International Journal of Scientific Research and Engineering Development-– Volume 8 Issue 5, Sep-Oct 2025
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Assessment of Some Heavy Metal Concentrations in Soil and Plant at Former Converted Central Dump Site to Residential and Farming Area in Enugu State, Nigeria

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Abstract:
This study aims to examine the levels of heavy metal contamination in the area around the former Enugu central dumpsite at Ugwuaji, which has been transformed into a residential and agricultural area. At 15-meter intervals in each of the four cardinal directions, we gathered soil and plants from the study area, while a 100-meter distance served as a control. To measure the extent of pollution, the pollution and geoaccumulation index was employed. According to the findings, the area is dirtier in the north and east than in the west and south. Of the four directions measured for soil PI, the two most abundant elements were cadmium and lead, with average concentrations of 245.28 mg/kg, 222.15 mg/kg, 239.53 mg/kg, and 218.48 mg/kg, respectively. Soil Pb PI values as follows: 28.87 mg/kg in east direction, 26.0 mg/kg in west direction, 28.01 mg/kg in north direction, and 20.92 mg/kg in south direction. While in plants the order is Pb>Cd>Cr>As>Hg, and in soil it is Cd > Pb>Hg >As > Cr, the pollution index and geoaccumulation index measure the same thing in plants. There is a great deal of contamination, as indicated by the high geoaccumulation index and pollution levels. The investigated area poses a significant risk to the environment and human health, rendering it unfit for farming or residential use unless substantial rehabilitation is carried out.

Key words: Ugwuaji, Assessment, Heavy metals, Pollution index, Geoaccumulation index, Direction.

Introduction

The high level of infrastructure development is one factor that causes people to leave rural areas and move to urban centers. There are over half of the world's inhabitants residing in urban areas, with a large portion of that population concentrated in large cities [1]. Over the next few decades, we should see this trend of increasing urbanization over the world [2]. Without proper demographic
Planning, the population of every city in Nigeria has exploded in recent decades, making this an enormous issue for the country as a whole. Still, most Nigerians leave the countryside for the city, which means that big towns like Lagos, Ibadan, Kano, Port Harcourt, Enugu, and others have extremely worrying yearly population growth.
Accommodation issues, poverty, a high crime and insecurity rate, food shortages, environmental contamination, and climate change are some of the outcomes of this exodus, as stated in [3]. As is evident in every city in Nigeria, the constant transformation of landfills into agricultural and residential areas is one of the environmental issues caused by the rapid urbanization and population boom. Before these regions are turned into residential and agricultural land, they are rarely subjected to a thorough examination of their pollution indices.
Heavy metals are one of the most common contaminants at landfills [4], [5]. Particularly concerning are the toxicity, persistence, and bioaccumulative nature of the following elements: lead (Pb), cadmium (Cd), chromium (Cr), arsenic (As), mercury (Hg), Nikel (Ni), zinc (Zn), and copper (Cu) [6]. Household garbage, industrial effluents, electronic trash, medical waste, pharmaceutical waste, and biological waste are some of the main anthropogenic sources of these metals found in

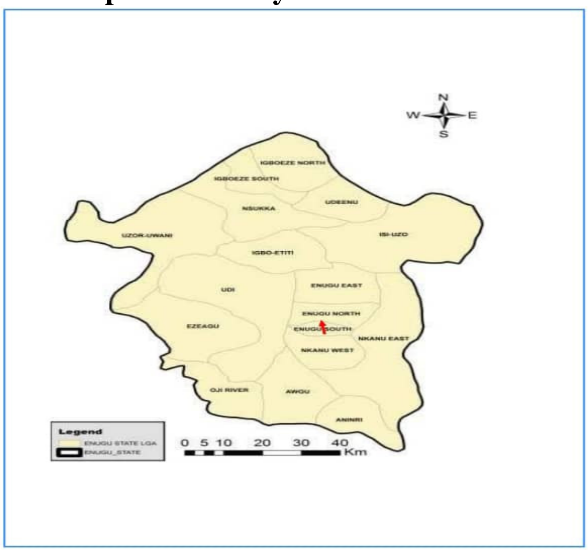
dumpsites. Metals like these can seep into groundwater and soil when trash is dumped in open dumps, endangering people and the environment [7]. Reduced soil fertility, contaminated subterranean water, changed microbial activity, and contaminated agricultural produce can all result from heavy metal deposition in soil [8].

