu (Table 3). The mean concentration in OB samples (157158±77872 mg kg^{-1}) shows that the total concentration of Fe in Obuguru is less than that in Burutu (238392±85732 mg kg^{-1}). High concentrations of iron in soils relative to other metals have been reported in various studies, indicating that Fe is naturally abundant in soils [39]**.** The average concentration of iron found in this study is higher than the values reported in similar studies in the Niger Delta region [22], [34], [40], [41].

4) Copper

Copper was detected in all the sample locations. The highest was recorded at BTL8 and it ranged between 2.30 and 7.15 mg kg^{-1} for soils in Obuguru but even though it was higher in Burutu (2.35-30.0 mg kg^{-1}) its concentrations in both communities were below the maximum allowable value 36 mg kg^{-1} (DPR, 2018) for all studied sites. It had an average value of 3.76±1.80 and 14.7±11.8 mg kg^{-1} in Obuguru and Burutu respectively (Table 3). The values recorded in this study are also relatively higher than those reported for some parts of the Niger Delta region [22], [40].

5) Nickel

Nickel concentrations varied between 0.29 and 109 mg kg^{-1} in OB soils while in BT soils it ranged between 10.9 and 194 mg kg^{-1} (the overall highest concentration). The concentrations recorded in six sampling points (OBL1; OBS5; BTL7; BTL8; BTL9; and BTL11) were higher than the target value of 35 mg kg^{-1} (DPR, 2018). These high concentrations of Ni could be attributed to waste Batteries, as well as the combustion of petroleum Fuel. This result is similar to the findings of [34] in the topsoil of Elebele community, Bayelsa State.

6) Cobalt

From the order of the mean concentrations of metals in this study, Co is ranked 6th. The mean concentrations for cobalt are 40.8±50.1 mg kg^{-1} and 32.5±60.8 mg kg^{-1} in the soils of Obuguru and Burutu respectively. Availability of Co in the samples ranged between 3.00 and 98.6 mg kg^{-1} in OB soils and between 1.30 and 156 mg kg^{-1} in BT soils. At all sampling sites except OBL1 (98.6) and BTL9 (156), the recorded concentrations were lower than the target value (20) according to DPR (2018). The high concentration in BTL9 may be due to the use of fertilizers at a nearby farm as well as coal combustion (firewood cooking) in the neighbourhood [42].

7) Lead

The average concentration of Pb in the surface soil of Obuguru (4.01±4.18 mg kg^{-1}) was observed to be lower than that of Burutu (68.3±95.4 mg kg^{-1}). Lead (Pb) was not detected in some of the sampling points (OBS5, OBS6 and BTS12) and the mean concentrations in both these communities were below the DPR (2018) target limit for Pb but the recorded concentration at BTL8 (108) and BTL9 (245) were higher. This concentration exceeds the target limit of DPR (2018). The likely source of lead in BTL8 and 9 is leaded petrol and diesel used in running generating plants near the locations.

Kindly put the numbering in the rest of the Heavy metal subtitles to maintain uniformity in your write-up, just as I have done for you in four metals above.

8) Manganese

Manganese showed an average mean concentration of 86.1±92.3 mg kg^{-1} with a range between 24.3 and 265 mg kg^{-1} in OB soils while the mean concentration in BT soils was 127±85.8 mg kg^{-1} with a range between 24.3 and 221 mg kg^{-1}. Similar ranges of concentration of Mn in soil have been reported in some parts of Ogoni Region, Rivers State, Southern Nigeria [22]

9) Chromium

Chromium was detected in all samples. The concentrations varied between 4.70 and 18.0 mg kg^{-1} in OB soils with a mean of 9.80±4.92 mg kg^{-1} while in BT soils it ranged between 3.95 and 15.4 mg kg^{-1} with a mean of 9.61±4.68 mg kg^{-1}. These values are below the maximum allowable level for soils (DPR, 2018). The concentrations recorded in this study are higher than those reported by [43] and [22], but lower than the values reported by [34].

