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Levels of heavy metals in selected farmlands near dumpsites in Port Harcourt, Rivers State, Nigeria

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Abstract
Soil samples from three farmlands close to dumpsite and a control station in Port Harcourt, Rivers State, Nigeria were collected at random within a depth range of 0-60cm to evaluate concentration of some heavy metals (Fe, Pb, Cu, Cd, Cr and Ni). The determination of the concentration of the heavy metals was determined using Atomic Adsorption Spectrometer (AAS). The level of all the investigated heavy metals in the selected farmlands were higher than that obtained from the control station. The results obtained revealed that the mean concentrations of the heavy metals in the farmlands were in the range of 199.38±9.15-209.45±15.58mg/Kg for Fe, 1.70±0.09-1.86±0.14mg/Kg for Pb, 0.12±0.03-0.32±0.15mg/Kg for Cd, 2.00±0.05-2.99±0.25mg/Kg for Cr, 2.78±0.42-3.49±0.49mg/Kg for Cu and 2.15±0.34-2.75±0.23mg/Kg for Ni. The level of the investigated heavy metals in the farmlands considering the range of occurrence were in the order Fe > Cu > Cr > Ni > Pb > Cd. The results indicated that the levels of all the studied heavy metals in the farmlands were far higher than those of the control station. Pollution evaluation indices applied in assessing the soil quality as a result of anthropogenic influence were: contamination factor (CF), pollution load index (PLI), contamination degree (CD), modified contamination degree (mCD), potential ecological risk coefficient (E^i_r), potential ecological risk index (RI), Geo-accumulation index (Igeo) and anthropogenicity. These indices applied showed that the selected farmlands were not contaminated by the studied heavy metals and therefore does not pose any ecological or health risk to the farmland and humans that make use of the farmland for agriculture.

Keywords: contamination, dumpsites, farmlands, heavy metals, pollution indices

Introduction

The rapid growth in industrialization all over the world during the last century has resulted in the production of pollutants and contaminants at greater levels and degree. Such pollutants include domestic refuse, sewage and poisonous contaminants that are persistent in the environments like heavy metals, pesticides, dioxins, polychlorinated biphenyls (PCBs), chlorofluorocarbons (CFCs), radioactive wastes, which are being released from industrial manufacturing processes, petroleum exploration, production and exploitation and other suchlike activities**.** The effect of pollutants on the general ecosystem is diverse and multifaceted (Ndiokwere, 1984) [33]. Organisms that are repeatedly exposed to pesticides and heavy metals may be impaired due to acute or chronic toxic effects and accumulation in plants and animals' body parts (Jire and Imeokparia, 2016) [26].

Pollution is a major and significant challenge all over the World which has resulted in thousands and millions of individuals all over the world suffering several health challenges which is traceable to industrial and atmospheric pollution. The increase in industrial activities and rapid urbanization have increased the environmental pollution status of the world (Filazi *et al*, 2003) [20]. Industries discharge effluents which contain heavy metals such as Mn. Zn, Cu, Ba, As, Vn, Cr Pb, Cd and Ni etc. into the environment (Chen and Chen 2001) [11] thereby affecting the ecosystem. Heavy metals are absorbed by plants from the soil that has been contaminated and also from other parts of the plants where contaminants have deposited (Zurera *et al*, 1987) [49]. Presently, heavy metals are noted as possibly hazardous to plants and other living organisms within the environment (Zurera *et al*, 1987) [49]. Incapability of heavy metals to be absorbed and made use of by the body and its accumulating potentials in the soft tissues of organisms brand them hazardous (Nwajei and Iwegbue, 2007) [36]. Heavy metals are hazardous to living organisms at certain concentration above the limit that is allowed in that given environment**.** Heavy metals possess the ability not to be changed in the environment for several years and therefore becomes toxic to man and other organisms (Thapa and Weber, 1991) [42]. The heavy metals which are commonly known to cause difficulties in the human systems are Pb, Hg, Cd, As, Ni and Al. These toxic metals have the potential to accumulate in the immune system, brain and kidneys where their actions can harshly affect the normal functioning of the organs (Dibofori-Orji and Edori 2013; Ama *et al*., 2017) [12, 5].

