



EVALUATION OF HEAVY METALS POLLUTION IN SOIL AND LETTUCE (*Lactuca sativa*) OBTAINED FROM IRRIGATED DUMPSITES IN MUBI NORTH ADAMAWA STATE, NIGERIA

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ABSTRACT

The use of dumpsite soils as organic manure is common in Mubi, Adamawa State, Nigeria, due to their perceived benefits on soil properties and plant productivity. However, these soils often contain hazardous heavy metals from anthropogenic sources, posing risks to environmental quality and human health through the food chain. This study assessed heavy metal concentration, transfer, and pollution indices in soils and lettuce from three irrigated dumpsites (Wuro-Alkali, Wuro-Gude, and Mayanka). Transfer factors (TF), pollution load index (PLI), geo-accumulation index (I-geo), contamination factor (CF), degree of contamination, and enrichment factor (EF) were calculated. Results showed TFs from 0.59 to 0.89, with copper (Cu), cadmium (Cd), and chromium (Cr) exhibiting the highest mobility. PLI exceeded 1 for all dumpsites, indicating progressive soil deterioration (Mayanka > Wuro-Alkali > Wuro-Gude). I-geo revealed moderate to high pollution for manganese (Mn), Cd, Cu, and zinc (Zn), attributed to fertilizer use and waste disposal. CF ranged from 0.87 (Pb) to 12.35 (Mn), and the degree of contamination exceeded 24 across all sites, classifying them as highly contaminated. In contrast, EFs were consistently below 2, indicating minimal enrichment. This integrated assessment reveals that while dumpsite soils are not enriched relative to background levels, they exhibit moderate to high contamination indices, reflecting cumulative anthropogenic influence. The elevated TFs for certain metals highlight the risk of heavy metal entry into the food chain, underscoring the need for careful management of dumpsite soils used as organic manure.

Keywords: Dumpsites, Heavy Metals, Transfer Factor, Pollution Load Index, Enrichment Factor

INTRODUCTION

The use of dumpsite soils as organic manure is widespread in Mubi, Adamawa State, Nigeria. This practice has been shown to improve soil properties such as organic matter, nutrients, porosity, aggregate stability, bulk density, and water retention, and as a result, increase plant productivity (Oluyemi *et al.*, 2008). However, it is known that some waste products contain hazardous metals such as Ni, Pb, Cd, Zn, and Hg (Olarinoye *et al.*, 2010), which affect the distribution and concentration of these metals in the environment.

Heavy metal pollution of agricultural soil and vegetables is one of the most severe ecological problems worldwide (Ahmad and Goni 2010) because of its toxicity to plants, animals, and humans, and its lack of biodegradability (Zhuang *et al.*, 2009). Heavy metals are ubiquitous in the environment, and their levels have been elevated due to both natural and anthropogenic sources (Harmanescu *et al.*, 2011). They pose potential threats to the environment and can damage human health through various absorption pathways such as direct ingestion, dermal contact, inhalation, and dietary intake via the soil-food chain (Lu *et al.*, 2011).

Environmental pollution is one of the major challenges facing humanity in the 21st century. Industrialization, urbanization and developmental projects are the major causes of environmental pollution which is associated with anthropogenic activities have increased within the last century globally (Chukwuyenum and Akandu 2024). The different components of the environment (mainly soil, water and air) are frequently impacted by anthropogenic activities and to a lesser extent natural effects. Anthropogenic activities are human activities that are carried out on the earth surface encompassing the various environmental components. Nearly all human activities are carried out on land. Chukwuyenum and Akandu (2024) reported that soil is a distinctive habitat for most living organisms. Most of the resources that are widely utilized by humanity are found in the soil. Soil also

plays several economic, social, ecological roles. The human activities on soil have direct or indirect effect on soil quality. The impacts also extend to water and air quality. Some of the notable activities that take place in the soil include construction works, erection of building structures, cultivation of vegetation, land transportation among others. As such, soil has been regarded as an integral part of landscape probably due to its diverse and unique characteristics. Soil is formed during weathering processes through the interaction of rock, geologic materials and microorganisms (Ayobami, 2022). The aim of this research is to assess the concentration and environmental pollution index of heavy metals in the soil and lettuce obtain from the irrigated dumpsite (pollution load index, enrichment factors and transfer factor).

MATERIALS AND METHODS

Description of Study Area

Mubi North is among the 21 Local Government Areas of Adamawa State and is located on latitude 11°51' N and longitude 13°51' E. It has altitude of 696 m above sea level with an annual mean rainfall of 1,220 mm and a mean temperature of 15.2 °C during hamattan periods from November to February and temperature of 39.7 °C. The town is essentially a mountainous landscape transverse by River Yedzaram and many tributaries. The Mandara and Adamawa Mountains formed part of this undulating landscape (Mansir, 2006) as shown in Figure 1.

