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Assessment of the Levels of Some Potentially Toxic Metals in Organic Manures from Major Refuse Dumpsites in Pankshin L.G.A of Plateau State, Nigeria

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Abstract
This study assessed the physicochemical properties and concentration of heavy metals namely, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Pb in five (5) refuse dumpsite site manures in Pankshin Metropolis. Samples were collected using standard sampling methods and analysed using ICP-OES. Organic Carbon (OC) and Organic Matter (OM) were analysed using Walkley-Black method (revised in 2018), while the pH and electrical conductivity (EC) were determined using standard methods. The results obtained shows that Cd range from 187.77±0.00 to 333.46±0.00 mg/kg, Cr, from 450.97±0.04 mg/kg to 165.92±0.04 mg/kg, Ni form 67.56±0.02 to 2.71±0.06 mg/kg, Zn, form 721.17±0.01 to 3437.31±0.07 mg/kg, Mn from 1152.71±0.03 to 3458.83±0.15 mg/kg, Fe from 78891.00±1.74 to 163361.70±6.47 mg/kg, Cu from 111.08±0.02 to 442.98±0.05 mg/kg and As, from 10.62±0.07 to 27.80±0.06 mg/kg. The concentration of Pb ranged from 199.75±0.04 to 93.42±0.01 mg/kg while that of Co was 22.83±0.02 to 50.64±0.00 mg/kg. The risk assessment of the metals such as contamination factor (CF), pollution load index (PLI), Geoaccumulation index (I-geo), Ecological risk factor (ErF) and Potential ecological risk factor (RI) of the metals, show a moderate to extremely contaminated soil. The results of the physicochemical parameters obtained were within the permissible limits specified by Food and Agricultural Organization and world health organisation (FAO & WHO, 2008), while the heavy metals content were above the limits specified by World Health Organization (WHO) and FAO for agricultural soils. The manures from these dumpsites are thus considered to be polluted with the heavy metals suggestively emanating from a variety of sources ranging from metal scraps, plastics, pesticides, insecticides, automobile oils, paint containers, sewage effluents, and combustion etc. It is therefore recommended that it should not be used for the cultivation of crops.

Keywords: Dumpsite, heavy metals, risk assessment, manure, soil

1. Introduction

Two major factors affecting the output and compositions of household and municipal solid wastes in Nigeria and around the world are changing lifestyles and population growth. Solid waste is an important ecological issue in the world because of the huge amount of it that is produced every day (Abdel-Shafy & Mansour, 2018; Das, Lee, Kumar, Kim, Lee & Bhattacharya, 2019). The environmental contamination issues raised by these wastes are more concerning, particularly in developing nations like Nigeria where the rate of generation greatly outpaces the capacity to handle them (Ike, Ezeibe, & Daud, 2018; Kehinde, Ramonu, Babaremu & Justin, 2020). It is estimated that

Nigeria produces more than 42 million metric tons of municipal waste annually (Ayodele, Alao & Ogunjuyigbe, 2018) with little or no capacity and facilities on ground to manage them adequately.

The level of education, civilization, income, lifestyle, and culture may all have little effect on the composition of municipal solid waste. Generally speaking, food waste, paper waste, wood waste, textile materials, metal scraps, cans, and various polythene and plastic wastes make up municipal solid wastes (Ugwu, Ozoegwu, Ozor, Agwu & Mbohwa, 2021). A range of heavy metals are released into the soil and air as a result of the frequent careless burning of these solid wastes at the dumpsites.

The group of metals and metalloids with a density of more than 4.5 g/cm3 and a relatively high atomic mass, such as Pb, Cd, Cu, Hg, Sn, and Zn, are referred to as "heavy metals" because they can be toxic (Ochiba, 2020). Low concentrations of these elements are found in soils naturally. Many of them are vital micronutrients for humans, animals, and plants, but because they are not biodegradable, they can easily build up in tissues of living organisms, which is susceptible to phytotoxicity and negative health effects at high concentrations (Gautam & Dubey, 2018).

