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Research Article

Assessment of Contamination of Potentially Toxic Elements (PTEs) from Soil Matrices of Nigeria Maritime University premise

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Abstract

This research study assessed the degree of contamination of potentially toxic elements (PTEs) from soil matrices of Nigeria Maritime University premise. Soil samples were further sieved using a nylon sieve (<125μm diameter). The samples were prepared in triplicates. Reagent blanks were included to check contamination. Twenty-five top soil samples were collected and analysed for PTEs using FAAS. The pollution level in soils were assessed using pollution load index (PLI) and potential ecological risk index (PERI). The mean values of the toxic elements in soil from the study area decreased in the order Cd < As < Fe < Pb < Co < Ni < Cu < Zn < Cr < Mn. The ranges were as follows: Cd (0.13-0.95 ppm); As (0.49-4.50 ppm); Fe (6.42-24.80 ppm); Pb (5.96-31.45 ppm); Co (2.93-51.80 ppm); Ni (4.27-82.48 ppm); Cu (7.42-84.90 ppm); Zn (9.10-184.36 ppm); Cr (29.80-234.00 ppm) and Mn (84.30-486.00 ppm). All the toxic elements were higher than crustal average values used as background values except Cr and Fe in some samples. Ni, As, Co and Cr were higher than FAO/WHO guidelines whereas only Cr was higher than EU standard in some soil samples. The PIs of Cu, Zn, Cd and Mn were within low to high contamination, Pb, Ni, Co, As and Cr were within low to middle contamination while Fe is categorized as low contamination. Pollution Load Index showed that the soil in the study area can be classified as unpolluted to moderately polluted and ranged from 0.28 to 2.76. The toxic elements showed Eir of <40 and indicated low ecological potential risk index except Cd, Co, Fe, As and Ni that showed low to moderate ecological potential risk. Cd contributed highest to the Ecological Risk (PERI) which ranged between 18.24 and 109.67 and indicated moderate risk.

Keywords: Potentially Toxic Elements; Pollution Investigation; Potential Ecological Risk; Pollution Index.

1. Introduction

Human health risk assessment is the characterization of the potential adverse health effects of human exposure to environmental contaminants [1, 2]. This process involves the determination of the likelihood that human exposure to toxic chemicals could result in adverse effects on human health and quantitatively estimate consequences. Risk assessment is useful in the determination of the significance of contamination in a site and the level of clean-up required for the intended use of the site. As a result, regulatory decision issues are based on risk assessment studies. Although health implications of environmental contaminants affect everyone but children are more prone to health effects than adult because of differences in metabolism, behavior, diet, physiological changes and functions. Each of these factors which changes at different stages of development affect the way in which children are exposed and react to environmental contaminants. Therefore, children's exposure to environmental contaminants differs widely from that of an adult because of their sensitivity and vulnerability to PTEs, moreover, their exposure starts at conception and during breast feeding as infants [3].

It has been noted that due to the importance of children's healthcare, no guidance document on risk assessment that did not recognize children's unique exposures and special vulnerability can be considered adequate to protect human health [4]. Soil provides an important link between humans and the various components that make up the environment; however, soil also acts as a sink to various PTEs released from various sources. These PTEs are known to be site-specific [5]. Of concern in this work is the potential impact on children as a result of exposure to soil during the course of recreational activity within the community playground. The dominant health risk to children is via intentional and unintentional ingestion of soil as a primary result of hand-to-mouth contact. Intentional ingestion may occur due to the pica tendencies of the child; however, unintentional ingestion is more likely to be due to the physical disturbance of the soil by the child resulting in increased contact.

Nigeria Maritime University (NMU) is located within riverine area of Delta state. The school is surrounded by different crude oil mining sites. Carbon sooths emanating from the sites are distributed across the communities within the exploration sites. Workers and other residents of the communities are largely exposed to the dangers associated with it. In most cases, wearing white clothes and travelling on the river leading to the school, one can experience large deposit of these carbon sooths on their clothes. These deposits are also seen on tiles, door handles, seats and other household items. Dust particles released from contaminated sites travel long distances and could be in constant contact with humans due to outdoor activities. This is because these dust particles have light weight. They are known to be fine solid particles and settle out under their own weight but could also remain suspended for some time in the atmosphere depending on its particle size.