Amongst the natural materials that is within the human direct environment, metals are the most common. They cannot be degraded neither can they be metabolized; which signifies lasting persistence in and within the environment (Sodhi, 2002). Heavy metals are metals that have density greater than 5.00 g/cm^3. Heavy metals

such as Zn, Mn, Co, Cu, and Mo are useful to the biological systems due to the physiological roles they play in the life of organisms (Eddy *et al*., 2006) [16]. While others like Pb, Se, As, Cd, Hg are poisonous at very low concentrations (Eddy *et al*., 2004) [17]. At certain concentrations all heavy metals in the environment, especially when it is above the threshold limit have the ability to jeopardize the natural ecological system and the health of the general public (Alegria *et al*., 1990). Heavy metals are mostly distinguishable from other pollutants and toxic substances in the environment due to their non-degradability and the accumulation tendencies within the global circle of ecology (Adekola *et al*., 2000) [2]. Heavy metals pollution in the environment occur through industrial and other human activities (Davies et al., 2008) [13]. Investigations have revealed that, certain of these heavy metals have polluted the soil, plants, water and the general system, that easily pass on to the animals possibly through the food chain or at the time of water intake (Ekwumemgbo, 2005) [18]. Some heavy metals target certain organs in the human body and certain sites in the system to accelerate the deterioration of the affected organ. The brain, kidney and blood for example are the target organs attacked by Pb.
Resources occur naturally and are rooted in the environment, and such factor(s) that produces stress within the ecology of the environment consequently will directly influence the biodiversity and the resources that are contained in the system. Natural exploitable resources in the environment can be threatened due to the rise in anthropogenic input and influence or due to natural occurrence (NDDC, 2006) [35]. Incessant contribution of pollutants from humans into the environment creates a possible hazard to the natural ecology due to the direct effect on the ecosystem and the organisms within the system. The entering of pollutants into the environment are mostly in chemical in form and the study of the release of these chemicals pollutants into the environment is a subject that need immediate response and interest (Flanagan *et al*., 2007) [21]. certain pollutants like heavy metals easily bioaccumulates and sometimes are being biomagnified in the food chain process and hence become hazardous to upper level feeders, which include humans. As a result of the long-time persistence of heavy metals on the environment, even the transference of little quantity through organisms is of great eco-toxicological significance (Wokoma 2014) [47].

Materials and Methods

Sample Collection

Soil samples were collected at three farmlands close to different dumpsites within the Port Harcourt metropolitan city at random at bi-monthly for a period of six months with soil auger at a depth range of 0-60 cm. Composite soil samples were formed after samples from three different point within a location has been pooled together. The Soil samples were collected in January, March and may, 2020. The soil auger for sample collection was washed and dried after each sampling to avoid contamination from one site to the other. The collected samples were kept and preserved in labelled polythene bags and then transported to the laboratory for pretreatment and digestion.

Sample Pretreatment and Soil Digestion

The soil samples were first air dried and then dried in an oven at a controlled temperature of 105°C overnight. The dried soil samples were sieved mechanically with 0.5 mm mesh and was crushed to 0.063 mm size after due homogenization as used by Madrid *et al* (2002) [28] and El-Sherbiny *et al* (2019) [19]. The soil particles that were pulverized were weighed at 1.00g±0.0 accuracy and perchloric acid and nitric acid ($HNO_3/HCLO_4$) in a mixture of 1:4 ratio was added for digestion. The sample was heated at 40°C for one hour and was increased to a temperature range of 140-170°C after the process of digestion of the sample until a clear solution was noted. The solution was then filtered and diluted to 50 ml by the addition of deionized water.

Determination of Heavy Metals

The levels of the studied heavy metals in the soil samples of the various farmlands were determined by Atomic Absorption Spetrophotometer (AAS) Model SG71906 (APHA- AWWA-WPCF) [14] method. The direct aspiration of the digested sample was performed with nitrous oxide/acetylene flame with the generation of a cathode lamp at a known wavelength which is specific for the particular heavy metal that is to be analyzed. For each metal to be studied, a standard and calibration curves were prepared and obtained for blank samples before any aspiration of the sample was performed. The monitor of the AAS (system) displayed at specific absorbance the level of the heavy metal in the soil sample. The levels of the heavy metals were measured in mg/Kg of soil sample at < 0.001 mg/Kg limit of detection. The heavy metals analyzed and determined in the farmland soils were Fe, Pb, Cu, Cd, Cr and Ni.