Industrial areas, mine tailings, leaded gasoline and paints, sewage sludge, pesticides, fertilizers, animal manures, waste-water irrigation, coal combustion residues, petrochemical spills, atmospheric deposition from various sources, and mine tailings are the primary anthropogenic sources of heavy metals (Nachana'a, 2019). The most difficult and persistent contaminants to get rid of from the environment are heavy metals. They endanger the health and welfare of both humans and animals in addition to deteriorating the quality of the air, waterways, and food crops (Akhtar, Syakir, Bhawani & Umar, 2021), because they are not broken down by metabolism like most organic substances are, metals build up in the tissues of living things. Zn, Ni, Co, and Cu are comparatively more hazardous heavy metals to plants, while As, Cd, Pb, Cr and Hg are relatively more toxic to higher animals.

Pankshin Local Government Area of Plateau State in Nigeria, is a non-industrialized town hence the solid wastes generated within predominantly comes from markets, offices, hospitals and households such as garbage, plastics, polythenes, textiles, stationeries, sludge from sewage, dead animals, ashes, wood, food and farm waste products. However, metallic materials from damaged vehicle parts, electronics, computers, cans, etc, are also disposed in the same way as the other non-metallic materials, thereby constituting a source of metal contamination and persistent organic pollutants.

Refuse dump sites are generally unsanitary and constitute breeding places in which disease-carrying vermin such as rats and flies proliferate (Kingsley, Paschal & Jude, 2016). A variety of gases are released into the surrounding air as microorganisms decompose the solid wastes and fires pollute the air with acrid smoke and other numerous volatiles. Liquids that ooze and seep through the solid waste heap ultimately reach the soil, surface water and ground water. Hazardous materials such as heavy metals, pesticides and hydrocarbons that are dissolved in this liquid often contaminate soil and water (Okakpu Okoye & Onuegbu, 2023).

More emphatic is the fact that local farmers within Pankshin excavate soils (organic manure) from the refuse dumpsites for use in their farms. Consequently manures from these dumpsites are potentially hazardous for agricultural purposes owing to likelihood of contamination from persistent organic pollutants and heavy metals.

2. Materials And Methods

Materials/Equipment

The materials used for this analysis were Agilent 720ICP-OES, (USA), Hanna pH meter, and Conductivity meter.

Sample Collection and Analysis

Soil samples were collected from four different locations within Pankshin metropolis in Plateau State. The samples were collected within a depth of 0-15cm using a soil auger from Pankshin Daily Market, Bwarak Community, Vel Community and GRA waste dumpsites. The samples were then transported to the laboratory in an air-tight polythene container for further treatment and analysis.

Sample Analysis

Physicochemical analysis

The samples were analyzed for organic carbon (OC) and organic matter (OM) using the method described by Walkley – Black (revised in 2018), while the pH and electrical conductivity (EC) were determined using the methods described by Abubakar et al. (2015). The heavy metals concentrations were analysed using ICP-OES

Risk Assessment

Contamination Factor (CF): The Contamination Factor (CF) is calculated using Equation (1) and shows site-specific contamination of toxic substances.

$$CF = \frac{CM\ (sample)}{CM\ (background)} \qquad (1)$$

Were Cm (sample) = metal concentration at a contaminated site; Cm (background) = concentration of a given element in the background sample. The CF is based on 4 categories of contamination: Low (CF < 1), moderate (1 < CF < 3), considerable (3 > CF < 6), and very high (CF > 6).

Pollution Load Index (PLI): This can be determined using Equation (3).

$$PLI = (CF_1 \times CF_2 \times CF_3 \ldots CF_n)^{1/n} \qquad (2)$$

Where CF = contamination factor, n = number of study metals, C metal = metal pollutant concentration in soil; C background = metal background value. PLI ≤ 1: No pollution, 1 < PLI ≤ 2: Moderate pollution, 2 < PLI ≤ 3: Serious pollution, PLI > 3: Severe pollution

