Evaluation of Heavy Metal Pollution in Soils of Warri and Environs, Southwestern Nigeria, Using Contamination Indexes

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Abstract—The concentrations of heavy metals (Pb, Cd, As, Ni, Cu, Zn) in soils of Warri and environs were determined using Atomic Absorption Spectrophotometer (AAS). The mean concentrations of heavy metals obtained in all samples from the study area showed an increasing order of As>Cd>Pb>Ni>Cr>Zn>Cu>Fe. In order to ascertain their pollution status, the environmental indexes: geoaccumulation index, contamination factor and enrichment factor were used to quantitatively ascertain the extent of soil pollution, especially from anthropogenic activities.The mean Igeo values had a decreasing trend as follows As (-0.66) > Zn(-4.93)>Cu(-5.8)>Fe(-5.31)>Cd(-5.76)>Pb(-6.35)> Ni(11.25) indicating that the soils of Warri and environs were not polluted by heavy metals.The mean CF values at all sampled locations were in the order Cu= Zn (0.08), < Cd (0.34)<Pb (0.02)<As (0.01)<Ni (0.00), indicating low contamination factor (<1).The mean EFs for the soils were: As (1.55)> Cd(1.53)> Cu(1.14)> Zn(1.07)> Pb(1.05) > Ni(1.02)> Fe(0.83), indicating that there was minimal enrichment (<2) in heavy metal concentration of the soil samples. Hierarchical cluster analysis (HCA) revealed that anthropogenic activities contributed to an extent on the accumulation of heavy metals in soils of the study area, but this was minimal, thereby posing no significant environmental threat.

Keywords—Contamination factor, Enrichment factor, Geoaccumulation index, Heavy metals, Soil.

1 INTRODUCTION

The increase in anthropogenic activities, especially in urban environments has intensified the accumulation of heavy metals in urban soils. Soils are a heterogeneous mixture of air, water, organic and inorganic solids, and micro-organisms, consisting of layers of variable thickness [1].Soil acts as repositories for the transfer, retention and domiciliation of these heavy metals and other toxic pollutants in the environment [2].The weathering of rocks amongst other geologic processes cause heavy metals to be naturally released and transported into the environment, and these result to natural background concentrations of heavy metals in the soil[3]. However, unregulated human activities have caused a significant increase in the concentration of heavy metals in the environment, when compared to those resulting from natural processes [4].These anthropogenic sources of heavy metals usually accumulate easily in the topsoil, hence, the reason why topsoils and dust in urban areas are indicators of heavy metal pollution from anthropogenic sources such as atmospheric deposition from industrial activities which include gas flaring, vehicular emission, fertilizer, pesticides, improper disposal of electronic and petroleum waste and waste from automobile workshops. While some of these heavy metals are essential at low concentrations, at higher concentrations, they are considered to be dangerous environmental pollutants because they are persistent, bioaccumulative, have reduced biodegradability, and are soluble hence their mobility increases when released into the environment [5], [6].Contamination of soils by heavy metals may result to serious consequences, such as loss of vegetation, agricultural productivity, reduced food chain quality, economic loss and health problems in humans and animals. Also these increasing concentrations of heavy metals in soils of the study area may migrate to shallow porous and permeable aquifers which occur in Warri and environs, if not checked.

Some isolated works to study the distributions of heavy metals in some localities around Warri have been carried out, but none has been undertaken using contamination indexes, which can estimate the extent of soil pollution by heavy metals resulting from impacts by humans. These contamination indexes are used to compute pollution factors for heavy metals, and determine the relation between natural and anthropogenic sources of these heavy metals in soil of the study area, which is important, because both lithogenic and anthropogenic sources result to heavy metals accumulation on the soil [7], [8]. The method has been applied in various studies [2], [9], [10], [11].

The objectives of the present study was to (i) determine the concentration of a suite of heavy metals in the soil of Warri and environs (ii) assess the extent of pollutionby calculating contamination indexes such as Geoaccumulation index, Enrichment Factor (EF), and Contamination Factor, in order to give a more precise appraisal of the influence of anthropogenic activities on heavy metal concentration in soils of the study area. It is expected, that the results of this study will aid in proper management strategies to reduce the potential hazards posed by soil pollution resulting from heavy metals in Warri and environs.