B. Pollution Indices

1) Geoaccumulation index (I_{geo})

The pollution levels of the analysed metals at the study site as shown by the calculated I_{geo} values, based on the world average shale values as background values [44] for the sampling sites, are illustrated in Table 4. The results suggest that in Obuguru (or OB samples), no pollution (or class 0) was recorded at all sites with Zn, Cr, Pb, Mn, and Cu while in Burutu only Cr, Mn and Cu recorded no pollution in 100% locations. There is none to moderate pollution (or class 1) with Fe and Zn (33.3% locations in both communities) as well as with Co, Ni and Pb (16.7% locations in both communities). I_{geo} calculations for Cadmium revealed mean values of 6.01±0.29 and 4.13±2.86 in Obuguru and Burutu samples respectively indicating extreme contamination (or class 5) with Cd in 100% and 66.7% locations in topsoils of Obuguru and Burutu communities, respectively.

2) Enrichment factor

The results of enrichment factor (EF) showed that there was significant to very high enrichment with Cd in 100% locations in Obuguru and 76.7% locations in Burutu (samples 1 to 10), with the highest and lowest Cd enrichment at OBL3 (EF =30) and BTS12 (EF =0.317) respectively. There was moderate enrichment of Pb at BTL9 with an EF value of 2.91. The other investigated metals showed deficient to minimal enrichments in all the locations. In general, metal enrichment in topsoils of the study area from highest to least was found to be in the order Cd>Fe>Co>Zn>Ni>Pb>Cr>Cu>Mn in Obuguru and Cd>Fe>Pb>Co>Zn>Ni>Cu>Mn>Cr in Burutu.

Assessments of anthropogenic pollution in soils of Obuguru and Burutu Communities.

Table 4. Geoaccumulation Index of the Samples for Heavy Metals in the Soil of the Study Sites

SITE	I_{geo} Class	**Sample ID**	**Zn**	**Cd**	**Fe**	**Cu**	**Ni**	**Co**	**Pb**	**Mn**	**Cr**
OBUGURU		OBL1	-1.26	**5.67**	0.04	-4.47	-0.02	**1.79**	-2.15	-5.71	-3.46
		OBL2	-0.42	**5.79**	**1.79**	-4.35	-4.17	-2.04	-2.74	-2.27	-4.11
		OBL3	-0.59	**6.40**	-0.12	-3.24	-2.90	-0.77	-1.49	-4.48	-3.71
		OBS4	-1.35	**6.06**	**1.65**	-4.88	-2.74	-0.51	-3.80	-5.03	-4.84
		OBS5	-0.32	**6.29**	**1.56**	-3.99	**0.10**	-3.25	N/A	-3.61	-2.91
		OBS6	-1.55	**5.88**	**0.92**	-4.76	-8.48	-0.70	N/A	-5.58	-4.58
		Mean	-0.91	**6.01**	**0.97**	-4.28	-3.04	-0.91	-2.55	-4.44	-3.93
		SD	0.53	0.29	0.84	0.60	3.16	1.69	0.98	1.32	0.72
		Min	-1.55	5.67	-0.12	-4.88	-8.48	-3.25	-3.80	-5.71	-4.84
		Max	-0.32	6.40	1.79	-3.24	0.10	1.79	-1.49	-2.27	-2.91
		Samples (%)									
	0	$I_{geo} \leq 0$	100	0	16.7	100	83.3	83.3	100	100	100
	1	$0 < I_{geo} < 1$	0	0	33.3	0	16.7	0	0	0	0
	2	$1 < I_{geo} < 2$	0	0	50.0	0	0	16.7	0	0	0
	3	$2 < I_{geo} < 3$	0	0	0	0	0	0	0	0	0
	4	$3 < I_{geo} < 4$	0	0	0	0	0	0	0	0	0
	5	$4 < I_{geo} < 5$	0	0	0	0	0	0	0	0	0
	6	$I_{geo} \geq 5$	0	100	0	0	0	0	0	0	0
BURUTU		BTL7	**0.85**	**6.04**	**1.51**	-2.40	**0.83**	-4.45	**0.57**	-2.80	-4.07
		BTL8	**0.97**	**5.73**	**2.40**	-1.17	**0.41**	-3.99	**1.85**	-4.63	-3.23
		BTL9	**1.31**	**5.86**	**2.17**	-1.26	**0.93**	**2.45**	**3.03**	-2.64	-3.14
		BTS10	-1.72	**6.19**	**1.43**	-4.84	-2.74	-0.60	-1.63	-5.71	-4.66
		BTS11	-1.22	**1.15**	**1.46**	-2.67	-1.38	-3.07	-3.23	-4.05	-3.68
		BTS12	-1.14	-0.17	**1.15**	-3.96	-3.23	-1.06	N/A	-2.53	-5.10
		Mean	-0.16	**4.13**	**1.69**	-2.72	-0.86	-1.79	**0.12**	-3.73	-3.98
		SD	1.34	2.86	0.49	1.46	1.85	2.59	2.54	1.29	0.78
		Min	-1.72	-0.17	1.15	-4.84	-3.23	-4.45	-3.23	-5.71	-5.10
		Max	1.31	6.19	2.40	-1.17	0.93	2.45	3.03	-2.53	-3.14
		Samples (%)									
	0	$I_{geo} \leq 0$	50.0	16.7	0	100	50.0	83.3	50.0	100	100
	1	$0 < I_{geo} < 1$	33.3	0	0	0	50.0	0	16.7	0	0
	2	$1 < I_{geo} < 2$	16.7	16.7	66.7	0	0	0	16.7	0	0
	3	$2 < I_{geo} < 3$	0	0	33.3	0	0	16.7	0	0	0
	4	$3 < I_{geo} < 4$	0	0	0	0	0	0	16.7	0	0
	5	$4 < I_{geo} < 5$	0	0	0	0	0	0	0	0	0
	6	$I_{geo} \geq 5$	0	66.7	0	0	0	0	0	0	0

