PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (1) 19-25 January 2024

Concentration and Ecological Risk Assessments of Potentially Toxic Elements in Soils around Lapite Dump Site, Akinyele Local Government Area, Ibadan, Nigeria

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ABSTRACT: The contamination and ecological risk posed by Potentially Toxic Elements (PTEs) on soils around Lapite dumpsite and its environs were assessed using different analytical techniques after complete digestion of the soil using mixed acids. Results showed that the mean concentration of chromium (Cr), cadmium (Cd), and lead (Pb) (153.2mg/kg, 13.83mg/kg, 137.2mg/kg and respectively) have higher concentrations than their crustal abundance (CA). The enrichment factor analysis revealed that most of the soils collected have been enriched with Pb showing the most enrichment at the upper and middle slopes while Cd is the most enriched at the downslope. The contamination factor showed that Cr, Pb and Cd are also the elements showing significant contamination with Cr and Pb moderately contaminating soil (1.54 and 1.62 respectively) and Cd showing very high contamination in the soil (17.3). The ecological risk indices revealed that only Cd has high risk of polluting the soils (519) of the study area while the whole area is considered to be at a high risk of various degrees of pollution (534). Considering the health implications of these concerned elements (Cr, Pb and especially Cd) to the body, the habitants of the study area are advised to move away from these dumpsite and also relocate their farmlands to more environmental friendly sites.

DOI: https://dx.doi.org/10.4314/jasem.v28i1.3

Cite this paper as: SMART, M. O; OKUMODI, B. O; IBIYEYE, D. E; ROBERTS, A. E; OLUNLOYO, O. O; ADEOYE, A. S; IBIRONKE, O. H. (2024). Concentration and Ecological Risk Assessments of Potentially Toxic Elements in Soils around Lapite Dump Site, Akinyele Local Government Area, Ibadan, Nigeria. *J. Appl. Sci. Environ. Manage.* 28 (1) 19-25

Dates: Received: 10 December 2023; Revised: 11 January 2024; Accepted: 21 January 2024 Published: 30 January 2024

Keywords: potentially toxic elements; enrichment factor; contamination; ecological risks; pollution

Potentially toxic elements (PTEs) are chemical elements in the environment posing a major health hazard due to their toxicity, persistence and bioaccumulation in human, animals and plants (Dong *et al.*, , 2018). They are released into the ecosystem by both geogenic and anthropogenic activities (such as soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff; refuse disposals and sewage discharge, insect or disease control agents applied to crops, and spent oil) but the presence of elevated levels in the environment originate mainly from human activities such as mining, smelting, lead-works, chemical production, foundries, incineration and open field waste disposal practices, vehicular transportation, amongst many others (Khan *et al.*, , 2015). Potentially toxic elements (PTEs) are among the most hazardous soil pollutants, being highly reactive; when organisms are unable to eliminate them chemically, they are retained in ecosystem, representing a potential risk. (Morita *et al.*, 2021). The presence of elevated levels of PTEs in the environment raises a lot of health concern because