Geological Accumulation Index Assessment. The geological accumulation index (I-geo) was proposed by Müller (1969) and has been widely used in heavy metal studies (Ji et al., 2008) The enrichment of heavy metals in the soil can be determined by comparing the current values with the background values. The I-geo of the tested soil was calculated using the following equation (2)

$$I\text{-}geo = \log_2 (Cn/1.5Bn) \qquad (3)$$

Where Cn is the measured concentration of every heavy metal found in the dumpsite soil (mg/kg), and Bn is the geological chemical background value of heavy metals found in soil (mg/kg). Uncontaminated: Igeo ≤ 0, Uncontaminated to moderately contaminated: 0 < Igeo ≤ 1, moderately contaminated: 1 < Igeo ≤ 2, moderately to heavily contaminated: 2 < Igeo ≤ 3, Heavily contaminated: 3 < Igeo ≤ 4, Heavily to extremely contaminated: 4 < Igeo ≤ 5, Extremely contaminated: Igeo > 5

Ecological Risk Factor (ErF). This is calculated using equation (4)

$$ErF = TR \times CF \qquad (4)$$

Where TR = toxic response factor, and CF = contamination factor

Toxic Response Factors (TRFs) or Toxicity Response Factors are used to quantify the toxicity of various pollutants. These factors help in assessing the potential harm caused by each pollutant, TF for Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Pb and As are 2, 1,1, 5, 3, 5, 1, 10, 5, 10

ERF < 0.1: Negligible ecological risk, 0.1 ≤ ERF < 1: Low to moderate ecological risk, 100 ≤ ERF < 1000: Extremely high ecological risk, ERF ≥ 1000: Catastrophic ecological risk

Potential Ecological Risk Factor (RI): This is calculated using equation (5).

$$RI = \sum ErF \qquad (5)$$

Where ErF is an Ecological Risk Factor

Interpretations of ErF and RI are as follows; ErF < 40 and RI < 150 is low risk; 40 ≤ ErF < 160 and 150 ≤ RI < 300 is moderate risk; 80 ≤ ErF < 160, 300 ≤ RI < 600 is considerable risk; 160 ≤ ErF < 320 is high; ErF ≥ 320 and RI ≥ 600.

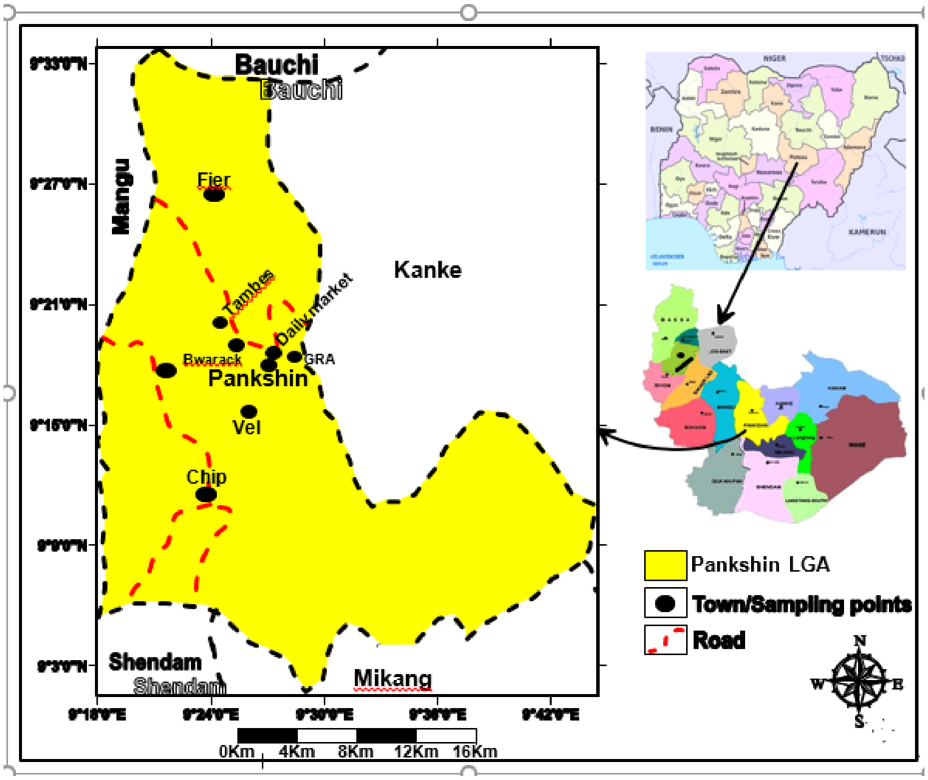

Figure 1: Map of Pankshin Local government Area

3. Result And Discussion

Result: Summary of the results of the heavy metals concentration as analysed from the wastes dumpsites are as presented in Table 1