Table 5. Enrichment Factors (EF) of all metals under study

SITE		**Sample ID**	**Zn**	**Cd**	**Fe**	**Cu**	**Ni**	**Co**	**Pb**	**Mn**	**Cr**
OBUGURU		OBL1	0.15	**18.1**	0.37	0.02	0.35	**1.23**	0.08	0.01	0.03
		OBL2	0.27	**19.7**	**1.23**	0.02	0.02	0.09	0.05	0.07	0.02
		OBL3	0.24	**30.0**	0.33	0.04	0.05	0.21	0.13	0.02	0.03
		OBS4	0.14	**23.8**	**1.12**	0.01	0.05	0.25	0.03	0.01	0.01
		OBS5	0.29	**27.8**	1.05	0.02	0.38	0.04	-0.00	0.03	0.05
		OBS6	0.12	**21.0**	0.67	0.01	0.00	0.22	-0.03	0.01	0.02
		Mean	**0.20**	**23.4**	**0.79**	0.02	**0.14**	0.34	**0.04**	0.02	0.03
		SD	0.07	4.71	0.39	0.01	0.18	0.45	0.06	0.03	0.01
		min	0.12	18.1	0.33	0.01	0.00	0.04	-0.03	0.01	0.01
		max	0.29	30.0	1.23	0.04	0.38	1.23	0.13	0.07	0.05
		Sample (%)									
	Deficiency to Minimal Enrichment	EF< 2	100	0	100	100	100	100	100	100	100
	Moderate Enrichment	EF 2 – 5	0	0	0	0	0	0	0	0	0
	Significant Enrichment	EF 5 – 20	0	33.3	0	0	0	0	0	0	0
	Very High Enrichment	EF 20 – 40	0	66.7	0	0	0	0	0	0	0
	Extremely High Enrichment	EF > 40	0	0	0	0	0	0	0	0	0
BURUTU		BTL7	0.64	**23.4**	**1.01**	0.07	0.63	0.02	0.53	0.05	0.02
		BTL8	0.70	**18.9**	**1.89**	0.16	0.47	0.02	**1.28**	0.01	0.04
		BTL9	0.89	**20.7**	**1.60**	0.15	0.68	**1.95**	**2.91**	0.06	0.04
		BTS10	0.11	**26.0**	0.96	0.01	0.05	0.24	0.12	0.01	0.01
		BTS11	0.15	0.79	0.98	0.06	0.14	0.04	0.04	0.02	0.03
		BTS12	0.16	0.32	0.79	0.02	0.04	0.17	-0.04	0.06	0.01
		Mean	**0.44**	**15.0**	**1.21**	0.08	**0.34**	0.41	**0.81**	0.04	0.03
		SD	0.34	11.5	0.43	0.06	0.29	0.76	1.14	0.02	0.01
		min	0.11	0.32	0.79	0.01	0.04	0.02	-0.04	0.01	0.01
		max	0.89	26.0	1.89	0.16	0.68	1.95	2.91	0.06	0.04
		Sample (%)									
	Deficiency to Minimal Enrichment	EF< 2	100	33.3	100	100	100	100	83.3	100	100
	Moderate Enrichment	EF 2 – 5	0	0	0	0	0	0	16.7	0	0
	Significant Enrichment	EF 5 – 20	0	16.7	0	0	0	0	0	0	0
	Very High Enrichment	EF 20 – 40	0	50	0	0	0	0	0	0	0
	Extremely High Enrichment	EF > 40	0	0	0	0	0	0	0	0	0