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these elements can be toxic, ubiquitous and cannot be degraded to non-toxic forms by any known method and as a result remain in the environment for decades. Water solubility of PTEs and lack of proper mechanism for their removal from the body make most of them extremely toxic even at low concentrations (Amin 2013). Soil contamination is an environmental problem affecting urban areas, particularly in developing countries (Boente *et al.*, 2022). Contamination sources have been attributed to unregulated overlapping of activities that influence soil quality, e.g., industrialization, urbanization, agriculture, and solid waste. Solid waste heterogeneity contributes with the enrichment of potentially toxic elements (PTEs) in soil according to Lashen *et al.* (2022), being currently considered as a major threat to soil and groundwater quality in urban areas. Previous studies (Zaynab *et al.*, 2022) described that the rapid growth of cities and their inhabitants has boosted global waste production, with an estimated global annual production of municipal solid waste (MSW), in 2025, of 2.2 billion metric tons. Contamination of soil by PTEs may pose health risk to humans through the food chain and can also lead to reduction in food quality. Crops and vegetables grown in soils contaminated with potentially toxic elements have greater susceptibility to uptake these elements. Waste dumpsite is final place for all types of waste, either municipal solid waste, collected and transported directly to landfills, or industrial waste or other materials from waste treatment facilities which are useless. In most developing countries like Nigeria, dumpsites are often used for planting of food crops and vegetables due to their richness in nutrients. The physicochemical properties of soil customarily affect the variety of vegetation available in such land. For example, soil structure and acidity affects the absorption and accumulation of mineral elements by plants (Ekere *et al*, 2014). The types and concentration of toxic elements in soil and crops around dumpsites are subject to the wastes types, run-off, topography, and level of scavenging (Ogbonna *et al.,* 2009). The long term exposure to PTEs can have carcinogenic, central and peripheral nervous system, gastrointestinal (GI), cardiovascular, hematopoietic, renal systems and circulatory effects on human (Pratas *et al*, 2013; Nwankwo *et al.,* 2019). Open dumpsites are used for disposal of solid wastes without environmental controls. Dumping of solid wastes in open is of serious health risk and constitutes problems on environment because they are mostly contaminated and unaesthetic. Most of the dump sites are not logically selected, planned or well managed (Odewumi, *et al.,* 2016). Some of these PTEs are essential micro nutrients, but after certain concentration they pose serious danger to soils around the dumpsites which also affect the crops planted on the affected soils causing public health risk to humans consuming the crops (Ataikiru, 2021). Thus, a need to constantly examine the level of PTEs in soils and their bioaccumulation in the edible crops or vegetables to ensure that the accepted levels are not exceeded, therefore the objective of this paper was to determine the concentration and ecological risk assessments of potentially toxic elements in soils around Lapite dump site, Akinyele Local Government Area, Ibadan, Nigeria.

MATERIALS AND METHOD

Area of Study: Lapite dumpsite (Figure 1) is located within Ibadan metropolis around Akinyele local government area and lies within longitudes 3^{o} 91^{I} 60^{II} E and 3^{o} 91^{I} 64^{II} E and latitudes 7^{o} 58^{I} 5^{II}N and 7^{o} 57^{I} 32^{II}N in southwestern Nigeria. It covers an approximate 20 hectares of land along Old Oyo Road. The study area falls within the humid and sub-humid tropical climate of southwestern Nigeria with a mean annual rainfall of about 1270mm and a mean maximum temperature of 32°C. The lack of thick vegetative cover has allowed instability of the material and allows wind and rain erosion to occur along the slope of the dumpsite. There are presence of the agricultural activities in the area which include banana plantation, maize and cassava farms and rearing of cattle. Material used for the field study include hand trowel, hand glove, maker, paper tape, nylon, field book, sample bag, and Global Positioning System (GPS).

Collection of Soil Sample: Systematic collection of soil samples was done at the depth of 0-15cm with the aid of hand trowel. At the upslope, mid-slope and down slope, soil samples were collected and bulked into four samples to represent each slope gradients both in the front and back of the dumpsite. After collection, the samples were dried before taken to the laboratory for sieving and analysis of the elemental constituents.

Procedure for Heavy Metal Analysis in Soils: The soil samples was air dried for 24 hours and sieve with 2mm mesh sieve. 0.5mm sieve was then used to sieve out from the 2mm sieve. 0.5g of the 0.5mm sieved soils was weighed into a beaker, 20mls of acid mixture of nitric/perchloric acid was added and the beaker content was placed on a heating mantle or a hot plate under a fume cupboard and allowed to undergo heating for 30mins thereabout, there was a colour change to colourless. The content was allowed to cool and then made up to 25mls with distilled water, this was read on a Buck Scientific Atomic Absorption Spectrometer model 210/211 VGP to determine the concentration of each metal in each sample.

Determination of Enrichment Factor (EF): Enrichment factor {EF} represents the extent to which PTEs are enriched or reduced comparative to a particular source. It is used to segregate between PTEs contributed by anthropogenic or geogenic provenance in the soil (Vega *et al.,* 2009). Enrichment factor of an element in the analysis sample is based on the standard of a measured element against reference element. A reference element is often the one characterized by low occurrence variability, such as the most commonly used elements e g Al, Fe, Si, e.t.c {Duzgoren-Aydin, 2007} It is calculated by:

$$EF = \frac{\frac{Metal}{RE}soil}{\frac{Metal}{RE}background} \qquad (1)$$

Where RE is reference metal concentration.