Of particular concern are children (< 6 years) and specifically those who may practice ‘pica’ (the habit of mouthing non-food substances and repetitive hand/finger sucking). Thus, urban dust is a repository of environmental contaminants. In assessing human health risk of potentially toxic elements (PTEs), it is not the concentration of PTEs in the environmental matrices that is of greatest concern but the fraction that is absorbed into the body via the exposure pathways. The determination of this fraction (i.e. the bioaccessible fraction) through the application of bioaccessibility protocols is the focus of this work. This study investigated human health risk of PTEs (As, Cd, Cr, Cu, Pb, Mn, Ni and Zn) from oral ingestion of soil / dust, inhalation of urban street dust and airborne dust (PM10) within the premises of Nigeria Maritime University.

The quest to improve on the living standard and also overcome environmental challenges has resulted in the release of contaminants into the environment, particularly PTEs, which are known to be ubiquitous, non-degradable and toxic. Of all the environmental matrices (soil, water and air), soil is the most affected either due to past or current human activities. Hence, humans are at the risk of adverse health effects due the presence of PTEs in environmental matrices. Workers at Nigeria Maritime University (NMU), residents of Escravos communities and other Industrial workers within the riverine are still being exposed to elevated concentrations of PTEs despite increased awareness of their environmental and health consequences. This represents a potential health risk to exposed populations.

The consistent exposure of humans to environmental PTEs as a result of accidental or intentional release of these contaminants has attracted the attention of international and local institutions, organisations and agencies such as World Health Organisation (WHO), the Organisation of Economic Cooperation and Development (OECD), European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC), the US Environmental Protection Agency (EPA) and England Department for Food, Environment and Rural Affairs (DEFRA) to the development and implementation of human health risk assessment and encourage studies in that direction. Hence, the use of risk assessment as a strategy for dealing with environmental pollution is gaining international recognition.

2. Methodology

2.1. Study Area

The Nigeria Maritime University is located across Escravos River in Delta Nigeria. “Escravos” is a Portuguese word meaning “slaves” and the area was one of the main conduits for slave trade between Nigeria and the United States in the 18th century. The length of the river is 57km with its source from Niger River, having a link to Atlantic Ocean and Gulf of Guinea. It lies within the coordinate of Latitude: 5° 34’ 59.99” N Longitude: 5° 09’ 60.00” E (Ibitola).

2.2. Sampling and Analysis

Sample preparation for FAAS analysis: Samples that were used for the determination of elemental content via flame atomic absorption spectrometer (FAAS) was further sieved using a nylon sieve (<125μm diameter).

2.3. Sample digestion

Reagent grade chemicals were used in all cases. Sample digestions were carried out by adopting method 3050B sample digestion protocol [6]. 10 ml nitric acid (HNO3) was added to beakers containing 1g soil sample, then covered with watch glass and heated for 15 minutes without boiling. Samples were cooled, 5 ml HNO3 was added and heated for 30 minutes (brown fumes was given off). More 5 ml HNO3 was added and no brown fumes was given off. Solution was allowed to evaporate to < 5 ml and allowed to cool. 2 ml water and 3 ml 30% hydrogen peroxide (H2O2) was added and heated for 2 hrs until effervesces ceased. Solution was reduced to 5ml via evaporation. 10 ml hydrochloric acid (HCl) was added and heated for 15 minutes without boiling. After cooling, the digested samples were filtered using a whatman filter paper (grade 41, pore size 20 μm) into 100 ml volumetric flask. The filtrate was diluted to the mark with ultrapure water of resistivity 18.2 MΩ-cm at 250C and ready for analysis using Flame Atomic Absorption Spectrophotometer (FAAS). Each sample was digested in triplicates for the purpose of reproducibility.

2.4. Flame atomic Absorption Spectrophotometer (FAAS) protocol

The samples were prepared in triplicates. Reagent blanks were included to check contamination. Six calibration standards over the range 0-10 μgmL-1 (mgL-1) were prepared from 1000 μgmL-1 Pb stock solution; this was used to calibrate the instrument and also to plot the calibration graph and the regression coefficient (R2) obtained was 0.999 (linear graph). Based on the excellent R2 value, the samples were analysed.

2.5. Data Evaluation and Contamination Assessments

Statistical analysis to determine range, mean and standard deviation was done by using the Excel software (Microsoft).

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Multivariate statistical analysis such as inter-elemental correlations and factor analysis were conducted using the SPSS software (version 16). The level of contamination of soil samples based on some potentially toxic elements was determined using the pollution index (PI) and potential ecological risk (PER) paramenters [7-9]. The non-carcinogenic and carcinogenic risk of these toxic elements were also calculated using hazard quotient and hazard index parameters.