Table 6a. Pearson correlation coefficient matrix (r) between Heavy metals and physicochemical properties of soil in Obuguru

	Zn	*Cd*	*Fe*	*Cu*	*Ni*	*Co*	*Pb*	*Mn*	*Cr*	*pH*	*EC μScm^{-1}*	*%TOC*	*Sand*	*Silt*	*Clay*
Zn	1														
Cd	0.477	1													
Fe	0.330	-0.096	1												
Cu	0.557	0.767**	-0.471	1											
Ni	0.228	0.017	-0.146	0.007	1										
Co	-0.491	-0.545	-0.597	-0.206	0.473	1									
Pb	0.150	0.195	-0.630	0.697**	-0.092	0.355	1								
Mn	0.704**	-0.146	0.634	0.020	-0.187	-0.442	-0.013	1							
Cr	0.620	0.363	-0.130	0.404	0.862***	0.104	0.030	0.049	1						
pH	0.643*	0.825***	-0.273	0.919***	0.211	-0.191	0.617	0.043	0.533	1					
ECμScm^{-1}	-0.083	0.333	0.113	-0.107	0.044	-0.472	-0.711**	-0.330	0.149	-0.181	1				
%TOC	0.394	0.619*	0.573	0.247	-0.396	-0.759**	-0.051	0.299	-0.181	0.418	0.038	1			
Sand	-0.250	0.205	0.242	-0.039	-0.509	-0.189	0.179	-0.104	-0.608	0.115	-0.318	0.703**	1		
Silt	-0.137	0.581	-0.095	0.264	-0.487	-0.621*	-0.236	-0.354	-0.249	0.091	0.744**	0.346	0.130	1	
Clay	0.233	-0.384	-0.205	-0.065	0.589	0.366	-0.106	0.182	0.601	-0.168	0.085	-0.769**	-0.960**	-0.400	1

[a] *r*-values are significant at **p*<0.10; ***p*<0.05; ****p*<0.01
[b] TOC= Total organic carbon,
[c] EC=electrical conductivity

Table 6b. Pearson correlation coefficient matrix (r) between Heavy metals and physicochemical properties of soil in Burutu

	Zn	*Cd*	*Fe*	*Cu*	*Ni*	*Co*	*Pb*	*Mn*	*Cr*	*pH*	*EC μScm^{-1}*	*%TOC*	*Sand*	*Silt*	*Clay*
Zn	1														
Cd	0.502	1													
Fe	0.780**	0.397	1												
Cu	0.885***	0.286	0.952***	1											
Ni	0.966***	0.538	0.644*	0.782**	1										
Co	0.570	0.248	0.390	0.481	0.491	1									
Pb	0.871***	0.410	0.766***	0.838***	0.774**	0.870***	1								
Mn	0.336	-0.239	-0.183	0.056	0.347	0.432	0.300	1							
Cr	0.779**	0.225	0.887***	0.944***	0.707**	0.527	0.812***	-0.070	1						
pH	-0.320	-0.722**	-0.189	-0.065	-0.259	-0.188	-0.257	-0.125	0.169	1					
ECμScm^{-1}	-0.723**	-0.089	-0.425	-0.559	-0.651*	-0.283	-0.515	-0.700*	-0.300	0.410	1				
%TOC	-0.222	-0.378	-0.143	-0.187	-0.406	0.170	-0.012	0.408	-0.357	-0.317	-0.316	1			
Sand	-0.445	-0.062	-0.851***	-0.755**	-0.287	0.069	-0.354	0.352	-0.655*	0.011	0.333	0.009	1		
Silt	-0.31	0.283	0.168	-0.080	-0.315	-0.607	-0.399	-0.956***	-0.036	-0.018	0.545	-0.371	-0.407	1	
Clay	0.528	0.008	0.874***	0.817***	0.355	0.062	0.463	-0.190	0.705**	-0.012	-0.453	0.080	-0.983***	0.234	1