The enrichment factor classification consists of five classes ranging from minimal enrichment to extremely enrichment (Li *et al.,* 2001); Minimal enrichment (EF<2), moderate enrichment (EF=2-5), significant enrichment (EF=5-20), very enrichment (EF=20-40), extremely enrichment (EF>40).

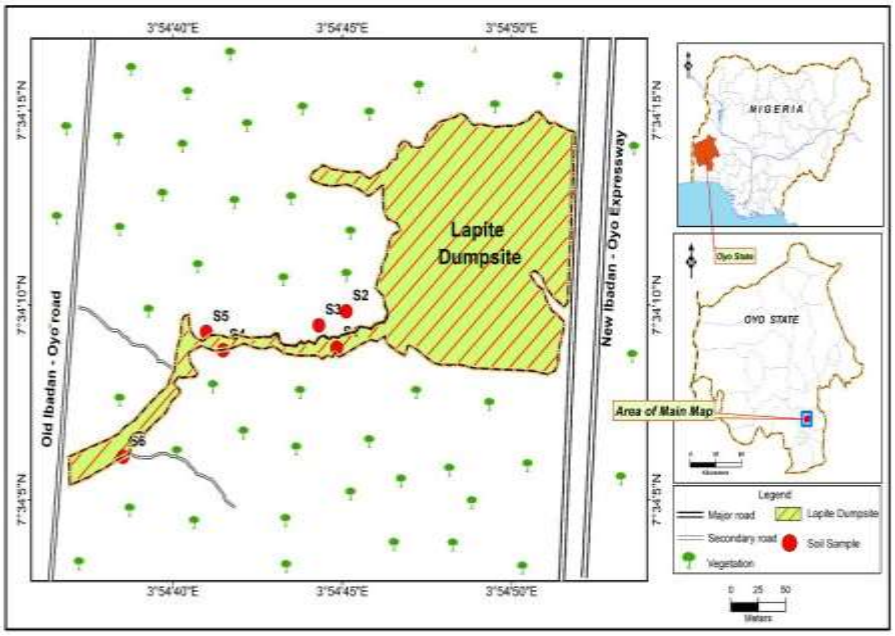

Fig 1: Map showing the soil collection points
Source: This Study, 2023

Risk Assessment Analyses: Contamination Factor (CF): The contamination factor calculation was used (Hakanson *et al.,* 1980 as used by Olatunji and Olisa 2014) to determine the level of contamination of PTEs in the soils around the study area and it's express as thus:

$$CF = \frac{Mean\ concentration}{Background\ value} \qquad (2)$$

The contamination factor classification consists of four classes ranging from low contamination to very high contamination; low contamination (CF < 1), moderate contamination (1≤CF<3), considerable contamination (3≤CF<6), and very high contamination (CF>6)

Ecological risk indices (Er and RI): The monomial potential ecological factor (Er) is used to express the potential ecological risk each PTEs has on the substance (the soil samples). It is expressed as;

$$Er = Tr \times Cf \qquad (3)$$

Where Tr is the toxic-response factor of the PTEs for the soils (Cd-30, Ni-5, Pb-5, Cr-2, Co-1) and CF is the Contamination Factor. The comprehensive potential ecological risk index (RI) is the sum of all Er values which was be used to express the potential ecological risk for a given environment.

$$RI = \Sigma Er \qquad (4)$$

The different grades for Er and RI (Hakanson *et al.,* 1980 as used by Hamid *et al.,* 2022) are shown in table 1.

Table 1. Grades of the Environment by Potential Ecological Risk Index

Er values	Grades of Er of single element	RI values	Grades of potential RI of the environment
Er<40	Low risk	RI<95	Low risk
40≤Er<80	Moderate risk	95≤RI<190	Moderate risk
80≤Er<160	Considerable risk	190≤RI<380	Considerable risk
160≤Er<320	High risk	RI>380	High risk
Er≥320	Very high risk		