Table 1: Concentration of heavy metals analysed from the wastes dump

Element	VEL	GRA	Daily market	Bwarak	Tambes	Who limit
Cr (mg/kg)	450.97±0.04	165.92±0.04	213.47±0.05	229.59±0.02	211.10±0.21	100
Mn (mg/kg)	3458.83±0.15	1152.71±0.03	1793.38±0.01	1530.50±0.02	1261±0.13	2000
Fe (mg/kg)	163361.70±6.47	78891.00±1.74	95861.21±1.52	106210.29±0.24	8124±0.02	70000
Co (mg/kg)	50.64±0.00	47.31±0.04	22.83±0.02	24.17±0.01	18.54±0.36	50
Ni (mg/kg)	67.56±0.02	2.71±0.06	40.15±0.04	34.35±0.04	23.43±0.22	50
Cu (mg/kg)	442.98±0.05	111.08±0.02	328.55±0.02	225.53±0.02	210.67±0.51	100
Zn (mg/kg)	3437.31±0.07	721.17±0.01	2477.58±0.04	1894.86±0.03	1745.55±0.11	300
As (mg/kg)	27.80±0.06	0.00±0.00	10.62±0.07	25.86±0.05	13.32±0.14	40
Cd (mg/kg)	333.46±0.00	187.77±0.00	236.82±0.03	269.59±0.01	194.54±0.02	3
Pb (mg/kg)	199.75±0.04	93.42±0.01	180.40±0.04	199.65±0.05	156.89±0.31	85
pH	4.32	5.21	5.11	4.87	4.64	6.5-7.
EC	469	286	415	377	396	1000
OC%	3.18 ± 0.21	0.83 ± 0.01	3.06 ± 0.04	3.03 ± 0.23	2.12±0.11	
OM%	4.34 ± 0.36	1.31 ± 0.61	4.82 ± 0.07	4.01 ± 0.35	3.52±0.48	

Discussion

Physiochemical Properties

The physiochemical properties of the manures (soils) from the different dumpsites vary significantly. The highest concentration of organic carbon (OC), 3.18 ± 0.21 % was recorded in Vel community, while the least was recorded in GRA with a concentration of 0.83 ± 0.01 %. The high difference in the concentration is as a result of the dense population, coupled with various human activities around Vel unlike the GRA, where the human population is scanty. The organic matter ranges from 1.31 ± 0.61 to 4.82 ± 0.07. The high concentration of organic matter recorded around the daily market may be as a result of various human activities taking place there. Therefore, the high OC and OM percentages at Vel, Bwarak and Daily market dumpsites of waste fractions might be due to the complete decomposition as reported by (Bisimwa et al., 2022). The percentages of OC and OM of the soils were higher than the findings of Agbeshie et al., (2020), where the OC recorded from soil samples from down-site and top-site dumpsites were 0.88, 2.10 and 1.36 % respectively. This result corroborates the findings of (Martin, 2014 & Ogochukwu et al., 2024) on waste dumpsites. These findings suggest that increased percentage OC and OM may be a result of addition of household and animal wastes which significantly impacts soil bulk density, porosity, plant growth, nutrient availability, and soil moisture content. Thus notwithstanding, there was no statistically significant difference ($p \leq 0.354$) between OC in three of the sampling sites of Vel, Bwarak and daily market areas; Similarly, there was no statistically significant difference between OM in three of the sampling sites of Vel, Bwarak and daily market areas ($p \leq 0.367$). This signifies that the waste from both the three sampling areas Vel, Bwarak and daily market dumpsites have similar OC and OM characteristics; and therefore, can be mined for similar purposes.