Apparatus and Instrument

Chopping board and Teflon knife were used to cut vegetable samples into pieces while air-circulating oven (WTC binder) was used for drying. Analytical balance (Sartorius analytic) was used to weigh the samples. Muffle furnace (Nabertherm) was used for the dry-ashing process of vegetable samples. Round bottom flasks with ground glass joint fitted with reflux

condenser were used for digesting the samples on block digester heating apparatus. Borosilicate volumetric flasks (50 ml and 100 ml) were used during dilution of sample and preparation of metal standard solutions. Measuring cylinders, pipettes, and micropipettes (100 µL – 1000 µL) were also used during measuring different quantities of volumes of the sample solution, acid reagents, and metal standard solutions. Metals determination was carried out by atomic absorption spectrophotometer (AAS) (Buck 210VGP) that used air-acetylene as a fuel-oxidant mixture and that was equipped with deuterium background corrector and hollow cathode lamps.

Chemicals and Reagents

All the reagents and chemicals used for this study were of analytical grade. Stock standard solution of concentration 1000 mg/L in 2% HNO₃ (BDH-Chemicals Ltd Poole England) of the metals Cu, Zn, Cr, Pb, Fe, Mn, and Cd standard solutions were used to prepare 100 mg/L intermediate standard solutions. From 100 mg/L intermediate standard, five different ranges working standard solution was prepared for each metal. Distilled water was used for dilution of the sample and intermediate metal standard solutions as well as for rinsing glassware and sample bottles.

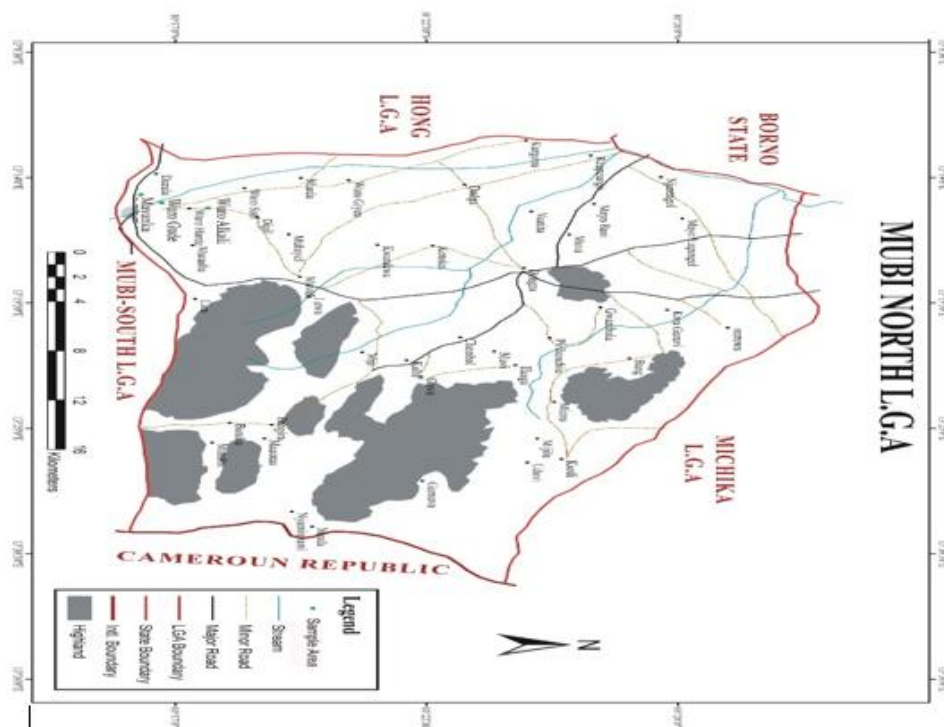


Figure 1: Map Showing the Three Different Sample Locations

Sample Collection

Vegetable samples were collected from Wuro-Gude (WG), Wuro-Alkali (WA) and Mayanka (MY) dumpsites. The sites were commercial vegetable farms and are considered one of

the most important sites that supply vegetable to markets within the town and beyond. The pictures of the dumpsites where the samples were collected are shown below.