Pollution Assessment Indices

These pollution assessment indices are useful tools in indicating the level of contamination/pollution and how intense the resultant effect anthropogenic input has added to the soil investigated**.** The evaluation indices adopted in this study are Contamination factor (CF), pollution load index (PLI), contamination degree (CD), modified contamination degree (mCD), geo-accumulation index (Igeo), enrichment factor (EF), potential ecological risk factor (E_F), potential ecological risk index (RI) and anthropogenicity (APn%). The background values for heavy metals used in this work were taken from Directorate of Petroleum Resources (DPR) (1991) [14].

Contamination Factor (CF)
The contamination factor or index was evaluated by applying the mathematical formula of Lacatusu (2000) [27]. The mathematical expression for calculating contamination is given as:

CF = Cn/Bn,

Where, Cn = the concentration of the metal and Bn = background concentration of the metal taken from DPR (1991) [14]. Contamination index category of contamination of the heavy metal first used by Hakanson (1980) [24] and also adopted by El-Sherbiny *et al*., (2019) [19], CF < 1 = low level of contamination, 1< CF < 3 = moderate level of contamination, 3 < CF < 6 = considerable level of contamination and CF > 6 = high level of contamination.

Pollution Load Index (PLI)
The PLI index assesses in general the level of contamination of all the investigated heavy metals in the soil**.** The PLI evaluation index was originally expressed mathematically by Tomilson *et al*. (1980) [44] and was applied in this research. The mathematical formula as expressed by Tomilson *et al*. (1980) [44] and was adopted in this research is:

$$\text{PLI} = [\text{CF1 x CF2 x CF3 x} \qquad \text{x CFn}]^{-n}$$

Where, CF = accumulation factor and n = number of metals investigated. The interpretation interval for pollution load index originated by Tomilson *et al*. (1980) are; > 0 PLI ≤ 1, not polluted to moderately polluted, >1 PLI ≤ 2, moderately polluted, > 2 ≤ 3, between moderately polluted to highly polluted, > 3 ≤ 4, polluted at high level and ≤ 5, extremely polluted.

Degree of Contamination (CD)
The mathematical formula of Hakanson (1980) [24] was used in this research. The formula is mathematically expressed as;

$$\text{CD} = \sum_{i=1}^{n} C\,F$$

Where, CD = contamination degree, CF = contamination factor and n = number of heavy metals studied. This index is an assessment method that add up all the contamination factors of the studied heavy metals in the environment of interest**.** The classification interval adopted for contamination degree are CD < 8; low level of contamination, 8 ≤ CD ≤ 16; moderate level of contamination, 16 ≤ CD ≤ 32; considerable level of contamination and Cd > 32; very high level of contamination.

Modified Contamination Degree (mCD)
The mCD assesses the total degree of contamination of all the heavy metals in the studied environment that has resulted in contamination or pollution Hakanson (1980) [24] The formula for calculating mCD is given as:

$$\text{mCD} = \frac{1}{N}\sum_{i=1}^{N} CFI$$

Where, CF = contamination factor, n = number of heavy metals investigated and I is the i^{th} metal.
The classification categories for interpreting modified contamination degree (mCD) initially given by Hakanson (1980) [24] and applied by Nwankwoala and Ememu (2018) [37] and used in this study were < 1.5; significantly low contamination level, ≤ 1.5 mCD < 2; low contamination level, ≤ 2 mCD < 4; moderate contamination level, ≤ 4 mCD < 8; high contamination level, ≤ 8 mCD < 16, very high contamination level, ≤ 16 mCD < 32 extremely high degree of contamination and ≥ 32, ultrahigh contamination level.