2.6. Pollution Index (PI)

Pollution Index is the ratio of element in the soil to the background concentration which is the concentration of the same element in the earth's crust.

PI = Cn/Bn (1)

Classification of PI is presented in Table 1 [10].

Table 1: Classification of Pollution Index.

PI ≤ 1	Low	Contamination
1 < PI ≤ 3	Middle	Contamination
PI > 3	High	Contamination

In addition, to give an assessment of the overall pollution status for a sample, the integrated pollution load index (PLI) or the Nemerow integrated pollution index (NIPI) (Nemerow, 1985) can be employed (Tomlinson et al., 1980; Luo et al., 2012; Lu et al., 2014; Chen et al., 2015; Odukoya et al., 2015; Li et al., 2020). The PLI and NIPI can be calculated using;

NIPI = (PI1 × PI2 × PI3 × … × PI n) 1/n (2)

The PLI and NIPI can be calculated using

According to, the classification based on PLI and Nemerow integrated pollution index (NIPI) is given in Table 2 [11].

Table 2: Classification Based on Pollution Index (PI) and Pollution Load Index (PLI) [11, 12].

PLI = 0	Background Concentration	NIPL = 0.7	Safe
0 < PLI = 1	Unpolluted	0.7 < NIPL = 1	Precaution
1 < PLI = 2	unpolluted to moderately polluted	1< NIPL = 2	Slight Pollution
2 < PLI = 3	Moderately polluted	2 < NIPL = 3	Moderate Pollution
3 < PLI = 4	Moderately to highly polluted	NIPL > 3	Heavy Pollution
4 < PLI = 5	Highly polluted	NIPL = 0.7	Safe
PLI > 5	Very highly polluted		

2.7. Potential Ecological Risk Factor

An ecological risk factor (Ei r) quantitatively expresses the potential ecological risk of a given contaminant as suggested by Håkanson, (1980) is expressed as

Ei r = Tr * Cf (3)

Where Tr is the toxic-response factor for a given substance and Cf is the contamination factor. The Tr values of heavy metals given by Håkanson is given in Table 3. The terminologies used to describe the risk factor are listed in Table 4.

Table 3: Pre-industrial reference level (kg/g) and toxic- response factor by Håkanson (1980).

Elements	Cd	As	Ni	Cu	Pb	Cr	Zn
Pre-industrial reference level	1	15		50	7	90	175
Toxic-response factor	30	10	5	5	5	2	1

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Table 4: The terminologies used to describe the risk factor.

ER	Ecological Potential Risk for Single Element	PERI	Ecological Risk
Eir<40	Low potential ecological risk	PERI < 150	Low
40≤Eir<80	moderate potential ecological risk	150 ≤ PERI <300	Moderate
80≤Eir<160	considerable potential ecological risk	300 ≤ PERI <600	Considerable
160≤Eir<320	high potential ecological risk	600 ≤ PERI	Very High
Eir≤320	very high ecological risk		

Table 5: Summary of Potential Toxic Elements in Soil within and around NMU premises.

Potential Toxic Metals (ppm)	Min.	Max.	Mean	Std. Dev.	FAO/WHO std	EU Std	Crustal Average
Cu	7.42	84.90	36.94	20.82	100	140	23
Pb	5.96	31.45	14.61	6.40	100	300	19
Zn	9.10	184.36	72.81	42.70	300	300	84
Ni	4.27	82.48	28.64	19.21	50	75	39
Co	2.93	51.80	14.62	7.15	50	Na	19
Fe	6.42	24.80	5.10	3.67	Na	Na	17
As	0.49	4.50	1.84	1.21	1.5	Na	1.5
Cd	0.13	0.95	0.16	0.03	3	3	0.2
Mn	84.30	486.00	349.14	314.19	Na	Na	586
Cr	29.80	234.00	89.76	56.40	100	100	86

FAO/WHO Guidelines- Chiroma et al., 2014: EU Guidelines – European Commission on environment, 2002

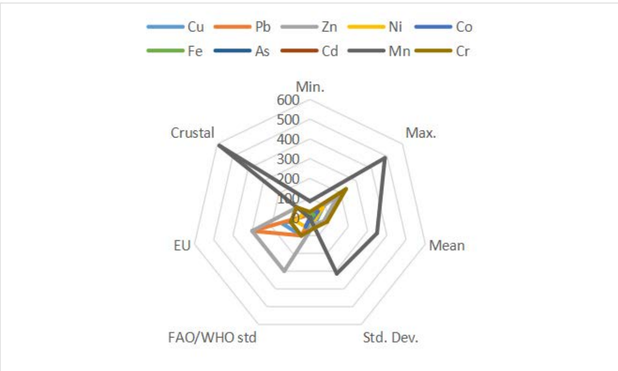

Figure 1: Summary of Potential Toxic Elements in Soil within and around NMU premises