Heavy metals

The concentration of Cadmium in the soil samples ranges from 187.77±0.00 to 333.46±0.00 mg/kg. This value is higher than the natural limits of 0.01- 3.0 mg/kg in soil as given by Sahrawat & Narteh (2002) and (Shehu-Alimi et al.,2020). This value is also above the maximum tolerable level proposed for agricultural soil. Cadmium is a poisonous heavy metal that can occur as a waste product from industrial workplaces. The high levels could be attributed to the availability of cadmium materials from sludge, cadmium batteries or metal scraps and metal plating, plastic stabilizers, PVC materials, coatings and motor oils and pesticides which leached into the underlying soils (Gairola, 2010).

The highest concentration of Cr recorded in the dumpsites which was 450.97±0.04 mg/kg was from Vel community, whereas the lowest concentration of 165.92±0.04 mg/kg recorded was from the GRA sample. These values are higher than the critical permissible level of 50 mg/kg for agricultural soils as recommended by Sahrawat & Narteh, (2002) and Shehu-Alimi et al. (2020). Cr has a varying oxidation state of +2 to +6. The trivalent state is the most stable. Although this stable Cr has been reported to be an essential nutrient, when inhaled, ingested, or interacted with at a high level, has a deleterious effect on human health (Wilbur et al., 2012).Sources of Cr in the soils could be due to waste consisting of lead-chromium batteries, coloured polythene bags, discarded plastic materials and empty paint containers (Moorberg & Crouse, 2017, Rai et al., 2010).

The concentration of Pb found in the dumpsites ranges from 199.75±0.04 to 93.42±0.01 mg/kg. This value is lower than the value reported by Shehu-Alimi et al. (2020) with an upper limit of 300 mg/kg, but falls within the maximum tolerable levels proposed for agricultural soils which range from 90-400 mg/kg (WHO, 1996 & NEPCA, 2010). The presence of Pb at the study site can be attributable to the disposal of waste materials containing batteries, food packaging materials, PVC materials, automobile exhaust fumes, engine oil spillage, combustion using diesel, sewage effluents, run-off of wastes, atmospheric deposition, combustion of solid wastes and insecticide residues.

The amount of Ni found in the dumpsites range from 67.56±0.02 to 2.71±0.06 mg/kg. The concentration in Vel is higher than the critical permissible concentration of 50mg/kg whereas those in the other areas are lower than the maximum permissible limit of 50mg/kg (Sahrawat & Narteh, 2002; Shehu-Alimi et al., 2020) and within the range of 2-200 mg/kg Ministry of Agriculture, Fisheries and Food (MAFF) (1992). Comparing the result for Nickel with the WHO maximum allowable limit for nickel in soil, the sample collected for all the sampling areas except for Vel within acceptable limit of 50mg/kg Chessed (2019). Furthermore, the concentration of Ni at the location could be a result of municipal wastes, sewage sludge, nickel-cadmium batteries, and fertilizer disposal of at the dumpsite (WHO, 1993; Eze et al., 2020A; Eze et al., 2020B & Bowen, 2024).

The concentration of zinc in the dumpsites which vary from 721.17±0.01 to 3437.31±0.07 mg/kg is above WHO's maximum allowable limit of 300 mg/kg. The values are also higher than the allowable limit of the Council of the European Communities (EC) (1986), Chessed et al. (2019). The presence of Zn within the dumpsite could be attributed to the disposal of heavy metal substances which includes the presence of dry cells and the burning of electronic wastes (NEPCA, 2010). It could also be due to the high usage of various types of pesticides, degradable chemicals and fertilizers (Ogunlana et al., 2021; Eze, 2020; Akanchise et. al., 2020; Twumasi et. al., 2016 & Chiroma et al., 2014). The level of Mn in the soil sample ranges from 1152.71±0.03 to 3458.83±0.15 mg/kg. The WHO maximum allowable limit for Mn is 2000 mg/kg. This implies that three samples are within the WHO acceptable limit except the sample from Vel community which is higher (Addis & Abebaw, 2017; Okeke & Ifemeje, 2021; Onwukeme & Eze, 2021 ; Eze et. al., 2023, 2024). The availability of Mn at the locations could be as a result of disposal of municipal waste, sewage sludge, degradable chemicals and fertilizers.