Geo-accumulation Index (Igeo)
This index is used in comparing the concentration of contamination of heavy metals at present and its original concentration before anthropogenic inputs affected the soil that are being investigated. The formula used by Muller (1969) [32] was applied in this work.

Igeo = Log2 [(Cn)/ (1.5Bn)]

Where, Cn the measured concentration of metal in the environment, Bn is background value of the investigated metal, 1.5 is constant that minimizes the resultant effect due to variation on the background concentration that resulted from lithologic developments. The category of interpretation for classiffying geo-accumulation index adopted from Odewande and Abimbola (2008) [38], are; Igeo < 0; no contamination, 0 < Igeo < 1; no contamination to moderate contamination, 1 < Igeo; 2, moderate contamination, 2 < Igeo < 3; moderate to strong contamination, 3 < Igeo < 4; strong contamination, 4 < Igeo < 5; strong to extreme contamination and Igeo > 5, extreme contamination.

Potential Ecological Risk Coefficient (E^i_r)

The index was first calculated by Hakanson (1980) [24], using the mathematical expression: $E^i = Tr \times C$

Where, Tr is the toxic response factor of the heavy metal, C_F = contamination factor. The toxic response factors for the heavy metals studied are; Pb =5, Cu = 5, Cd = 30, Cr = 2 and Ni = 5.

The interval of classification for interpreting potential ecological risk coefficient are; $E^i_r < 40$; low risk, $40 \leq E^i_r < 80$; moderate risk, $80 \leq E^i_r < 160$; considerate risk

Potential Ecological Risk Index (RI)

The RI index is expressed mathematically as:

$$RI = \sum (E^i_r)$$

The index calculates the sum of the risk factors of the different heavy metals and also assesses the toxicity levels of the various heavy metals in the soil that was investigated. The interval of classification used to measure the level of risk for potential ecological risk index are RI < 150; low risk, 150 ≤ RI < 300; moderate risk, 300 ≤ RI < 600; considerate risk and RI > 600; very high risk.

Enrichment Factor

The enrichment factor index is calculated using the mathematical expression;

$$EF = \frac{\left(\frac{Cn}{Cref}\right)sample}{Bn/Bref}$$

Where, Cn (sample) is the recorded concentration of the element studied, Cref is the obtained concentration for the element referenced in the environment during the study, Bn is the value of the background referenced element and Bref is the value of the background reference element in the investigated environment referenced in shale's average (Turekian and Wedepohl, 1961) [45].

This index is used in evaluating heavy metals' developments and enrichment amongst regions and is useful in envisaging the possible source and origin of the spread of heavy metals in a given environment (Pekey, 2006) [39]. The interval of interpretation for enrichment factor are given as; EF < 2; negligible enrichment, 2 ≤ EF < 5; reasonable enrichment, 5 ≤ EF < 20; noteworthy enrichment, 20 ≤ EF < 40; very high enrichment and EF > 40; tremendously high enrichment.

Anthropogenicity (APn %)

This is an evaluation index used in measuring directly the anthropogenic contribution on the concentration of the metal in percentages. The index is expressed mathematically as,

$$APn\% = [\mu/Bn] \times 100$$

Where, μ = the concentration obtained in the investigation and Bn = the background value.

The background value of the studied heavy metals in the soils used in the calculation of anthropogenic input applied in this work were the target values given by the Directorate of Petroleum Resources (DPR) which is measured in mg/Kg. The DPR background values for the heavy metals are Fe = 47000, Pb = 85, Cu = 36, Cd = 0.80, Cr = 100 and Ni = 35.