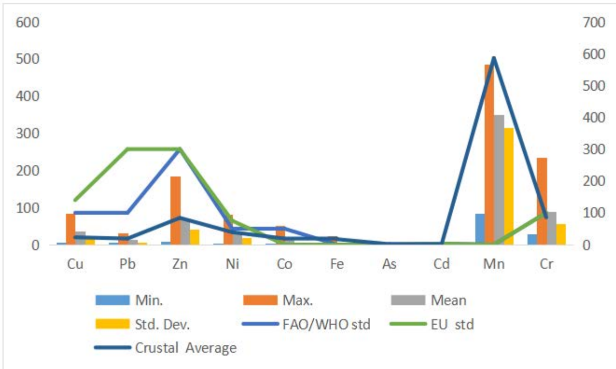

Figure 2: Summary chart of Potential Toxic Elements in Soil within and around NMU premises

3. Results and Discussion

The statistics of PTEs content around premises of Nigeria Maritime University (NMU) are shown in Table 6. The concentrations of ten PTEs (Cd, As, Pb, Cr, Cu, Ni, Mn, Co, Fe and Zn) were determined around the areas. The mean values of the toxic elements in soil from the study area decreased in the order Cd < As < Fe < Pb < Co < Ni < Cu < Zn < Cr < Mn. The ranges were as follows: Cd (0.13-0.95 ppm); As (0.49-4.50 ppm); Fe (6.42-24.80 ppm); Pb (5.96-31.45 ppm); Co (2.93-51.80 ppm); Ni (4.27-82.48 ppm); Cu (7.42-84.90 ppm); Zn (9.10-184.36 ppm); Cr (29.80-234.00 ppm) and Mn (84.30-486.00 ppm). All the toxic elements were higher than crustal average values used as background values except Cr and Fe in some samples (Table 5). Ni, As, Co and Cr were higher than FAO/WHO guidelines whereas only Cr was higher than EU standard in some soil samples (Table 5) [13-20].

3.1. Assessment of Contamination of Potentially Toxic Elements

To assess the degree of contamination in the study area, Pollution Index (PI), Pollution Load Index (PLI) and Potential Ecological Risk Index were used

3.2. Pollution Index (PI) and Pollution Load Index (PLI)

The PIs of the toxic elements are presented in Table 6 and figure 3; and showed the decreasing order of Fe<As<Co<Cr<P-

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b<Ni<Mn<Zn<Cd<Cu. The PIs of Cu, Zn, Cd and Mn were within low to high contamination, Pb, Ni, Co, As and Cr were within low to middle contamination while Fe is categorized as low contamination. Pollution Load Index showed that the soil in the study area can be classified as unpolluted to moderately polluted and ranged from 0.28 to 2.76 (Table 6 and figure 3).

Table 6: Results of Pollution Load Index in NMU premise.

Potential Toxic Elements	Pollution Index (Range)	Pollution Index (Mean)	Interpretations
Cu	0.4-4.2	2.20	Low to High Contamination
Pb	0.5-1.9	1.20	Low to Middle Contamination
Zn	0.2-3.4	1.82	Low to High Contamination
Ni	0.2-2.4	1.34	Low to Middle Contamination
Co	0.3-1.9	0.94	Low to Middle Contamination
Fe	0.04-0.7	0.18	Low Contamination
As	0.2-1.9	0.84	Low to Middle Contamination
Cd	0.4-3.6	1.84	Low to High Contamination
Mn	0.2-2.8	1.70	Low to High Contamination
Cr	0.4-2.8	1.09	Low to Middle Contamination
PLI	0.28-2.76	1.52	Unpolluted to moderately polluted