Figure 1: Map of the study area.

2 Materials and Methods

2.1 Study Area

Warri and its environs in Delta State, in the oil rich Niger Delta Basin of Southwestern Nigeria, is mainly a lowland which lies within latitudes 5.29°N and 5.34°N and longitudes 5.41°E and 5.49°E (Fig. 1). One of the national refineries, where associated gas is flared on a daily basis is located within the study area.The climate of Warri and Environs is mainly tropical with analternating wet and dry season. The dry season occurs annually from November to March, while the rainy season usually occurs from April to October. Mean annual temperatures range from about 220C to 340C, while mean annual rainfall is between 1,501 mm and 2000 mm; mean evapotranspiration is 1117 mm [12], [13], with high humidity [14]. Geologically, the study area is underlain by the Benin Formation, which is overlain by superficial deposits of alluvium of a Quaternary to Recent age known as the Sombreiro-Warri Deltaic Plain sands.

2.2 Sample Collection

Soil samples were taken from twenty-four different locations to cover industrialized, agricultural and housing areas. A Garmin model GPS device was used to determine the geographical coordinates of each sampled site. In order to obtain representative sampling, a regular sampling grid network composed of cells was adopted to sample the soils in the study area. To achieve this, the base map was divided into squared grids, however this was not strictly adhered to due to inaccessibility at some study locations. The soil samples were obtained at a depth of 0 - 15 cm from each site using a clean stainless steel soil auger. Soil samples were collected from the middle and all edges of each grid and mixed properly to give a composite sample mixture which was kept in labeled polythene sample bags for analysis .Soil samples were collected from parks, commercial areas, main roadside, from housing areas, and from industrial areas. The soil auger was washed and rinsed with distilled water after each sampling in order to reduce the likelihood of sample cross-contamination.

2.3 Sample Preparation and Statistical Analysis

All Heavy metals analyzed in all soil and sediment samples are cadmium, lead, chromium, arsenic, nickel, zinc, iron and copper. Wet Oxidation method was adopted to extract the heavy metals from samples through digestion. The samples were air dried at room temperature, and then loosened using a ceramic pestle and mortar, after which they were sieved using a 2 mm mesh sieve in order to remove coarse materials and other debris. Afterward, 5g of the dried fine soil and sediment samples were ground and blended with an agate mortar until a fine powder which could pass through a 0.15 mm polyethylene sieve was obtained. Then about 2g of this powder was taken, and transferred into a 250cm3 acid washed conical flask, this was digested with 1ml of perchloric acid ($HClO_4$) and 3ml of nitric acid (HNO_3) for 10 minutes at room temperature. The digested mixture was heated on a hot plate in a fume cupboard at 400C until the digestion was completed. After the mixture had been cooled at room temperature, it was filtered using Whitman No.1 filter paper into a 50 ml flask. The filtrate was then stored in polythene bottles ready for analysis. The same procedures were carried out for the blank samples. The sample solution, the standard, and the blanks were aspirated respectively into the air-acetylene flame of Atomic Absorption Spectrophotometer (AAS) for heavy metal analyses using different heavy metals cathode lamps. Varian Spectra Model 220 (Fast Sequential) AAS was used for the analyses. All samples were analyzed in duplicate and during the analysis, it was ensured that the instruments were well calibrated and operated according to the specifications of the manufacturer.

Statistical analyses of all the data obtained from all sampled sites in the present study were carried out with IBM Statistical Package for the Social Sciences (SPSS) 20.0 software. Hierarchical Cluster Analysis (HCA) was done to further identify the sources of the heavy metals in the soils of the study area.

2.4 Calculation of Pollution Intensity Indexes

The extent of heavy metal pollution in the soil samples was quantitatively assessed using the pollution intensity indexes geoaccumulationindex (Igeo), Contamination Factor (CF), and

enrichment factor (EF). These indexes are methods widely used for the assessment of the impacts of anthropogenic activities on soils and sediments and they generally involve calculating the contamination factors for the heavy metal concentrations against uncontaminated background levels [15]. These indexes have been extensively used in different studies [9], [16].