Results and Discussion

Concentrations of Heavy Metals in the Farmlands

The results recorded for the levels of heavy metals in the selected farmland soils in Port Harcourt close to dumpsites are shown in Tables 1 to 3 and the mean level of the studied heavy metals are shown in Table 4. The average level of the heavy metals in the studied farmland were in the range of 199.38±9.15-209.45±15.58mg/Kg and 165.38±10.55mg/Kg in the control site for Fe, 1.70±0.09-1.86±0.14mg/Kg and 0.05±0.02mg/Kg in the control site for Pb, 0.12±0.03-0.32±0.15mg/Kg and 0.01±0.01mg/Kg in the control site for Cd, 2.00±0.05-2.99±0.25mg/Kg and 0.24±0.05mg/Kg in the control site for Cr, 2.78±0.42-3.49±0.49mg/Kg and 0.55±0.19mg/Kg in the control site for Cu and 2.15±0.34-2.75±0.23mg/Kg and 0.27±0.02mg/Kg for Ni. The results indicated that the levels of all the studied heavy metals in the farmlands were far higher than that obtained from the control station. This observation revealed that the high occurrence of heavy metals in the farmlands as compared to the control station was as a result of the proximity to the dumpsites. The level of heavy metals in the farmlands considering the range they occurred were in the order Fe > Cu > Cr > Ni > Pb > Cd.

The recorded values of heavy metals in this investigation were lower than that recommended by Directorate of Petroleum Resources (DPR) (1991) and also within acceptable limit as allowed by NOAA (world soil reference) which is 37, 13, 16, and 1.6 for Cr, Ni, Pb and Cd respectively (Martinez-Mera *et al*., 2019) [29], which are hazardous heavy metals. The values obtained in this study were lower than that obtained by Gbarako and Konne (2016) [22], Boisa and Bekee (2017) [10]. There were slight variations of the levels of heavy metals recorded in the selected farmlands used in the study. The result obtained might be due to the fact that similar refuse was being dumped at the different dumpsites close to the farmlands investigated. The soil formation and distribution within these farmlands might be similar and the low contamination level recorded for the heavy metals may be due to the fact that most of the refuse are agricultural in nature. The rate at which these heavy metal contaminants are released and deposited within the farmlands might also be a factor of the low level of contamination. This observation is corroborated in by certain authors (Birch *et al*., 2001) [9].

Table 1: Concentrations of Heavy Metals in Selected Farmlands close to Dumpsites in Port Harcourt in January

Heavy Metals (mg/Kg	Stations			
	Ogbogoro	Rumuokoro	Rumuigbo	IAUE (Control)
Fe	188.67	206.01	196.41	160.02
Pb	1.81	1.63	1.71	0.03
Cd	0.49	0.32	0.11	0.01
Cr	3.31	2.72	1.94	0.19
Cu	4.16	3.11	2.19	0.56
Ni	1.92	2.07	2.46	0.30

Table 2: Concentrations of Heavy Metals in Selected Farmlands close to Dumpsites in Port Harcourt in March

Heavy Metals (mg/Kg	Stations			
	Ogbogoro	Rumuokoro	Rumuigbo	IAUE (Control)
Fe	198.44	212.71	231.36	156.70
Pb	1.70	2.04	2.04	0.04
Cd	0.12	0.14	0.09	0.02
Cr	2.71	2.24	1.99	0.24
Cu	3.08	3.08	3.15	0.81
Ni	1.89	2.78	3.01	0.27

Table 3: Concentrations of Heavy Metals in Selected Farmlands close to Dumpsites in Port Harcourt in May

Heavy Metals (mg/Kg	Stations			
	Ogbogoro	Rumuokoro	Rumuigbo	IAUE (Control)
Fe	211.03	189.65	200.59	180.11
Pb	1.59	1.52	1.82	0.07
Cd	0.36	0.27	0.16	ND
Cr	2.94	2.66	2.06	0.30
Cu	3.22	2.76	3.01	0.77
Ni	2.63	3.10	2.79	0.25

Table 4: Mean Concentrations of Heavy Metals in Selected Farmlands close to Dumpsites in Port Harcourt within the Months

Heavy Metals (mg/Kg	Stations			
	Ogbogoro	Rumuokoro	Rumuigbo	IAUE (Control)
Fe	199.38±9.15	202.79±9.69	209.45±15.58	165.38±10.55
Pb	1.70±0.09	1.73±0.22	1.86±0.14	0.05±0.02
Cd	0.32±0.15	0.24±0.08	0.12±0.03	0.01±0.01
Cr	2.99±0.25	2.54±0.21	2.00±0.05	0.24±0.05
Cu	3.49±0.49	2.98±0.16	2.78±0.42	0.55±0.19
Ni	2.15±0.34	2.65±0.43	2.75±0.23	0.27±0.02