A number of indicators, including the enrichment factor, geoaccumulation index, contamination factor, pollution index, potential contamination index, and modified pollution index, are used to assess the level of heavy metal contamination detected in the soil. In addition, to evaluate the danger linked to metals in soil, the potential ecological risk index and the modified potential ecological risk index are utilized [9].

Many scholars have identified instances of heavy metal contamination in the former Enugu central dumpsite at Ugwuaji [10], [11],[12], [13]. But as far as we are aware, after the area was turned into garbage sites and farmlands, very little research was conducted there. Thus, the study aims to: (i) assess the soil and crop quality parameters of Ugwuaji, the formal Enugu Central Dumpsite; (ii) determine the levels of heavy metals in soil and plants; (iii) assess the contamination status of heavy metals; and (iv) evaluate the hazards of heavy metal pollution to human health.

2.0 Materials and Methods

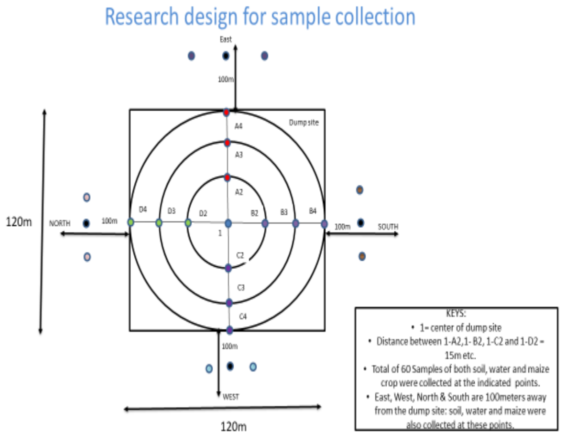
2.1 Description of study area



Enugu state is one of five states in Nigeria's southeastern area. It is located between the coordinates of 6°.00'N and 7°.00'N and 7°.00'E and 7°.45'E. The area of southeastern Nigeria where it is located has humid tropical rainforests. The weather changes every two years, with dry and wet seasons. The rainy season lasts from March to October, and the dry season follows. The temperature can be anywhere from 20.3°C to 32.16°C, and the amount of rain that falls each year can be anywhere from 937.2 mm to 2243.3 mm [14],[15]. 722,664 people lived in Enugu as of the 2006 census [14]. The Enugu State Waste Management Authority (ESWAMA) MSW dumping facility is located in the southern part of Enugu Metropolis, at an elevation of 186 meters with GPS coordinates of 6°26.27 degrees north and 7°32.831 degrees east. It covers more than 7,878 hectares of land.

Figure 1 shows that the waste location is around 1.6 kilometers from the Enugu-Port Harcourt road. From the middle of the property, there is a gentle slope that goes down in all directions. The dumpsite is where all the trash from Enugu's homes, businesses, farms, and construction and demolition sites ends up. Due to poor management, not enough staff, and a lack of the right technology, what used to be a landfill has turned into a big open waste. We didn't compress the bottom or line it to keep leachate from leaking. Without a fence around the dumpsite, scavengers and stray animals can freely travel about it. ESWAMA's job is to pick up trash from the Enugu metropolitan area and take it to the central dumpsite. However, its real job is not to manage waste but to pick up trash. The garbage is not processed in any way before it is thrown away.