The geoaccumulation Index (Igeo) was introduced by [17]. This approach involves comparing the current concentration of heavy metal in a system to pre-industrial concentrations. The method has been commonly used to evaluate heavy metal contamination in urban soils and sediments.Geoaccumulation index were calculated as follows:

$$Igeo = \log2 (Cn /1.5Bn) \quad (1)$$

Where Cn is the measured concentration of the element in question measured at a certain site, Bn is the geochemical background value of the element in the soil [17]. The constant 1.5 was used in the Igeo equation to reduce possible effects of varying background values which may have resulted from varying lithology [18]. The geoaccumulation index has been subdivided into seven enrichment classes based on their values as follows: Igeo < 0 = unpolluted; 0-1 = unpollutedto moderately polluted; 1-2 = moderately polluted; 2 -3 = moderately to heavily polluted; 3-4, heavily polluted; 4-5 = heavily to extremely polluted; > 5 = extremely polluted [17], [7], [19], [11].

Contamination factor was used to assess the extent of contamination of each heavy metal in soils in relation to their background concentrations [20]. The CF is derived by dividing the concentration of each metal in the soil or sediments by the background value [9], and was calculated as follows:

$$CF=Cs / Cn \quad (2)$$

Where CF is the contamination factor of the element of interest, Cs and Cn are the concentration of the element in the sample and the background concentration respectively. In this study, the continental crustal averages have been used [21].CF is defined according to four categories : CF < 1,no or low contamination; 1 ≤ CF < 3, moderate contamination; 3≤ CF < 6, considerable contamination; 6 ≤ CF, very high contamination [22], [9].

Enrichment factors have been widely used to calculate the ratio between uncontaminated background levels and contaminated soil or sediment [10], [11].It also integrates the concentration of a measured element against a reference element. The reference element is usually characterized by low occurrence variability. The EFs were calculated using the relation

$$EFX= [XS/ ES(ref)]/ [XC/ EC(ref) \quad (3)$$

Where EFX = the enrichment factor for the element X, XS= the concentration of the element of interest in a sample, ES(ref) = the concentration of the reference element used for normalization in the sample, XC = the concentration of the element in the crust and EC(ref) is the concentration of the reference element used for normalization in the crust [21]. The following EF classification was used to evaluate the data EF <3, minor enrichment, EF between 3-5, moderate enrichment; EF 5-10, moderately severe enrichment; EF between 25 and 50, very severe enrichment; EF > 50, extremely severe enrichment [11].Values of EF lower than 1.5 [7] or <2 [23] indicate that the metal is entirely from crustal materials or natural processes, while EF values higher than 1.5 or 2 suggest an increasing portion of the anthropogenic sources [23]. Average shale value was used as the background value of heavy metals in this study [24], and Fe was used as the reference element.

3 Results and Discussion

3.1 Concentration of Heavy Metals in Soil

The mean concentration of heavy metals obtained from the soil samples in the study area is presented in Table 1. The concentration of lead ranged from 0.001 mg/kg to 1.11 mg/kg, with a mean value of 0.1692 mg/kg. The highest value recorded during the study was within the vicinity of the Warri Refinery and Petrochemical Company. It is likely that these increased levels of Pb in that vicinity is caused by atmospheric deposition via gas flaring in the study area. Lead can be inhaled in dust from Pb based paints, or waste gases from leaded gasoline.

The mean concentration of arsenic was 0.0064 mg/kg.The concentrations of As obtained from this study are comparable to those recorded by [25], and [26] in their study on heavy metal analysis of soil samples within the same region.

Nickel concentrations ranged from less than 0.001 to 0.34 mg/kg, with a mean value of 0.852 mg/kg. Nickel concentrations in soils of the study area were generally within that of the control sites and below standard limits. Further, the concentration range reported in this study was similar to concentration range values reported in a similar study [25].

Copper had relatively low values ranging from 0.001 mg/kg to 0.17 mg/kg with the control site recording concentration less than 0.001 mg/kg. High values of copper are attributed to the presence of electronic and automobile wastes containing electrical and electronic parts, such as copper wires, electrodes and copper pipes and alloys from corroding vehicle scraps which corrode and gradually leach into the sol. Within the study area the low levels of copper recorded may be attributed to the activities of scavengers, who go about picking up metal scrap and selling them off to recycling companies at a profit. These levels of Cu recorded in this study were similar to those recorded by [25] but were however lower than those recorded by [27].