Contamination Factor, Pollution Load Index, Contamination Degree and Modified Contamination Degree

The contamination factor results obtained in the selected farmlands in Port Harcourt close to dumpsites are provided in Table 5. The results recorded that Fe was 0.004 in all the stations, Pb; 0.020-0.022 with a mean level of 0.021, Cd; 0.150-0.400 with a mean level of 0.283, Cr, 0.020-0.030 with a mean level of 0.025, Cu; 0.077-0.097 with a mean level of 0.086 and Ni; 0.061-0.076 with a mean level of 0.071. Applying the contamination factor index originated by Hakanson (1980) [24] and also applied by El-Sherbiny *et al*., (2019) [19] all the heavy metals in the respective farmlands close to dumpsites were within the category CF < 1 which is low level of contamination. The results from the farmlands indicated that the level of contamination of heavy metals in the farmlands were still at a negligible stage as at the time of investigation. The degree of contamination of the selected farmlands close to dumpsites by the heavy metals followed the pattern Cd > Cu > Ni > Cr > Pb > Fe. The contamination index revealed that the degree of contamination of the farmlands by heavy metals observed in this study were far lower than those of Nwankwoala and Eremu (2018) in soils close to filling stations at Okpoko in Eastern Nigeria and also that observed by El-Sherbiny *et al*., (2019) [19] in Saudi Arabia around a cement industry.

The results for the pollution load index, (PLI), is shown in Table 5. From the classification interval of pollution load index formulated by Tomilson *et al*. (1980) [44] and adopted in this work, it shows that the selected farmlands were not polluted anyway by the studied heavy metals. For all the studied farmland recorded values of 0.000 for pollution load index. The PLI values recorded in this research actually revealed that thew farmlands have not been contaminated anyway by the investigated heavy metals when compared to other researches such as recorded by El-Sherbiny *et al*., (2019) [19] in a cement factory and that of Nwakwoala and Eremu (2018) [37] in Okpoko soils near filling stations where degrees of contaminations were observed.

The results for contamination degree recorded in this investigation were within the range 0.349 to 0.612 and a mean value of 0.469 within the studied farmlands. The order of contamination followed the order Ogbogoro > Rumuigbo > Rumuokoro. Based on the interval of classification for contamination degree showed that the farmlands were not yet contaminated for they were far lower than the lowest interval of CD < 8, which is for low contamination degree.

The results obtained for modified contamination degree (mCD) in the farmlands within Port Harcourt ranged from 0.058 to

0.102 with a mean level of 0.071. The interval of classification used for modified contamination degree (mCD) as originally given by Hakanson (1980) [24] and used also by Nwankwoala and Ememu (2018) and adopted in this work revealed that all the farmlands were in the classification of < 1.5; which means it was still at the stage of contamination by the heavy metals were at very low degree of contamination. The level of contamination, were in the order Ogbogoro > Rumuokoro > Rumuigbo.

Table 5: Contamination Factor (CF), Pollution Load Index (PLI), Contamination Degree (CD) and Modified Contamination Degree (mCD) Analysis of Heavy Metals in Selected Farmlands in Port Harcourt

Heavy metals	Stations			Mean
	Ogbogoro	Rumuokoro	Rumuigbo	
Fe	0.004	0.004	0.004	0.004
Pb	0.020	0.020	0.022	0.021
Cd	0.400	0.300	0.150	0.283
Cr	0.030	0.025	0.020	0.025
Cu	0.097	0.083	0.077	0.086
Ni	0.061	0.076	0.076	0.071
PLI	0.000	0.000	0.000	0.000
CD	0.612	0.508	0.349	0.469
mCD	0.102	0.085	0.058	0.078