2.2 Collection and preparation of the soil and plant samples



2.3 Sample collection

The region was split into four equal parts, each measuring ninety degrees, to make it easier to collect data. It started in the middle of the trash site and went on until the job was done. The process of putting concentric rings every 15 meters was done. It was chosen to get trial soil samples at nodes where the concentric loops and the radial lines, which were 90 degrees apart, crossed. There were nodes along the radial lines 1-A4, 1-B4, 1-C4, and 1-D4, and they were all 15 meters distant from the center of the dumpsite. They were also around the edge of the dumpsite. The purpose of these samples was to figure out how many loops we needed to do before we could start sampling in earnest. When there was no clear variation in the amount of pollution between two nodes on consecutive loops, there was no need to add more loops. This meant that there was no longer a need for extra loops. Because of this, concentric loops with equal spacing of 15 meters were erected starting in the middle of the dumpsite, and intense sampling began using these loops. It was chosen to collect soil samples from the nodes that were created by the central placement of the dumpsite and from the points where the loops crossed the radial lines at a right angle. Using auger bits, soil samples were taken from the nodes at depths between 0 and 0.60 meters. We gathered these samples. There are a total of thirteen sample locations for each of the three situations: soil, water, and poisoned maize plants. Also, four samples of soil, water, and plants were taken from a distance of one hundred meters from the edge of the dump site, along the radial lines 1-A4, 1-B4, 1-C4, and 1-D4 (see Figure 1 for more information). After the samples were collected, they were carefully put into clear polythene bags and taken to the lab for analysis. After drying in the oven, they were mashed with a pestle and mortar until they were very fine. Following the sifting phase, one gram of each of the finely powdered samples was used to carry out the digesting process. The digestion process took place in an open vessel and used thirty percent hydrogen peroxide and supra pure-merck nitric acid. We used a calibrated atomic absorption spectrophotometer (AA320N) to examine the materials and find out whether heavy elements were present. Using this strategy made the results more accurate representations of the actual field situation at the dump site. During the current monitoring, numerous metals are being watched, such as lead, arsenic, chromium, and cadmium. Soil type A-2-6 is often called lateritic soil when it is found. It is reddish, sandy, and silty. The American Association of State Highway and Transportation Officials (ASHTO) uses this classification system. The area that is being looked into has examples of this kind of soil. This soil might have the following properties: A percentage that can pass the No. 200 screen, a limit of 49 for liquid, a limit of 39 for plastic, a plasticity index of 11, a moisture content of 12.5%, a bulk density of 2.1 g/cm3, a dry density of 1.98 g/cm3, a specific gravity of 2.41, and a porosity of 0.36 are all characteristics that are required for the material to be considered acceptable. Based on the soil characterization report from [16], the following are the soil attributes in this area: The material is made up of 52% rocks, 14% sand, 16% silt, and 18% clay.

2.4 Risk assessment were performed using the following already established indices

2.4.1 Enrichment factor (EF).

The Enrichment Factor (EF) is a geochemical index used to evaluate the extent of anthropogenic influence on heavy metal concentrations in environmental matrices like soil or sediment. It compares the concentration of a heavy metal in a sample to a reference background value, normalized by a conservative element [17],[18].

The EF is calculated using the following formula:
EF= (Ci/Cref) background(Ci/Cref) sample). (1)

Where: Ci is the concentration of the heavy metal of interest, Cref {ref} is the concentration of the reference (or normalizing) element. The denominator represents the natural or background ratio from uncontaminated reference samples or average crustal values [19].

2.4.2 Pollution index (PI).

Pollution index is a quantitative measure used to assess the degree of heavy metal contamination in soils and defined as the ratio of average concentrations of individual metal in the dumpsite to that of baseline concentrations. Pollution index is calculated as the ratio of the mean concentration of each heavy metal to the baseline or background concentration. It is defined as follows [20].

$$PI=\frac{Ci}{Si} \quad (2)$$

Where C_i is the average concentration of individual metal in the dumpsite and S_i is the baseline concentration. PI values < 1 indicate low level of pollution, 1 ≤ PI ≤ 2 indicate moderate level of pollution, 2 ≤ PI ≤ 5 indicate high level of pollution, while PI ≥ 5 indicate extreme pollution level.

2.4.3 Geoaccumulation Index (Igeo).

The Geoaccumulation Index (Igeo) is a quantitative measure used to assess the degree of heavy metal contamination in soils, sediments by comparing current concentrations to pre-industrial levels. Introduced by Müller in the 1960s for sediments, it has since been widely adopted for evaluating pollution in soils as well as water and plant.

$$Igeo = \log_2 \frac{Ci}{1.5XSi} \quad (3)$$

- Si = geochemical background concentration of the metal (often from local or global background values)
- 1.5 = background matrix correction factor (accounts for natural lithogenic variations)
- Ci = metal concentrations at the study area

Igeo Classification indicator

The Igeo values are interpreted using a classification scale proposed by Müller: When it is less than 0 it is classified as unpolluted. If it lies between 0-2, it is moderately polluted. When it lies between 2-4 it is heavily polluted and when it is more than 5 it is extremely polluted.

3.0 Results and Discussions

3.1 Distribution of heavy metal concentrations in soil (0.60m depth) at 1-100m distance along East, West, North and South directions of the former waste dump site.