The concentration of Fe in the samples ranges from 78891.00±1.74 to 163361.70±6.47 mg/kg. The values are higher than those obtained in a similar study for agricultural soil in Port Harcourt metropolis (Iyama et.al., 2022) and soil from the waste dumpsites in Kaduna metropolis (Wunzani et. al., 2020). The decomposition and mineralization of the biodegradable solid wastes in the dumpsites might have been responsible for these higher concentrations.

Cu in the current study, has result that varies from 111.08±0.02 to 442.98±0.05 mg/kg. This result is higher than that of Wunzani et. Al., (2020) in some waste dumpsites in the Kaduna metropolis, but lower when compared to studies carried out by Long et. Al., (2011). These values are higher than the permissible value for copper in agricultural soils. The high concentrations of Cu within the study area may be as a result of Cu being one of the conventional heavy metals with extensive distribution in municipal solid waste components. The sources are mostly kitchen wastes, ash, plastic wastes, paper and metal scraps which have a high universality in municipal wastes (Long et. Al., 2011). Cu in high concentration is toxic to microorganisms which can consequently cause changes in soil biological equilibrium with adverse effects on both soil fertility, plant development and yield.

Arsenic was detected in only four of the samples and the concentration varies from 10.62±0.07 to 27.80±0.06 mg/kg. This concentration is higher than those reported by Ibrahim et. al., (2020) in some dumpsites in Potiskum, Nigeria. The concentration was also found to be higher than the WHO permissible limit of 40 mg/kg. In addition to skin cancer, long-term exposure to arsenic may also cause cancer of the bladder and lungs. The International Agency for Research on Caner (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans (WHO, 2022).

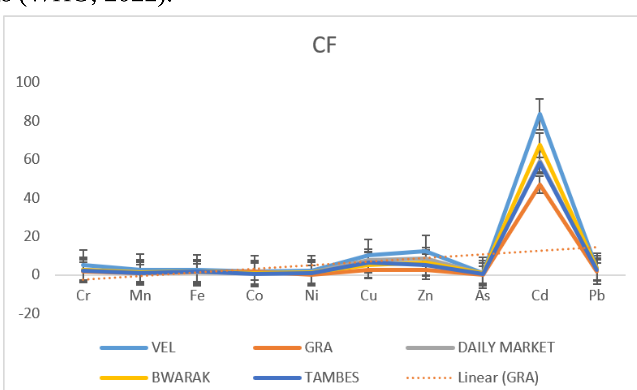

Figure 1: Contamination factor

Contamination Factor (CF) is a metric used to assess the level of contamination in environmental media. From figure 2, the CF for Cr in all the sampling points shows moderate to significant contamination, according to the defined classes.The finding of this study was lower than of Adewuyi et al., (2020), Oyediran et al., (2019) and Nwankwo et al., (2018) in some parts of Nigeria. Similarly, Mn, Fe, Co, and Ni all show moderate contamination in all the samples analysed. This study was found to have lower values compared to Adewuyi et al, (2020), Oyediran et al, (2019) and Nwankwo et al., (2018). Cu and Zn were considered to fall within the heavy to extreme contamination categories according to the Muller, (1969) contamination factor categories. Arsenic in all the samples analysed, has values belonging to the no contamination category, whereas Cd was categorized as extremely contaminated in all the samples which is similar to the reports of Adewuyi et al. (2020) in some waste dumpsites in Lagos Nigeria. According to Muller, Pb in the present study was also categorized as moderately contaminated (Muller, 1969). Elevated levels of Cr, Cu, and Zn in VEL sediments indicate potential contamination. Mn and Fe levels vary across locations, suggesting differences in sediment composition. Co and Ni levels are relatively low, except in VEL.As and Pb levels are elevated in some locations, warranting further investigation. Cd levels are high across all locations, indicating widespread contamination.