Geo-accumulation Index

The results for geo-accumulation index of the farmlands investigated were Fe, 0.001 with 0.001 as mean in all the stations, Pb, 0.004 with 0.004 as mean in all the stations, Cd range was between 0.030 to 0.080 with 0.057 as the mean within the stations, Cr range was 0.004 to 0.006 with 0.005 as the mean within the stations, Cu range was 0.015 to 0.019 with 0.017 as the mean within the stations and Ni range was 0.012 to 0.015 with 0.014 as the mean within the stations. The low level of geo-accumulation observed in this study is similar to that reportedly observed by Bhutiani *et al*., (2017) [8] and Aghoghovwia *et al*., (2018). Fundamentally, the positive values of contamination factor and the negative values of geo-accumulation index are pointers to anthropogenic sources of heavy metals. Scholars have credited this tendency to the pattern of natural occurrence of the environmental ecology (Bhutiani *et al.*, 2017) [8]. Also, the low degree of contamination in the farmlands were possibly as a result of the lithological value of 1.5 which is a constant in the geo-accumulation index equation (Abrahim and Parkers, 2008). The 1.5 in the geo-accumulation index is a constant that is used in compensating natural fluctuations that arises in a certain metal and also for minor anthropogenic influences in the environment investigated (Guan *et al*., 2014; Ngwoke *et al*., 2019) [23, 34]. The geo-accumulation index is useful in comparing the contamination of the different heavy metals investigated in an environment (Todorova *et al*., 2016; Izah *et al*., 2018) [43, 25]. The accumulation of heavy metals in the environments (soil, sediment and water) is related to the anthropogenic activities (direct and indirect) taken place within that area (Wei and Yang, 2010; Mmolawa *et al*., 2011; Zhao *et al*., 2013; Mazurek *et al*., 2017; Izah *et al*., 2018) [46, 31, 48, 30, 25].

Table 6: Geo-accumulation Index (Igeo) Analysis of Heavy Metals in Selected Farmlands in Port Harcourt

Heavy metals	Stations			Mean
	Ogbogoro	Rumuokoro	Rumuigbo	
Fe	0.001	0.001	0.001	0.001

Pb	0.004	0.004	0.004	0.004
Cd	0.080	0.060	0.030	0.057
Cr	0.006	0.005	0.004	0.005
Cu	0.019	0.017	0.015	0.017
Ni	0.012	0.015	0.015	0.014

Potential Ecological Risk Coefficient and Potential Ecological Risk Index

The results for Potential Ecological Risk Coefficient and Potential Ecological Risk Index are provided in Table 7. The results obtained for potential ecological risk coefficient and potential ecological risk index of the selected farmlands close to dumpsites within Port Harcourt showed that Pb range was 0.100-0.110 with an average of 0.105, Cd; 4.500-12.000 with an average of 8.490, Cr; 0.040-0.060 with an average of 0.050, Cu; 0.385-0.485 with an average of 0.450 and Ni; 0.305-0.380 with an average of 0.355. The mean values obtained from the results showed that the potential ecological risk coefficients were in the order Cd > Cu > Ni > Pb > Cr in the soils of the selected farmlands. From the interval used in the interpretation of ecological risk coefficient, the heavy metals investigated fell below the least category of $E_F < 40$, which indicated that all the investigated heavy metals were at the level of no risk. The results obtained were far lower compared to that obtained by Bekee *et a*l (2021) in the clay soils of Ara-Ekiti and Kono-Boue where the studied heavy metals showed low risk level to very high-risk level.

The obtained results for potential ecological risk index for the soils of the selected farmlands within Port Harcourt soils were in the range of 5.415-12.950 and a mean value of 9.430. The values obtained were far lower than that recorded by Bekee *et al* (2021) in the clay soils of Ara-Ekiti and Kono-Boue. Interpretation of the obtained results based on the classification interval showed that the farmlands close to the dumpsites were at no ecological risk at the time of investigation since they were all far below the least category of RI < 150 which is for low ecological risk.