The concentration of iron in the dry season was higher than those of the rainy season, with values ranging from 0.87 mg/kg to 1451.02 mg/kg. A mean value of 499.971 mg/kg

was recorded in the dry season. The highest concentration of iron during the study was recorded at Iyara. This was expected, considering its proximity to Rubber Plantation, which is a metal scrap yard littered with several auto mechanic workshop. Further, the topsoil in Warri comprises of "Coastal Plain Sand", which is a member of the Benin Formation. The soil is without a lateritic cover which characterizes the tropics, hence which was reflected by low Fe content of 0.44 mg/kg at the control site.

The concentration of zinc ranged from 0.001 mg/kg to 19.58 mg/kg with a mean value of 6.076 mg/kg. Elevated levels of zinc at some sample locations may be from the use of fertilizers and pesticides at these locations [28]. Zinc oxide is a component of paint, so the high zinc levels in the soils of the study areas could be as a result of the activities of the spray painter and also vehicle body paints. Zinc is also a component of automobile exhaust and part of additives to lubricating oils [5] and so its high concentration could also be attributed to these. Other increased sources of Zn content in some of the samples may have been from traffic sources, especially automobile tyres and emissions. Zn is also used as a vulcanization agent in automobile tyres. High levels of zinc cause anaemia and skin irritation in humans and are phytotoxic to plants.

3.2 Evaluation of Heavy Metal Pollution

The computed values of Index of geo-accumulation, contamination factor, and enrichment factor of soil samples in the study area are shown in Tables 2 - 4. The mean Igeo values had a decreasing trend as follows As (-0.66)>Zn(4.93)>Cu >Zn(-4.93)>Cu(-5.8)>Fe(-5.31)>Cd(-5.76)>Pb(6.35)>Ni(11.25).The results show that all the geoaccumulation indexvalues for all heavy metals in all soil samples collected were less than zero (<0), indicating that the soils of Warri and environs were not polluted by heavy metals based on [17]interpretation. Low Geoaccumulation values (>0) which show that the soils were not contaminated by heavy metals were also reported by [2], in a similar study of urban soils within the same region.

The CF values ranged from 0.01 to 0.08. The mean CF values at all sampled locations were in the order Cu= Zn (0.08), < Cd (0.34) <Pb (0.02) <As (0.01)<Ni (0.00), indicating low contamination factor (<1). [22] reported that CF values between 0.5 and 1.5 indicate that the metal is completely derived from crustal materials or natural processes; whereas CF values higher than 1.5 suggest that the sources are more likely to be anthropogenic. The sediment pollution extent based on the EFs and Igeo values was comparable with the most recent

The computed EF results for all sampled locations showed values ranging from 0.58 to 1.89. The mean EFs for the soils were: As (1.55)> Cd(1.53)>Cu (1.14)>Zn (1.07)> Pb(1.05) > Ni(1.02)> Fe(0.83), indicating that there was minimal enrichment (<2) in heavy metal concentration of the soil samples. At some locations, the EF values for some heavy metals were greater than 1.5 (Table 4). [30] reported that EF values within 0.5-1.5 indicate that the heavy metals are entirely from lithogenic or natural sources, while EF values higher than 1.5 suggests that the source is likely from human activities. Increasing EF values implies increasing contribution by anthropogenesis to heavy metals in the soil [31]. This implies that from the computed EF values human activities had contributed to an extent in the concentration of heavy metals in the soils of Warri and environs, however, the effect was minimal at the time of this study.

TABLE1

AVERAGE HEAVY METAL CONCENTRATION IN SOIL SAMPLES OF THE STUDY AREA (MG/KG).