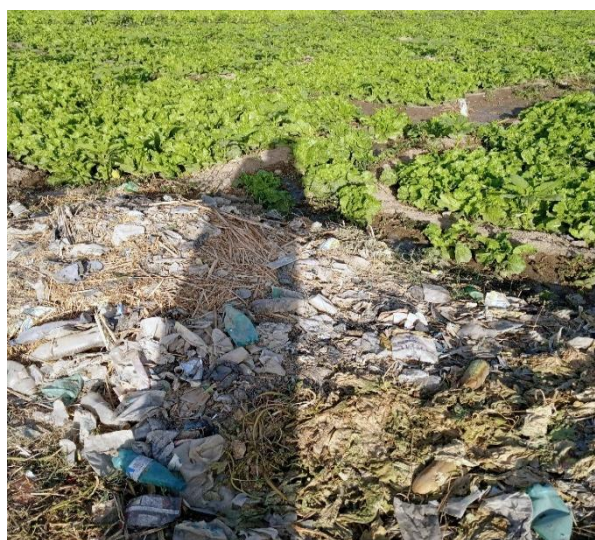


Figure 2: Dumpsite from Wuro Gude



Figure 3: Dumpsite from Wuro – Alkali



Figure 4: Dumpsite from Mayanka



Figure 5: Lettuce from Dumpsite Wuro-Alkal



Figure 6: Lettuce from Dumpsite Wuro-Gude

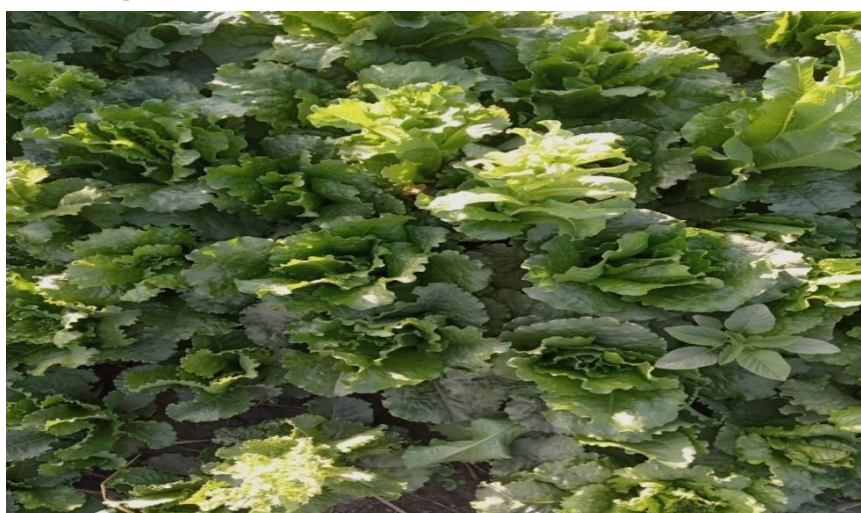


Figure 7: Lettuce from Dumpsite Mayanka

Sample Preparations

Two kilogramme of leaf samples of lettuce (*Lactuca sativa*) were collected, packed, labeled and transport to the laboratory. The samples were washed with tap water to

eliminate soil and other dirt; the edible parts were separated from the other portions, rinsed with distilled deionized water, shredded (lettuce). The samples were air-dried in paper bags and then grounded, sieved, homogenized, and heated in an

oven at 105 °C to constant weights. The contents was cooled and placed in clean paper bags and store in desiccators until digestion. (Alexander. P. 2015)

A soil sample (1 kg) was collected from 0 - 15 cm depth in triplicates from the sites where the plants originated with an auger and placed in clean polyethylene bags. The composite soil samples was air-dried in a dry and dust-free place at room temperature (25 °C) for 5 days, followed by oven drying to constant weights. The samples were then ground with a mortar and pestle to pass through a 2 mm sieve and homogenized. The dried, sieved, and homogenized soil sample was stored in clean and dry container till digestion. (Alexander. P. 2015)

Ashing of Vegetable Samples

Vegetable samples were digested using the dry ashing method (Alam *et al.*, 2013). Then 0.5 g of grounded powder samples was weighed and transfer to a clean crucible, which was label according to the sample number, and dry-ashing process was carried out in a muffle furnace by stepwise increase of the temperature up to 550 °C and was then left to ash at this temperature for 6hrs (Alam *et al.*, 2013). The samples were removed from the furnace and allowed to cool in the hood carefully. The ash was wet with 1ml distilled water and 2.5ml conc. HCl was added. It was then cool and filters using Whatman No.1 filter paper. The filtered samples were diluted up to mark of 100 ml.

Atomic Absorption Spectrophotometer (AAS) Analysis

The ash solution was aspirated into the instrument after all necessary set-up and standardization procedures. All metals were determined with an atomic absorption spectrophotometer (AAS), 210 VPG Buck Scientific Model, produced by the United States in the Department of Chemistry, Adamawa State University. For analytical quality assurance, the result of each metal was corrected by subtracting the value from the blank. After every five sample readings, standards were run to make sure that the obtained results are within range. A 10cm long slot-burner head, a lamp and a standard air acetylene flame were used. (Alexander and Ubandoma 2014)

Heavy Metals Analysis of Soil Sample

The soil sample was digested using a method adopted from Joel and Amajuoyi, (2009). A measured quantity of the samples was transferred into a Kjeldahl flask; 20 ml of concentrated nitric acid (HNO₃) was added and the sample pre-digested by heating gently for 20 minutes. More acid was added and the digestion continued for 30 – 40 minutes. Digestion was stopped when a clear digest was obtained. The flask was cooled and the content transferred into a 50 ml

volumetric flask and made to the mark with distilled water. The resulting solution was analyzed for heavy metals using the Atomic Absorption Spectrophotometer.