RESULTS AND DISCUSSION

Potentially Toxic Elements Concentration: The summary of PTEs concentration on soil samples were presented in Table 2. The concentration table above showed that the mean concentration of Cr, Cd, and Pb (153.2mg/kg, 13.83mg/kg, 137.2mg/kg and respectively) in the soil samples are above their corresponding crustal abundance (CA) on the earth indicating high concentration of these elements in the soil while Co and Ni have mean concentrations (15.80mg/kg and 24.6 mg/kg) lower than their respective CAs, indicating normalcy in the concentration of these elements in the soils of the study area. The mean concentration of Cr is higher when compared with the mean concentrations of Kronum and Amakom dumpsites (67mg/kg and 77mg/kg respectively) of Kumasi, Ghana by Akanchise *et al.,* (2020). The high concentration of Cr may be due to the increased rate at which leather wastes are disposed in study area and disposal of Cr plating materials. The mean concentration of Pb is higher when compared with that of Awotan dumpsite and farmland in Ibadan (0.49mg/kg and 0.10mg/kg respectively) of Hammed *et al.,* (2017) who worked on the heavy metal contents in soils and plants at dumpsites. The high concentration of Pb in the dumpsite may be due to high disposal of lead batteries and paints, PVC pipes, and agricultural activities. The mean concentration of Cd is higher when compared with that of Awotan dumpsite (0.48mg/kg) and Ajakanga dumpsite (0.84mg/kg) of Hammed *et al.,* (2017). The high concentrations of Cd in the soil samples from the dumpsite may be due to disposals of batteries, plastics and synthetic rubber materials in the dumpsite. Soil samples collected at the downslope has the highest concentration values of Cr and Cd while the soil samples collected from the second point of the upper slope has the highest value of Pb in all the sampling points. In the soil samples, all the PTEs have standard deviation (SD) far from their means indicating that their source of toxicity is not uniform. This means that aside the dumping activities in the area, other anthropogenic activities like solid waste incineration, auto-repair workshop, and vehicular movement along the expressway are raising the concentration of the heavy metals in the soil samples.

Table 2. Summary of PTEs Concentration in Soil Sample

S/N	ID	Co	Cr	Cd	Pb	Ni
1	SSU_1	7.30	21.05	0.00	19.55	8.30
2	SSU_2	16.50	45.20	3.45	190.35	20.50
3	SSU_3	19.00	48.05	2.30	83.95	18.85
4	SSM_1	22.30	70.55	6.70	158.65	25.65
5	SSM_2	12.95	43.95	1.65	201.50	49.7
6	SSD_1	16.70	690.10	68.85	169.20	24.6
	Mean±SD	15.80±5.18	153.2±263.5	13.83±27.75	137.2±70.89	24.6±13.76
	CA	50	100	0.8	85	35

Key: *CA= Crustal Abundance (Pandey, 2012); SSU_1=Soil Samples of Upslope (1st point); SSU_2= Soil Sample Upslope (2nd point); SSU_3= Soil Sample Upslope (3rd point); SSM_1= Soil Sample Midslope (1st point); SSM_2= Soil Sample Midslope (2nd point); SSD_1= Soil Sample Downslope*

Enrichment Factor: This was calculated to know the extent to which elements concentrations are enriched or reduced in the soils using aluminum (Al) as the reference element. From the Enrichment factor analysis above, it can observed that most of the enrichment cut across each samples collected except the samples collected from the first point of the upper slope (SSU_1) which has minimal enrichment of the PTEs throughout. The samples collected at the second point of the upper slope (SSU_2) revealed that Co, Cr and Ni have minimal enrichment (0.33, 0.44, and 0.59 respectively) in the samples while Cd and Pb (2.83 and 4.57) have moderate enrichment in the samples collected. The soil samples collected at the third point of the upper slope (SSU_3) revealed that only Pb has moderate enrichment (2.01) while the other elements have minimal enrichment (2.01). This revealed that lead (Pb) is the element with the most enrichment level in all the soils of the upper slope and this is consequent due to the fact that many lead batteries, burnt materials and materials with coated paints (these are major sources of lead toxicity) are highly disposed-off as refuse in the dumpsite as at the time the field work was carried out.