Location	Pb	Cd	As	Ni	Cu	Fe	Zn
Ekpan	0.05	0.23	0.01	0.02	0.46	1131.54	5.64
Refinery	0.42	0.68	0.01	0.07	5.28	677.73	14.02
Ubeji	0.07	0.63	0.01	0.03	7.29	436.33	11.16
NPA	0.03	0.01	0.01	0.34	0.13	1244.37	19.58
Jakpa	0.03	0.01	0.01	0.00	0.14	1078.02	2.04
NNPC Estate	0.00	0.70	0.01	0.00	0.46	1196.61	2.45
Ejeba	0.02	3.56	0.01	0.00	5.54	676.03	16.74
Ogunu	0.60	0.12	0.01	0.00	0.00	28.37	1.45
Aladja	0.35	5.92	0.01	0.26	8.12	991.12	12.62
Udu Rd	0.56	0.69	0.00	0.00	0.81	66.74	4.02
Ugbomro	0.55	0.07	0.01	0.00	0.36	10.06	0.22
Esiri Rd	0.01	0.01	0.00	0.01	2.00	503.28	7.97
PTI Road	0.00	0.54	0.01	0.01	0.57	85.44	3.94
Ugborikoko	0.00	0.09	0.01	0.01	2.78	3.18	0.01
Iyara	0.11	0.53	0.01	0.06	0.00	1451.02	8.77
Ovwian	0.01	0.01	0.01	0.08	0.68	1.96	0.07
Main Mkt	0.01	0.01	0.01	0.01	0.00	3.62	0.00
Ekete	0.01	0.01	0.01	0.01	0.12	1.05	0.00
Okere Mkt	0.01	0.03	0.00	0.01	0.46	28.00	4.12
Lower Erejuwa	1.11	0.55	0.01	0.01	0.11	1285.66	15.28
Ogunu	0.01	0.01	0.01	0.01	4.06	0.87	0.00
Enerhen Road	0.01	0.01	0.01	0.02	0.11	3.91	0.09
Urhobo College	0.01	0.01	0.01	0.07	0.00	5.50	0.45
Okere Airport	0.10	0.41	0.01	0.01	0.37	1088.95	15.24
Mean	0.17	0.62	0.01	0.04	1.66	499.97	6.08

TABLE 1

GEOACCUMULATION INDEX OF HEAVY METALS IN SOILS OF WARRI AND ENVIRONS.

Location	Pb	Cd	As	Ni	Cu	Fe	Zn
Ekpan	-6.23	-6.73	-0.56	-10.12	-5.43	-3.77	-2.11
Refinery	-5.44	-5.79	-0.68	-11.23	-6.43	-5.88	-1.88
Ubeji	-7.11	-6.11	-0.67	-12.36	-5.60	-6.56	-1.77
NPA	-5.63	-5.44	-0.57	-10.11	-4.33	-3.66	-1.67
Jakpa	-6.44	-5.43	-0.67	-11.21	-5.64	-3.77	-3.56
NNPC Estate	-6.55	-5.33	-0.55	-11.22	-6.00	-3.56	-4.44
Ejeba	-6.99	-2.11	-0.56	-12.91	-3.29	-5.66	-1.68
Ogunu	-5.22	-7.45	-0.68	.-10.102	-4.56	-5.77	-2.78
Aladja	-6.44	-2.33	-0.77	-10.78	-5.43	-5.11	-1.67
Udu Rd	-6.00	-5.12	-0.67	-11.22	-5.11	-6.73	-3.00
Ugbomro	-6.00	-6.00	-0.78	-11.00	-6.77	-5.78	-6.88
Esiri Rd	-5.77	-5.99	-0.67	-11.88	-3.44	-6.78	-5.89
PTI Road	-6.03	-5.40	-0.68	-10.33	-5.33	-5.66	-4.72
Ugborikoko	-7.99	-6.34	-0.77	-10.12	-2.34	-6.88	-10.11
Iyara	-5.95	-5.11	-0.66	-11.11	-6.78	-5.89	-6.79
Ovwian	-7.11	-6.94	-0.70	-11.00	-4.56	-6.77	-5.78
Main Mkt	-7.94	-5.44	-0.56	-11.78	-6.55	-4.77	-10.22
Ekete	-8.11	-5.01	-0.62	-10.67	-5.44	-3.99	-10.56
Okere Mkt	.-7.334	-6.71	-0.65	-12.22	-6.78	-4.45	-6.67
Lower Erejuwa	-3.55	-7.22	-0.55	-11.33	-5.56	-6.99	-1.67
Ogidi St Ogunu	.-5.332	-6.78	-0.71	-12.22	-2.22	-5.12	-10.89
Enerhen Road	-5.33	-7.33	-0.77	-11.00	-5.55	-4.34	-6.57
Urhobo College	-6.44	-6.79	-0.67	-10.99	-6.55	-6.11	-5.80
Okere Airport	-7.33	-5.32	-0.60	-11.94	-4.67	-3.34	-1.11
Mean	-6.35	-5.76	-0.66	-11.25	-5.18	-5.31	-4.93

TABLE 3
CONTAMINATION FACTORS OF HEAVY METALS IN SOIL OF WARRI AND ENVIRONS.