Environmental Pollution Studies

Transfer Factor (TF)

The concentration of metal in the extraction of soil and vegetables were calculated on the basis of dry weight. The transfer factor (TF) was calculated using equation 1 (Jolly *et al.*, 2013). TF indicates the movement of metals from soil to vegetables. This movement is dependent on the physical and chemical properties of the soil and of vegetable species. These properties could be altered by many environmental and human factors including pH, sorbent nature, root exudates and nutrients (Jolly *et al.*, 2013).

$$TF = \frac{C_{vegetable}}{C_{soil}} \quad (1)$$

Where $C_{vegetable}$ and C_{soil} represent the toxic metal concentration in extraction of vegetables and soils on dry weight respectively

Pollution Load Index

Pollution load index (PLI) provides a simple, comparative means for assessing soil quality. PLI is represented as geometric mean of Cf value of n number of metals estimated at the contaminated site by using the following equation:

$$PLI = (CF_1 \times CF_2 \times \dots \times CF_n)^{1/n} \quad (2)$$

Where n is the number of metals (n = 7 in this study) and Cf is the contamination factor (Cf) of each metal present in the soil. $PLI \leq 0$ indicates perfection or control and PLI value of $> 0 - 1$ represents the baseline level of pollutants, while $PLI > 1$ indicates progressive deterioration of site due to elevated metal content (Gupta *et al.*, 2013).

Geo-Accumulation Index

The Geo-accumulation Index (Igeo) was originally defined by Muller (Barbieri, 2016) for metal contamination in the 2-micron fraction and was developed as global standard shale values. This index is expressed as follows:

$$I_{geo} = \frac{\log_2 C_n}{1.5 \times B_n} \quad (3)$$

C_n is the measured concentration of the element in the soil, B_n is the geochemical background value and the constant 1.5 allows us to analyze natural fluctuation in the content of a given substance in the environment and to detect very small anthropogenic influence. Muller has defined seven classes of geo-accumulation index ranging from class 0 (Igeo = 0, unpolluted) to class 6 (Igeo > 5, extremely polluted). The highest class (class 6) reflects at least a 100 fold above background values as shown below:

Table 1:

Class	Value	Soil Quality
0	$I_{geo} \leq 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Contaminated to moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately to heavily contaminated
4	$3 < I_{geo} < 4$	Heavily contaminated
5	$4 < I_{geo} < 5$	Heavily to extremely contaminated
6	$I_{geo} \geq 5$	Extremely contaminated

Source: Mafuyai M.G. *et al.*, 2015

Contamination Factor and Degree of Contamination

The level of metal contamination can be expressed by the contamination factor (CF). Contamination factor is the ratio between the metal content in the soil to the background value

of the metal Sivakumar *et al.*, (2016). It is an effective tool for monitoring the pollution over a period of time and it is calculated as follows;

$$CF = \frac{C_{heavy\ metal}}{C_{background}} \quad (4)$$

According to Sivakumar *et al.*, (2016), $CF < 1$ indicates low contamination; $1 < CF < 3$ is moderate contamination; $3 < CF < 6$ is considerable contamination; and $CF > 6$ is very high contamination.

To facilitate pollution control, Sivakumar *et al.*, (2016) proposed a diagnostic tool named degree of contamination, CD and it is determined as the sum of the contamination factor (CF).

The degree of contamination is aimed at providing a measure of the degree of overall contamination in the surface layers in a particular core or sampling site. Sivakumar *et al.*, (2016) proposed the classification of the degree of contamination as:
 $CD < 6$ Low degree of contamination
 $6 < CD < 12$ Moderate degree of contamination
 $CD > 24$ High degree of contamination

Enrichment Factor (EF)

The enrichment factor (EF) was used to assess the level of contamination and the possible anthropogenic impact on the sediments of the study area. Al, Fe, or Si could be used as the geochemical normalization. However, researchers have successfully used Fe for the geochemical normalization of metal contaminants (Bhuiyan *et al.*, 2011). Therefore, Fe was used as a conservative tracer to differentiate natural from anthropogenic components in this study. The EF is defined in equation 4 (Sutherland (2000).

$$EF = \frac{(M/x)_{sample}}{(M/Fe)_{background}} \quad (5)$$

Where: $(M/x)_{sample}$ is the ratio of metal and Fe is the concentration of the sample, and $(M/Fe)_{background}$ is the ratio of metal and Fe concentration of a background. Enrichment factor categories proposed by Sutherland (2000) is then use as follows: $EF < 2$ = deficiently to minimal enrichment, $2 \leq EF < 5$ = moderate enrichment, $5 \leq EF < 20$ = significant enrichment, $20 \leq EF < 40$ = very high enrichment

and $EF \geq 40$ = extremely high enrichment. For this work, metal enrichment was considered when $EF \geq 1.5$, symbolizing minimal enrichment and above.