Table 7: Potential Ecological Risk Coefficient (E^i_r) and Potential Ecological Risk Index (RI) Analysis of Heavy Metals in Selected Farmlands in Port Harcourt

Heavy metals	**Stations**			**Mean**
	Ogbogoro	**Rumuokoro**	**Rumuigbo**	
Fe	NA	NA	NA	NA
Pb	0.100	0.100	0.110	0.105
Cd	12.000	9.000	4.500	8.490
Cr	0.060	0.05	0.040	0.05
Cu	0.485	0.415	0.385	0.430
Ni	0.305	0.380	0.380	0.355
RI	12.950	9.945	5.415	9.430

Enrichment Factor (EF)

The enrichment factor analysis for the different farmlands is provided in Table 8. The mean values obtained in the selected farmlands within Port Harcourt for enrichment factor for the heavy metals were Cd > Ni > Cr > Pb > Cu. The values of enrichment factor ranged 4.717 to 4.910 and a mean value of 4.827 for Pb, 33.660 to 94.294 and a mean value of 65.828 for Cd, 4.488 to 7.048 and a mean value 5.808 for Cr, 1.737 to 2.285 and a mean value of 1.980 for Cu and 14.481 to 17.631 and a mean value of 16. 553 for Ni. From interval of interpretation for E_F Cu is within negligible enrichment to reasonable enrichment, Pb was reasonably enriched, Cr was in the range of reasonable enrichment to noteworthy enrichment, Ni was noteworthily enriched and Cd was in the range of very high enrichment to tremendously high enrichment. The values recorded showed enrichment corresponding to anthropogenic input, for value range of 0.5 to 2.0 is usually attributed to natural input while enrichment values higher than 2.0 is an indication of enrichment related to anthropogenic influence (Ata *et al*., 2009; Sekabira *et al*., 2010) [6, 40].

Table 8: Enrichment Factor Analysis of Heavy Metals in Selected Farmlands in Port Harcourt

Heavy metals	**Stations**			**Mean**
	Ogbogoro	**Rumuokoro**	**Rumuigbo**	
Fe	NA	NA	NA	NA
Pb	4.853	4.717	4.910	4.827
Cd	94.294	69.531	33.660	65.828
Cr	7.048	5.887	4.488	5.808
Cu	2.285	1.919	1.737	1.980
Ni	14.481	17.548	17.631	16.553

Anthropogenicity

The values of anthropogenicity obtained in the studied farmlands are provided in Table 9. The results shown ranged 0.424-0.446% with an average of 0.434% for Fe, 2.000-2.188% with an average of 2.074% for Pb 15.000-30.000% with an average of 23.533% for Cd, 2.000-2.990% with an average of 2.510% for Cr, 7.722-9.694% with an average of 8.565% for Cu and 6.143-7.857% with an average of 7.190% for Ni. The order of anthropogenic input of the heavy metals from the mean values obtained were Cd > Cu > Ni > Cr > Pb > Fe. The recorded values in percentages indicated that Cd had the most anthropogenic input then followed by Cu and Ni in the selected farmlands. The obtained results were in agreement with that recorded by Nwankwoala and Ememu (2018) [37], which were obtained around filling stations. The observed anthropogenic input of heavy metals into the farmlands might have arisen due to the proximity of the dumpsites.

Table 9: Anthropogenicity (APn %) of Heavy Metals in Selected Farmlands in Port Harcourt

Heavy metals	Stations			Mean
	Ogbogoro	Rumuokoro	Rumuigbo	
Fe	0.424	0.431	0.446	0.434
Pb	2.000	2.035	2.188	2.074
Cd	25.600	30.000	15.000	23.533
Cr	2.990	2.540	2.000	2.510
Cu	9.694	8.278	7.722	8.565
Ni	6.143	7.571	7.857	7.190

Conclusion

The concentration of heavy metals (Fe, Pb, Cd, Cr, Cu, and Ni) occurrence in the selected farmland soils within Port Harcourt, Nigeria revealed low level of contamination despite being close to dumpsites although the levels at the different farmlands were higher than that of the control station. This was made possible since the study locations were not in the main hub of industrial activities in the city and also the dumps contain refuse mainly from agricultural and household products. The contamination level of the heavy metals, were still at a very low degree in the various farmland when subjected to pollution assessment indices such as contamination factor, pollution load index, contamination degree, modified contamination degree, geo-accumulation index potential ecological risk coefficient, potential ecological risk index, enrichment factor and anthropogenicity. The relevant government agencies should therefore swing into action at this stage to and restrict the dumpsites being close to farmland so that there will not be a sudden rise in the level of heavy metals in farmlands which may eventually pass to humans through the food chain.

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