Location	Pb	Cd	As	Ni	Cu	Fe	Zn
Ekpan	0.01	0.34	0.02	0.01	0.08	0.01	0.09
Refinery	0.11	0.43	0.01	0.01	0.09	0.01	0.06
Ubeji	0.03	0.53	0.01	0.01	0.09	0.01	0.05
NPA	0.00	0.15	0.02	0.01	0.10	0.01	0.04
Jakpa	0.00	0.25	0.01	0.01	0.08	0.01	0.06
NNPC Estate	0.01	0.68	0.01	0.00	0.09	0.01	0.07
Ejeba	0.01	0.18	0.01	0.01	0.09	0.01	0.09
Ogunu	0.01	0.16	0.01	0.00	0.08	0.01	0.06
Aladja	0.00	0.15	0.01	0.00	0.07	0.01	0.05
Udu Rd	0.01	0.25	0.01	0.00	0.07	0.01	0.04
Ugbomro	0.11	0.67	0.01	0.01	0.07	0.01	0.03
Esiri Rd	0.00	0.34	0.02	0.01	0.08	0.01	0.06
PTI Road	0.00	0.43	0.01	0.00	0.10	0.01	0.66
Ugborikoko	0.01	0.53	0.01	0.00	0.08	0.01	0.09
Iyara	0.00	0.15	0.02	0.01	0.09	0.01	0.06
Ovwian	0.01	0.25	0.01	0.01	0.09	0.01	0.05
Main Mkt	0.04	0.67	0.01	0.01	0.10	0.01	0.04
Ekete	0.17	0.18	0.01	0.01	0.08	0.01	0.06
Okere Mkt	0.01	0.16	0.01	0.01	0.09	0.01	0.07
Lower Erejuwa	0.00	0.15	0.01	0.01	0.09	0.01	0.09
Ogidi St Ogunu	0.01	0.25	0.01	0.01	0.08	0.01	0.06
Enerhen Road	0.01	0.67	0.01	0.01	0.07	0.01	0.05
Urhobo College	0.01	0.18	0.01	0.01	0.07	0.01	0.04
Okere Airport	0.00	0.34	0.02	0.01	0.07	0.01	0.03
Mean	0.02	0.34	0.01	0.00	0.08	0.01	0.08

TABLE 4
ENRICHMENT FACTORS OF HEAVY METALS IN SOIL OF WARRI AND ENVIRONS

Location	Pb	Cd	As	Ni	Cu	Fe	Zn
Ekpan	1.76	1.12	1.24	0.95	1.49	0.85	1.49
Refinery	0.65	1.79	1.86	0.83	1.76	0.95	1.76
Ubeji	0.85	1.77	1.22	1.13	0.83	0.97	0.83
NPA	0.88	1.12	1.87	1.75	0.94	0.86	0.94
Jakpa	1.45	1.79	1.22	0.81	0.87	0.58	0.87
NNPC Estate	0.71	1.77	1.89	0.95	1.12	0.76	1.12
Ejeba	1.76	1.12	1.24	0.83	0.97	0.85	0.97
Ogunu	0.65	1.79	1.86	0.95	0.84	0.95	0.84
Aladja	0.85	1.12	1.22	0.83	1.49	0.97	1,49
Udu Rd	0.88	1.79	1.87	1.13	1.76	0.86	1.76
Ugbomro	1.45	1.77	1.22	1.75	0.83	0.58	0.83
Esiri Rd	0.71	1.12	1.89	0.81	0.94	0.76	0.94
PTI Road	1.76	1.79	1.24	0.95	0.87	0.85	0.87
Ugborikoko	0.65	1.77	1.86	0.83	1.12	0.95	1.12
Iyara	0.85	1.12	1.22	0.95	0.97	0.97	0.97
Ovwian	0.88	1.79	1.87	0.83	0.84	0.86	0.84
Main Mkt	1.45	1.12	1.22	0.95	1,49	0.58	1,49
Ekete	0.71	1.79	1.89	0.83	1.76	0.76	1.76
Okere Mkt	1.76	1.77	1.24	0.95	0.83	0.85	0.83
Lower Erejuwa	0.65	1.12	1.86	0.83	0.94	0.95	0.94
Ogidi St Ogunu	0.85	1.79	1.24	1.13	0.87	0.97	0.87
Enerhen Road	0.88	1.77	1.86	1.75	1.49	0.86	1.12
Urhobo College	1.45	1.12	1.22	0.95	1.76	0.58	0.97
Okere Airport	0.71	1.79	1.87	0.83	0.83	0.76	0.84
Mean	1.05	1.53	1.55	1.02	1.14	0.83	1.07