RESULTS AND DISCUSSION

Environmental Pollution Studies

The level of contamination of heavy metals in the three different dumpsites was assessed by using the following contamination indices: Transfer factor, degree of contamination, Geo-accumulation index, Pollution load index and Enrichment factor.

Transfer Factor from the Three Soil Dumpsites

Figure 3.1 shows the graph of transfer factor of different heavy metals from soil to vegetable. In this study, the transfer factor of different heavy metals from soil to vegetable from the three dumpsites ranges from Cd 0.78 - 0.84, Zn 0.65 - 0.79, Fe 0.64 - 0.80, Mg 0.72 - 0.79, Cr 0.68 - 0.81, Mn 0.59 - 0.79, Pb 0.63 - 0.78, and Cu 0.78 - 0.89. It can be seen from the graph that the highest TF was recorded as 0.89, 0.84 and 0.81 for Cu, Cd and Cr respectively. These may be due to high mobility of Cu, Cd and Cr with natural occurrence in soil (Alam *et al.*, 2003). However, the higher concentration level of Cu, Cd and Cr from the three different dumpsites indicates that anthropogenic activities, application of phosphate fertilizer may have introduced these heavy metals into the soil. This study recorded moderate-to-high transfer factors (TF) for Cd (0.78–0.84), Cr (0.68–0.81), and Cu (0.78–0.89) from dumpsite soils to vegetables, and Omada *et al.*, (2024) found similarly high Cd TF (0.75–1.38) at Abuja’s Gosa Dumpsite. Both studies confirm Cd high concern due to its bioavailability and easy plant uptake. Although Omada *et al.*, did not report Cr/Cu TF, elevated soil and plant levels point to anthropogenic sources (waste, fertilizers). These consistent findings highlight health risks of eating vegetables grown on dumpsite soils.

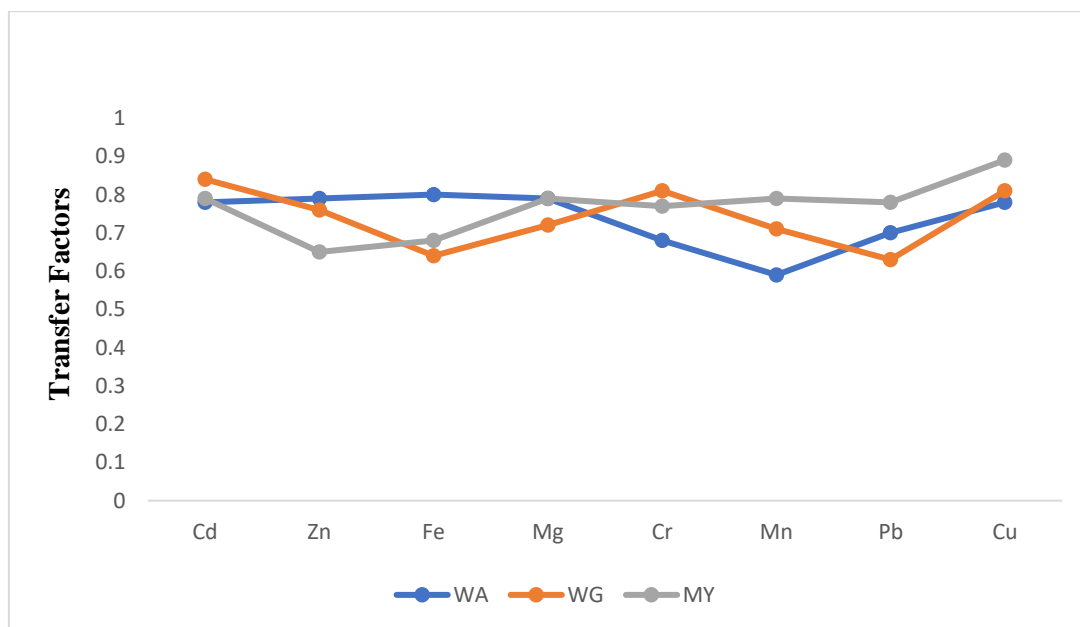


Figure 8: Transfer Factor of Heavy Metals in the Three Dumpsites

Pollution Load Index

Figure 3.2 shows the graph of pollution load index for heavy metals in the three dumpsites. It can be seen from the graph that the degree of contamination by the eight metals is in the