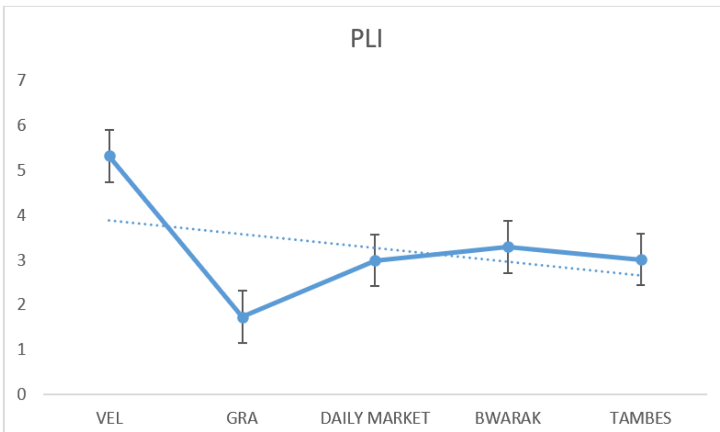

Figure 2: Pollution load index

The Pollution Load Index (PLI) is a widely used metric to assess the level of pollution in environmental media, such as soil, water, and air. PLI values range from 0 to infinity, with increasing values indicating greater pollution. From figure 2, GRA was the only point which was considered to have low pollution. The other four samples have a pollution load index that varies from moderate to high pollution.

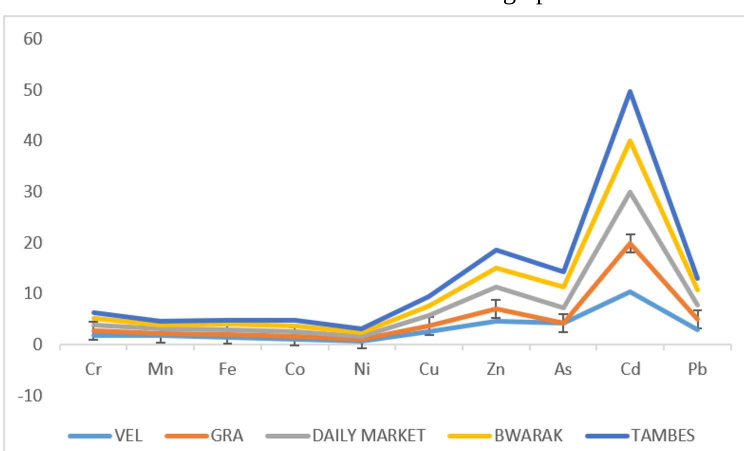

Figure 3: Geo-Accumulation index (I-geo)

The I-geo (Geoaccumulation Index) is a widely used metric to assess the level of metal contamination in sediments, soils, and other environmental media. The I-geo index ranges from 0 to 7, with increasing values indicating greater contamination. Concerning figure 3, Cr, Mn, Fe, Co, and Ni are considered to be classified as moderately contaminated. The findings of this study were lower compared to earlier studies carried out by Adewuyi, et al. (2020), Ayediran, et al. (2019), and Nwankwo et al. (2018). Similarly, Cu and Pb were considered to vary from moderately to heavily contaminated, however, the values obtained from this research were in line with the work of Ayediran, et al. (2019). Zn, As and Cd in the sampling points were extremely contaminated. Notwithstanding, there was a significant difference between Cr (p=0.042), and Mn (p=0.024) in all the sampling locations. The significant differences suggest variations in I-geo values for Cr and Mn across locations, while there was no significant difference between Fe (p=0.279), Co (p=0.716), Ni (p=0.375), Zn (p=0.181), Cd (p=0.920) and Pd (p=0.132) in the five sampling locations.