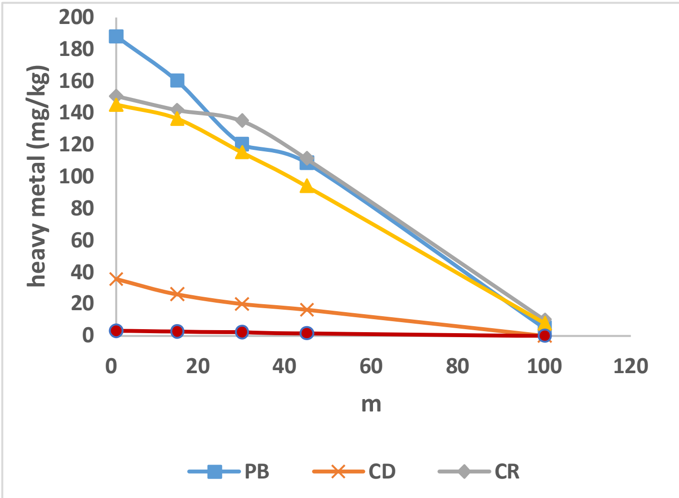


Figure i: Distribution of heavy metal concentration in the soil at the study area along the east direction (ED).

Figure i shows the distribution of heavy metal content in soil samples taken at a depth of 0.60 m in the east direction (ED) of the study region, within a range of 1-100 m. Metal concentrations peak near the dump site and fall off sharply as one moves farther away, as seen in the figure. Heavy metals deposited into the soil by percolation and leaching from precipitation and surface runoff account for this pattern [21]. Given the minimal depth of the sampling (0.60m), the results emphasizes the susceptibility of topsoil, the primary zone for crop rooted and the layer most exposed to humans through direct touch. The chemical characteristics, mobility, and affinity for soil particles of the various heavy metals shown in the figure may impact the variation seen. Iron (Fe) and manganese (Mn) may diffuse more easily depending on soil pH and texture, but lead (Pb) and cadmium (Cd) are known to firmly bond to organic materials and clay, resulting in localized buildup [22]. Bioaccumulation in crops and groundwater contamination are conceivable outcomes of the dump site's continued status as a point source of contamination, given the closeness of increased concentrations within the first 30-50 m. Even though heavy metal concentrations decrease as one moves away from the dump site, contamination can be detected up to 100 meters to the east, as shown in Figure i. This is likely caused by the terrain in the region. Brain diseases, kidney damage, and decreased agricultural yields have all been linked to prolonged exposure to high concentrations of lead, cadmium, mercury, and other harmful metals [23],[24]. Figure i's distribution profile lends credence to the idea that polluted soils necessitate phytoremediation, soil washing, or immobilization before they may be safely used for other purposes [25].

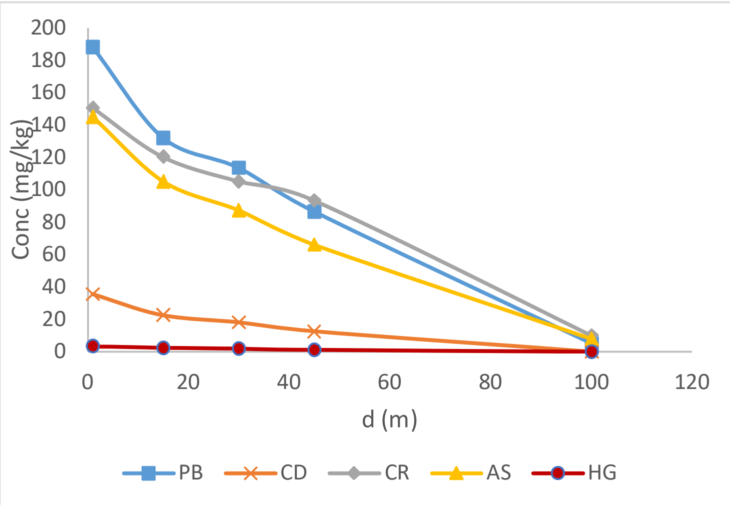


Figure ii: Distribution of heavy metal concentration in the soil at the study area along the west direction (WD).

Soil heavy metal content distribution along a westward (WD) axis, as shown in Figure ii. Figure ii shows how the amounts of heavy metals in the soil changed as one moved westward from the dumpsite. Lead (Pb) levels begin to drop off sharply after the first 30 meters, according to the results. This pattern illustrates how Pb is bound to soil organic matter and clay particles strongly despite its limited mobility [24]. As a result of the dangers of dust inhalation and hand-to-mouth play, particularly for children living in urban areas, the presence of lead in topsoil is cause for concern [23]. In comparison to Pb, cadmium (Cd) is more mobile; it can be detected at quantities as low as 80 m in soil. This poses a threat to agriculture because Cd can be readily taken up by plant roots and ends up in edible parts of the body [26]. It is probable that metallic components in municipal garbage or residues from industrial processes contribute to the localized hotspots where chromium (Cr), although less mobile, is found. The hexavalent form of Cr, known as Cr VI, is especially worrisome since it can cause cancer [27]. The moderate westward distribution of arsenic (As) is linked to its tendency to bond with iron oxides in soil and its leaching from organic-rich waste [22]. Concerningly, mercury (Hg) can persist in soils at low concentrations and can either volatilize or be transformed into methyl mercury, an extremely harmful form for ecosystems and humans [23].