[a] *r*-values are significant at **p*<0.10; ***p*<0.05; ****p*<0.01
[b] TOC= Total organic carbon,
[c] EC=electrical conductivity

C. Correlation Analysis

Tables 6 (a & b) depicted the correlation coefficient matrix for the studied physicochemical parameters and heavy metal in the soil samples taken from both communities. The r-values were found to be significant at ±**0.697** ($\boldsymbol{p < 0.05}$) in Obuguru and at ±**0.705** ($\boldsymbol{p < 0.05}$) in Burutu. The data corresponding to the correlation coefficient matrix for the different categories (between physicochemical properties, between metals and physicochemical properties as well as between metals only) portrayed several positive/negative correlations as discussed below:

i. the physicochemical parameters

In Obuguru topsoil, the most significant positive correlation was discovered between electrical conductivity (EC) and silt levels with a r-value 0.744, showing that, in about 74.4% cases, the electrical conductivity of soil was observed to increase with an increase in silt content and vice versa. There were also significantly strong negative correlations between Clay and sand (r=-0.96 at p<0.01). Whereas in Burutu topsoil the strongest and only significant correlation was observed between Sand and Clay (r=-0.983 significant at p<0.01).

ii. physicochemical parameters and the various metals

Cu of the soil in Obuguru exhibited the strongest positive correlation with its pH (r-value of 0.919) which was significant at p<0.01. Other significantly positive/negative correlations included pairs of pH/Cd (r=0.83 at p<0.01), and %TOC/Co (r=-0.76 at p<0.05). However, in Burutu, most of the strong positive correlations were between Clay and metals. Clay had significant positive correlations with Fe, Cu, and Cr at r-value =0.874 (at p<0.01), 0.817 (at p<0.05) and 0.705 (at p<0.05) respectively. Several other non-significant correlations to varying degrees were also observed.

iii. levels of selected metals in the collected soil samples

The strongest positive correlation between metals in Obuguru was found between Cr and Ni at a r-value of 0.862 (significant at p<0.01), indicating that in 86.2% cases the concentration of Cr increases as the concentration of Ni increases, thus having the same origin in the soil matrix. The next strongest positive correlation was observed between Cu and Cd pair (0.767 significant at p<0.05) and this was closely followed by Mn and Zn (r-value 0.704 not significant at p<0.05). In Burutu, the strongest positive correlation was found between Zn and Ni at a r-value of 0.966 (significant at p<0.01), thereby showing that in 96.6% cases the concentration of Zn went in parallel with the concentration of Ni, thus sharing a similar origin in the soil matrix. Other Significant and very strong positive correlations were also observed between Cu and Fe pair (0.952 at p<0.01), Cu and Cr (r-value 0.944 significant at p<0.01). In both communities, several non-significant positive/negative correlations to varying degrees were found for the other metal pairs.

IV.CONCLUSION AND RECOMMENDATION

A. Conclusion

The study's findings have established that the topsoil of the study area is sandy and its pH is slightly acidic to moderately alkaline. It has also shown that Cadmium (Cd) is the main metal responsible for pollution of the topsoil in the study area. Pollution assessment performed by geo-accumulation index (Igeo) and Enrichment factor (EF) showed that Cadmium (Cd) is found to be associated with anthropogenic activities and soil parent material was responsible for the concentrations of other metals especially Cu, Mn and Cr. The correlation matrix analysis' findings show that metals in the study area exhibit different degrees of correlation. In addition, the knowledge on heavy metal contents of the soil from this study may serve as baseline data for the determination of mineral contents and physicochemical properties of soil in the study area.

B. Recommendations

There should be further studies to assess the health risk of Cadmium pollution in the soil and water of the study area.

Also, since the concentrations of most of the investigated metals are presently low, build-up of heavy metals associated with changes in soil properties should be monitored in the study area to ascertain when the soils are likely to be polluted.

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