3.3 Clustering Analysis

Cluster Analysis (CA) was applied to further assist in the identification of pollutant sources. CA is often carried out to help classify elements of different sources on the basis of their similarities and to identify homogeneous variables having similar properties[29]. Cluster multivariate analysis of heavy metal concentrations of soil samples collected in the dry season shows the heavy metal source apportionments in the soil samples. From the dendrogram (Fig. 2) two cluster groups were identified, based on the various sources of heavy metals in the soil samples. They were; geogenic source (Iron) and anthropogenic sources (Cadmium, Arsenic, Nickel, Lead, Chromium, Copper and Zinc). A natural source was suggested for iron because of its separate clustering from the other heavy metals.

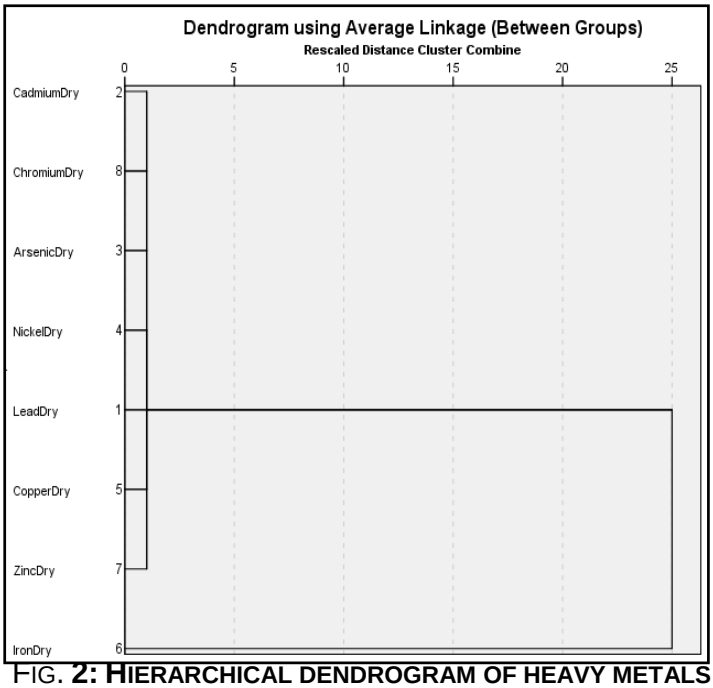

FIG. **2: HIERARCHICAL DENDROGRAM OF HEAVY METALS IN THE SOIL SAMPLES**

4 CONCLUSION

The mean concentrations of heavy metals obtained in all the samples in the study area showed an increasing order of As>Cd>Pb>Ni>Cr>Zn>Cu>Fe. Evaluation of the extent of pollution in all soil samples using calculated geoaccumulation index, contamination factor and enrichment factor values, calculated from the observed concentrations of heavy metals, showed that the soils of the study area were unpolluted. Hierarchical cluster analysis (HCA) was employed in order to further investigate the sources of heavy metal at all sampled sites in the study area, and it revealed that the heavy metals in all the sampled media had a common ori gin and were associated with anthropogenic activities in the study area. Generally, the present study showed that there was no substantial accumulation of the heavy metals in soils of Warri and environs.

The results of this study show that the surface soils in Warri and environs are affected by anthropogenic activities such as the use of fertilizers, atmospheric depositions from gas flaring, etc., but their concentrations do not pose a significant environmental impact.

ACKNOWLEDGMENT

The authors are grateful to the contributions of Prof. G.I. Nwankwor and Prof. C.A. Ahiarakwem.

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