order of Mayanka > Wuro-Alkali > Wuro-Gude. The total pollution load index for the eight elements for each dumpsites were 4.11, 3.89 and 4.24 for Wuro-Alkali, Wuro-Gude and Mayanka respectively with manganese, cadmium and copper

being the major contributor of pollution load in each of the dumpsites respectively. All the three different dumpsites showed progressive deterioration of the sites $PLI > 1$ due to elevated metal content. The deterioration of the dumpsites suggested that the input from anthropogenic sources attributed to the increase in the metal content in the studied

sites. This study found $PLI > 1$ for all three dumpsites (Mayanka 4.24, Wuro-Alkali 4.11, Wuro-Gude 3.89), with Cd, Mn, and Cu as major contributors which differs with Hamid *et al.* (2025) found $PLI > 2$ (Cd, Cu, Pb). All confirm that anthropogenic waste disposal elevates soil metals, posing environmental and health risks.

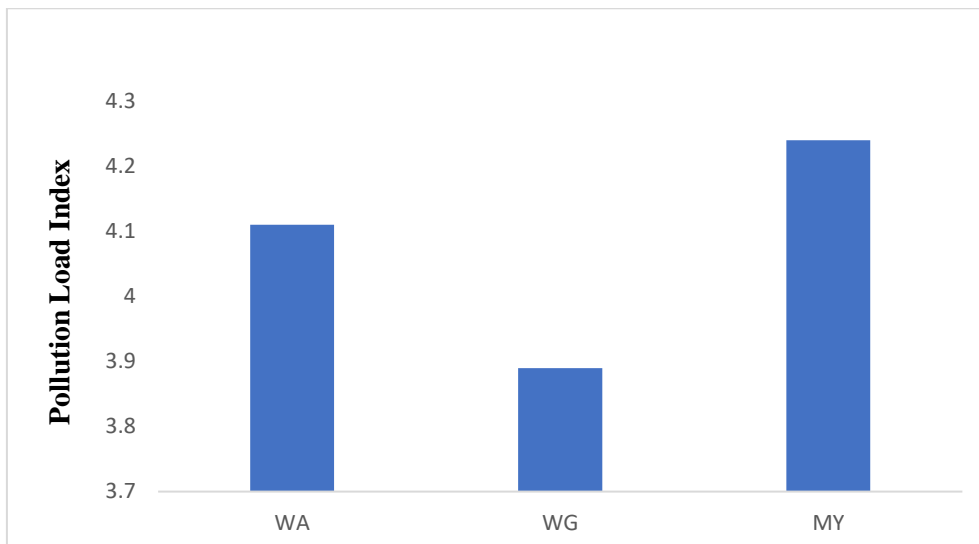


Figure 9: Pollution Load Index (PLI) for Heavy Metals in Three Dumpsites, WA Stands for Wuro-Alkali, WG:Wuro-Gude and MY;Mayanka

Geo-accumulation Index (I-geo)

Figure 3.3 shows the graph of geo-accumulation Index in the three dumpsites for heavy metals. It can be seen from the graph that the geo-accumulation values in Wuro-Alkali followed this trend ; Mn (2.47) > Zn (1.25) > Cd (1.06) > Mg (0.75) > Cr (0.74) > Cu (0.71) > Pb (0.40) > Fe (0.40) while in Wuro-Gude the geo-accumulation followed this order ; Cd(2.10) > Mn (1.91) > Zn (1.19) > Mg (0.90) > Cr (0.66) > Cu (0.46) > Fe (0.38) > Pb (0.27) and also the geo-accumulation values in Mayanka followed this sequence ; Cu (1.76) > Zn (1.63) > Mn (1.40) > Cr (1.18) > Cd (0.910) > Mg (0.75) > Fe (0.47) and Pb (0.17). Based on the I-geo index values Mn and Fe had the highest and the lowest values in Wuro-Alkali while in Wuro-Gude dumpsite Cd and Pb had the highest and the lowest I-geo index values and from Mayanka dumpsite, Cu and Pb had the highest and lowest

values respectively. Based on the seven proposed grades of the geo – accumulation index, the soil from Wuro-Alkali dumpsite was classified to be moderately polluted to highly polluted with Mn, moderately polluted with Cd and Zn and unpolluted to moderately polluted with Mg, Cr , Cu, Pb and Fe. The soil from Wuro-Gude dumpsite was moderately polluted with Zn, Cu, Mn and Cr and unpolluted to moderately pollute with Cd, Fe, Mg and Pb. The moderately polluted to highly polluted, unpolluted to moderately polluted values of geo – accumulation index is as a result of anthropogenic activities and application of fertilizers, Mafuyai M.G. *et al.*, 2015. The I-geo values show moderate to high pollution (Mn up to 2.47, Cd up to 2.10, Cu up to 1.76), which aligns with recent studies (Omada *et al.* 2024; Ayodele *et al.* 2026 that also report Cd, Cu, and Mn as priority metals from anthropogenic waste disposal.