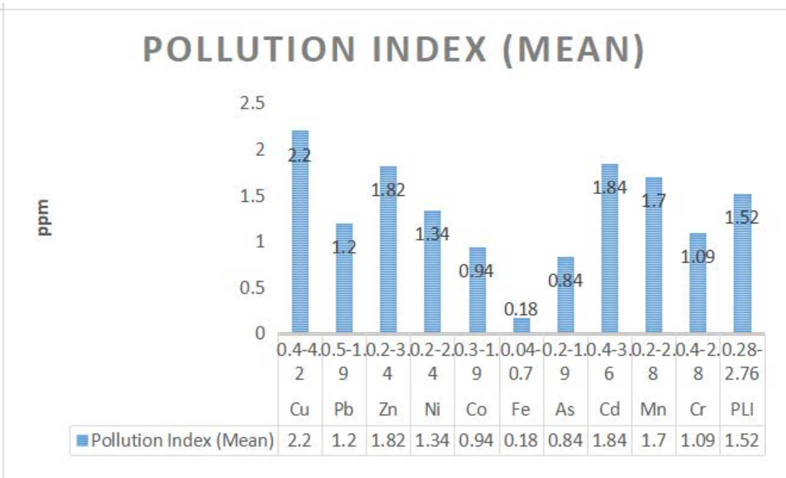

Figure 3: Results of Pollution Load Index in NMU premise

3.3. Ecological Risk Index (Eir) and Potential Ecological Risk Index (PERI)

The Ecological Risk Index (Eir) calculated for the toxic elements showed that the order of pollution was Cd>Co>Fe>As>Ni>Cu>Mn>Pb>Zn>Cr. The toxic elements showed Eir of <40 and indicated low ecological potential risk index except Cd, Co, Fe, As and Ni that showed low to moderate ecological potential risk (Table 7). Cd contributed highest to the Ecological Risk (PERI) which ranged between 18.24 and 109.67 and indicated moderate risk (Table 7).

Table 7: Result of Potential Ecological Risk Index.

Potential Toxic Elements	Eir (min)	Eir (max)	Eir (mean)	Interpretations
Cu	1.64	19.40	10.50	Low potential ecological risk
Pb	2.90	14.35	8.60	Low potential ecological risk
Zn	1.48	8.60	6.43	Low potential ecological risk
Ni	2.80	21.38	11.84	Low to moderate potential ecological risk
Co	4.32	52.00	28.20	Low to moderate potential ecological risk
Fe	2.14	34.82	16.48	Low to moderate potential ecological risk
As	3.42	22.41	12.60	Low to moderate potential ecological risk
Cd	5.40	58.70	32.12	Low to moderate potential ecological risk
Mn	1.34	28.66	9.39	Low potential ecological risk
Cr	0.24	3.69	1.87	Low potential ecological risk
PERI	18.24	109.67	67.80	Moderate risk

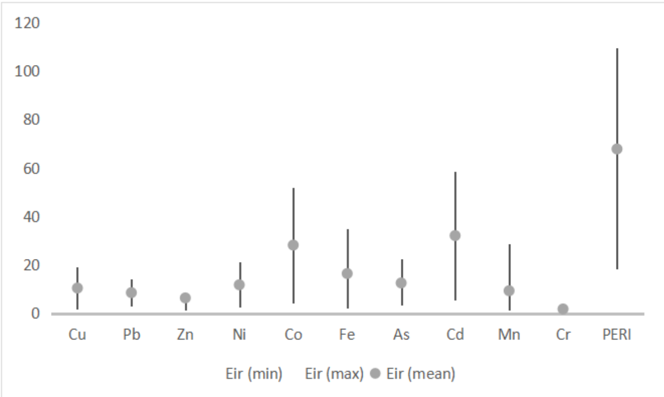

Figure 4: Result of Potential Ecological Risk Index.

4. Conclusion

The result of PTEs content around premises of Nigeria Maritime University (NMU) shows that the mean values of the toxic elements in soil from the study area decreased in the order Cd < As < Fe < Pb < Co < Ni < Cu < Zn < Cr < Mn. All the toxic elements were higher than crustal average values used as background values except Cr and Fe in some samples. Ni, As, Co and Cr were higher than FAO/WHO guidelines whereas only Cr was higher than EU standard in some soil samples. The PIs of the toxic elements showed the decreasing order of Fe<As<Co<Cr<Pb<Ni<Mn<Zn<Cd<Cu. The PIs of Cu, Zn, Cd and Mn were within low to high contamination, Pb, Ni, Co, As and Cr were within low to middle contamination while Fe is categorized as low contamination. The Ecological Risk Index (Eir) calculated for the toxic elements showed that the order of pollution was Cd>Co>Fe>As>Ni>Cu>Mn>Pb>Zn>Cr. The toxic elements showed Eir of <40 and indicated low ecological potential risk index except Cd, Co, Fe, As and Ni that showed low to moderate ecological potential risk.

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