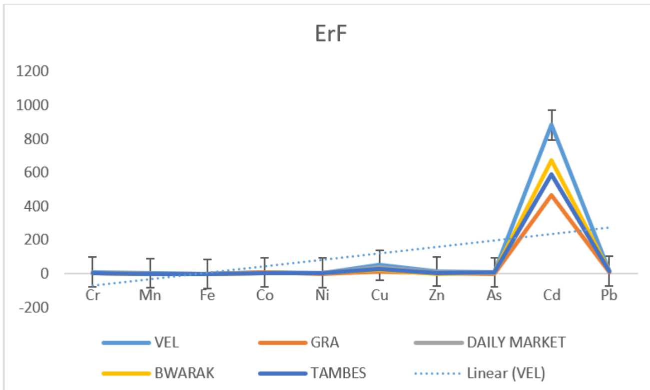

Figure 5: Ecological risk factor

Cr, Co, Ni, and Arsenic show a moderate ecological risk whereas Fe shows a low ecological risk in all the sampling points. Cu and Pb in all the sampling points are considered to have high ecological risk. Cd in all the sampling points are considered to have very high ecological risk. The contaminant concentration poses extreme ecological risk, likely causing severe harm to organisms and ecosystems. ANOVA was used at (p=0.05) to test the significant difference between each of the elements in the sampling locations. There was a statistically significant difference for Cr at (p=0.04), Co (p=0.002), Ni (p=0.013), Cu (p=0.004), and Zn (p=0.023). The significant differences suggest variations in elemental concentrations across locations (Vel, GRA, Daily Market, Bwarak, and Tambes). This might indicate distinct geological or environmental factors influencing each location. Similarly, there was no significant difference for Mn (p=0.143), Fe (p=0.703), As (p=0.194), Cd (p=0.785), and Pb (p=0.924) in the five sampling locations, signifying that the waste from both the five sampling locations have similar ErF characteristics.

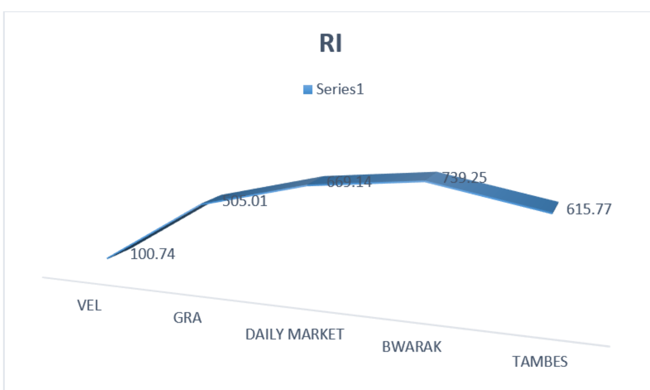

Figure 6: Potential Ecological Risk Factor (RI)

The Potential Ecological Risk Factor (RI) is a quantitative measure that evaluates the potential ecological risks posed by contaminants or pollutants to aquatic or terrestrial ecosystems. The result of all the sampling points shows very high risk. There was no statistically significant difference ($p<0.001$) in the dumpsite of GRA, Daily Market, and Tambes. This signifies that the wastes from the three sampling areas has similar RI characteristics; and therefore, can be mined for similar purposes. Similarly, there was a statistically significant difference ($p<0.001$) between the RI in the Vel and Bwarak communities.

4. Conclusion

Manure samples were collected from five (5) refuse dumpsites in Pankshin Metropolis and analysed using ICP-OES to assess the levels of some heavy metals namely, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Pb. The risk assessment of the metals such as Contamination Factor (CF), Pollution Load Index (PLI), Geoaccumulation Index (I-geo), Ecological risk Factor (ErF) and Potential Ecological Risk Factor (RI) of the metals, show a moderate to extremely contaminated soil. The results of the physicochemical parameters obtained were within the permissible limits specified by Food and Agricultural Organization and World Health Organisation, while the heavy metal contents were above the limits specified by World Health Organization (WHO) and FAO for agricultural soils. The manures from these dumpsites are thus considered to be polluted with the heavy metals suggestively emanating from a variety of sources ranging from metal scraps, plastics, pesticides, insecticides, automobile oils, paint containers, sewage effluents, and combustion. It is therefore recommended that the manure from these dumpsites should not be used for the cultivation of crops.

Acknowledgement

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Competing Interests

The authors have declared that no competing interests exist.

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