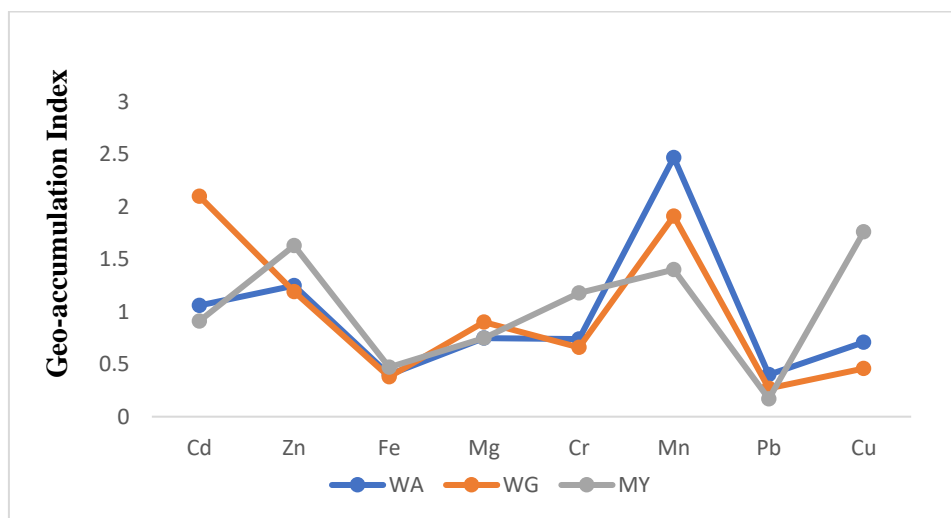


Figure 10: Geo-accumulation Index (I-GEO) of Heavy Metals in the Dumpsites. WA Stands for Wuro-Alkali; WG, Wuro-Gude and MY: Mayanka

Contamination Factors and Degree of Contamination of Heavy Metals in the Studied Dumpsites

Figure 3.4 shows the graph of degree of contamination for the Eight Metals Studied in the three dumpsites. It can be seen from the graph that the degree of contamination of Mn have the highest contamination values of 12.35 from dumpsite in Wuro-Alkali, followed by Cd (10.46) from Wuro-Gude and Cu (8.81) dumpsite in Mayanka. The contamination values ranges from Cu 2.31 - 8.81, Mn 6.98 - 12.35, Zn 5.97 - 8.14, Fe 1.92 - 2.36, Cr 3.30 - 5.91, Pb 0.87 - 1.99, Cd 4.57 - 10.46 and Mg 3.75 - 4.51. Lead had the least contamination values of 0.87 - 1.99 in the three different sites studied. Based on the rating of the contamination intensity by Sivakumar *et al.*, (2016), these three dumpsites soil are classified as being moderately contaminated with the heavy metals. From the

degree of contamination, Mayanka had a highest value of (41.39) then the Wuro-Gude Site (39.36) followed by Wuro-Alkali (38.94). Based on the classification, the values obtained for the degree of contamination in the three dumpsites were greater than 24 (> 24) and this indicates that the dumpsites are highly contaminated, Sivakumar *et al.*, (2016). This study recorded very high contamination factors for Mn (12.35), Cd (10.46), and Cu (8.81) and total C_{deg} values >24 (38.94–41.39), confirming highly contaminated dumpsites, a finding strongly supported by recent Nigerian studies (Ogungbile *et al.*, 2025; Ayodele *et al.*, 2026; Ikoto, Ugwuaji, Tudun Wada dumpsites) that consistently identify Cd, Mn, and Cu as priority anthropogenic pollutants.