Table 3: Enrichment Factor of PTEs in the Soil

S/N	ID	Co	Cr	Cd	Pb	Ni
1	SSU_1	0.14	0.20	0.00	0.46	0.24
2	SSU_2	0.33	0.44	2.83	4.57	0.59
3	SSU_3	0.38	0.47	1.89	2.01	0.54
4	SSM_1	0.45	0.69	5.50	3.81	0.74
5	SSM_2	0.26	0.43	1.35	4.83	1.44
6	SSD_1	0.33	6.83	53.29	4.06	0.71
	CA	50	100	0.8	85	35
	RE (Al)	1900	1950	2900	950	1870

Key: *CA= Crustal Abundance (Pandey, 2012): SSU_1=Soil Samples of Upslope (1st point); SSU_2= Soil Sample Upslope (2nd point); SSU_3= Soil Sample Upslope (3rd point); SSM_1= Soil Sample Midslope (1st point); SSM_2= Soil Sample Midslope (2nd point); SSD_1= Soil Sample Downslope*

For the samples collected at the middle slope, it is also shown that Co, Cr and Ni all have minimal enrichment in the soils of this slope. In the first point of the middle slope (SSM_1), samples collected revealed that Pb has moderate enrichment (3.81) while Cd has significant enrichment in the samples. For the second point of the middle slope, only Pb has moderate enrichment (5.50) while the other elements have minimal enrichments. This also revealed that in the middle slope, lead (Pb) is also the element with the most enriched level across the soils of this slope and it also consequent due to the fact that we have disposal of lead batteries, burnt materials, together with used PVC pipes disposal at a high rate in that part of the dumpsite. For the soil samples collected at the downslope, Co and Ni showed minimal enrichment (0.33 and 0.71) while Pb showed moderate enrichment (4.06) in the soil samples collected along this slope. Cr has significantly enriched the soils (5.83) while Cd has extreme enrichment in the soils at this slope (53.29). The extreme enrichment of Cd is due to the high rate of plastic and synthetic rubber materials found in this slope which are the major source of Cd toxicity.

Contamination Factor of PTEs: This was used to determine the degree of contamination each PTE has on the soils around the study area. The results of the calculated CFs are as shown; Co-0.32, Cr-1.54, Cd-17.3, Pb-1.62, Ni- 0.70. The contamination factor calculation showed that Co and Ni have low contamination (0.32 and 0.70 respectively) in the soils of the study area while Cr and Pb have moderate contamination in the soils (1.54 and 1.62). This has revealed that the enrichment of Cr and Pb found in some parts of the dumpsite have caused contamination of these soils. Cd has very high contamination in the soils of the study area (17.3) and this is also consequent to the fact that only Cd has extreme enrichment in a part of the dumpsite and this extreme enrichment has led to very high contamination.

Ecological Risk Indices (Er and RI): The potential ecological risk indices (Er) and the comprehensive ecological risk index (RI) was calculated to determine the risk posed by the PTEs in the soils all over the study area and the environment wholly.

Table 4 Ecological Risk Indices of PTEs

Metals	Er (Soil Samples)	RI	Tr
Co	0.32		1
Cr	3.08		2
Cd	519		30
Pb	8.1		5
Ni	3.5		5
		534.0	

The Er values and RI value of the studied metals from all the soil samples are presented in the table above using the toxic responses (Tr) of each elements as the constant factors. From the soil samples studied it can be shown that all the soils in the dumpsite has very high risk of Cd pollution (519) and this is unhealthy going with the fact that Cd toxicity has adverse effect on the body or any matter making use or consuming it. The other elements have low risk of pollution in the soils of the dumpsite (Er<40), and this consequently mean that despite the moderate enrichment and contamination of Pb and Cr in the soils of the dumpsite, they have a low risk of causing pollution to the soils of the dumpsite. The comprehensive potential ecological risk index (RI) showed that the environment as a whole is at high risk of pollution (534.0). This indicates that, considering the soils studied and other matters (both living and non-living), the environment are at high risk of various degrees of pollution which will cause serious health problem to the habitants and other living things in the dumpsite.

Conclusion: Different analytical factors revealed various responses of PTEs to the soils samples collected. These factors revealed that Pb and Cd are the elements with the most adverse effect in the soils with Cd being the element affecting all the slopes of the dumpsite. Considering the effect of these elements on the soils, plants, and human, farmlands making use of these soils should be relocated to friendlier environment with fertile soils and the habitants should also move away from this dumpsite area.

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