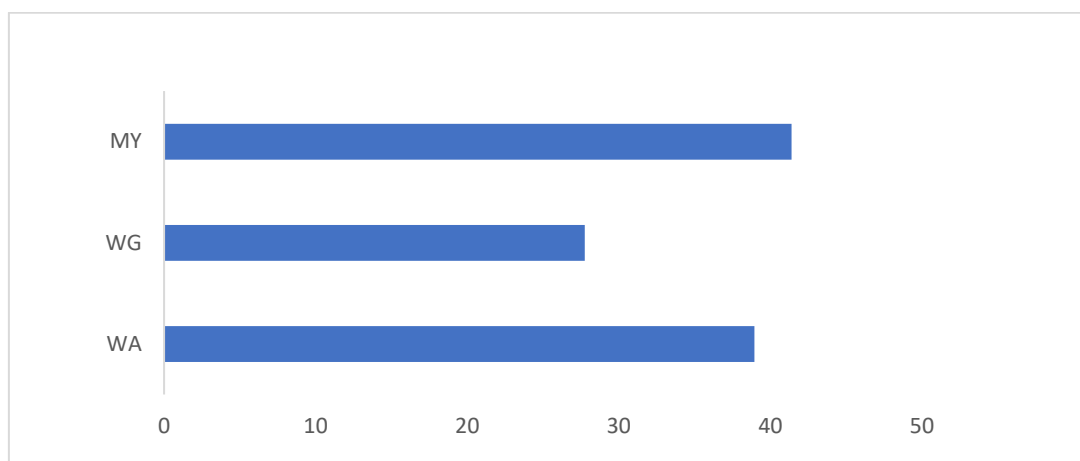


Figure 11: Degree of Contamination for the Eight Metals Studied in each Site. WA Stands for Wuro-Alkali; WG, Wuro-Gude and MY: Mayanka

Enrichment Factor

Five contamination categories are recognized on the basis of the enrichment factor (Sutherland, 2000), namely: EF (< 2 : deficiency to minimal enrichment ; 2 - 5 : moderate enrichment ; 5 - 20 : significant enrichment ; 20 – 40: very high enrichment ; 40 : extremely high enrichment).

Figure 3.5 shows the graph of enrichment factor for heavy metals in the three dumpsites. It can be seen from the graph that the enrichment factors in the Wuro-Alkali dumpsite followed this trend: Mn (0.28) > Pb (0.13) > Zn (0.06) > Cu (0.04) > Cr (0.03) > Mg (0.009) > Cd (0.003). In Wuro – Gude, the enrichment factors was in this order; Mn (0.23) > Pb (0.10) > Zn (0.06) > Cu, Cr (0.03) > Mg (0.01) > Cd

(0.007) while in Mayanka dumpsite, the enrichment factor are in this sequence; Mn (0.14) > Cu (0.09) > Zn (0.06) > Pb, Cr (0.05) > Mg (0.008) > Cd (0.003). In Wuro- Alkali, Mn and Cd had the highest and the lowest enrichment factors respectively in the three different dumpsites. Based on the five contamination categories on the basis of the enrichment factor, all the soils from the three dumpsites are classified as being deficiency to minimal enrichment with all the studied elements respectively. The low EF values (Mn 0.14–0.28, Cd ~0.003) indicate minimal enrichment, contrasting with recent Nigerian studies (Omada *et al.*, 2024; Ogungbile *et al.*, 2025) reporting moderate to extreme EF. This discrepancy likely reflects different background reference values.

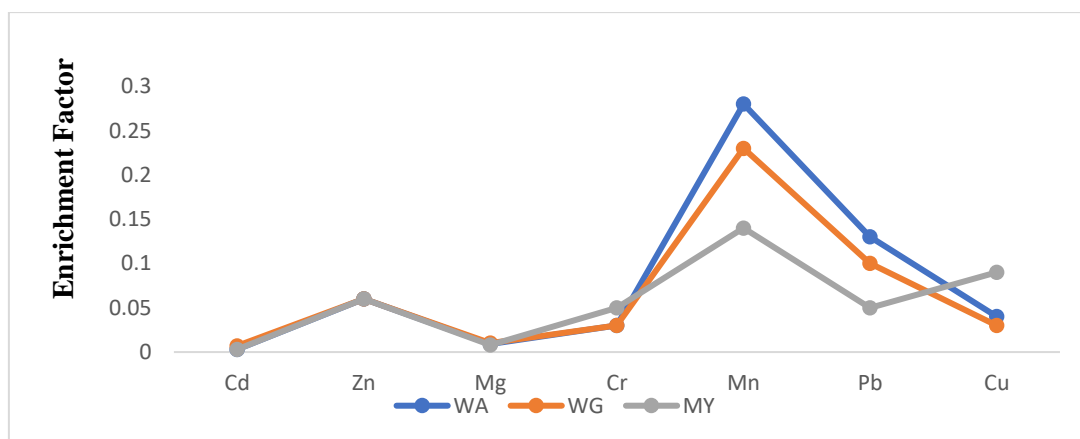


Figure 12: Enrichment Factor for Heavy Metals in three Dumpsites. WA Stands for Wuro-Alkali; WG, Wuro-Gude and MY: Mayanka

CONCLUSION

The dumpsite soils showed high transfer factors (0.59–0.89) for Cu, Cd, and Cr, indicating potential food chain contamination. All sites had pollution load index >1, with contamination order Mayanka > Wuro-Alkali > Wuro-Gude, primarily due to Mn, Cd, and Cu. Geo-accumulation indicated moderate to high pollution for some metals, attributed to anthropogenic sources like fertilizers and waste. Contamination factors ranged up to 12.35 (Mn), and degree of contamination exceeded 24, classifying sites as highly contaminated, though enrichment factors remained below 2 (minimal enrichment). Overall, the soils are highly contaminated but not enriched above background, posing risks if used as manure.

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