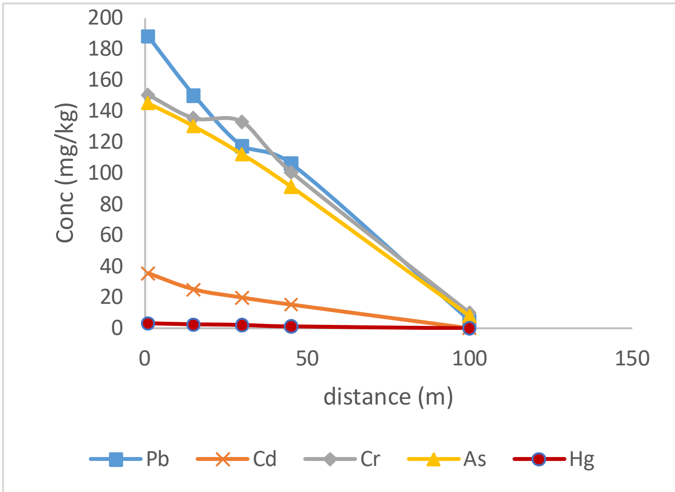


Figure iii: Distribution of heavy metal concentration in the soil at the study area along the north direction (ND).

The pattern of heavy metal concentrations as they go northward is seen in Figure iii. The contamination gradient is flatter to the east than the west, which might be because less water flows in that direction. Lead levels are still high in the immediate vicinity of the landfill, although they drop sharply after 50 meters. Nevertheless, the fact that Pb remains in close proximity to residential areas raises concerns about the potential neurological harm that children may experience from prolonged exposure [24]. Because of its solubility and poor adsorption in soils, Cd remains detectable levels even at greater distances, which is a greater cause for concern. Cd accumulation in crops due to agricultural operations in this zone might increase dietary health concerns [28]. Anthropogenic and lithogenic factors are both reflected in the unequal distribution of Cr. Cr can cause malignancies and skin problems at hazardous amounts [27]. As is present in quantifiable quantities in both directions, drawing attention to the dangers of long-term exposure. There is evidence that consuming As-contaminated food or water over an extended period of time can cause cancer and cardiovascular problems [23]. Even at low concentrations, mercury can bioaccumulate and pose a threat to future food crops grown in the same soil [29]. Taken together, the data in Figure 3 show that even seemingly unaffected regions are actually rather vulnerable to heavy metal contamination.

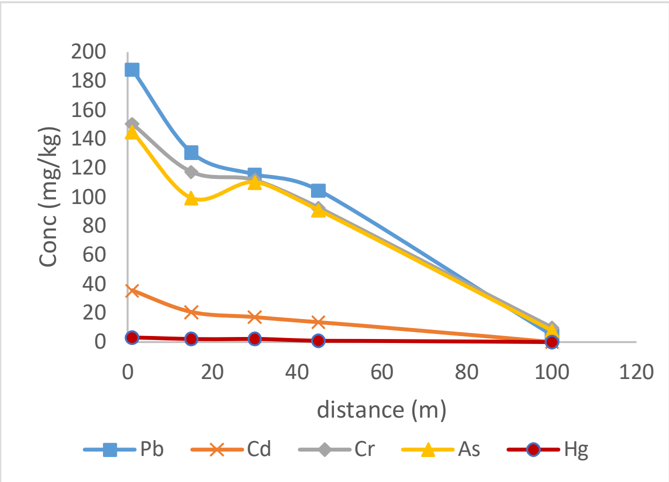


Figure iv: Distribution of heavy metal concentration in the soil at the study area along the south direction (SD).

The southward distribution, as shown in Figure iv, seems to be one of the soil orientations with the highest contamination levels. It is probable that the concentrations are higher because the slope and drainage improve the flow of leachates. Particularly hazardous for residential or agricultural use is the direction with the highest Pb concentrations, which occur within the first 50 m. Cd levels are also high and rising, which is another evidence of the element's mobility and the major problems it poses to agriculture. The substantial Cr pollution is a result of the contributions from industrial wastes. Chronic inhalation of soil contaminated with Cr increases the likelihood of developing lung diseases and malignancies [27]. It appears that there may be leaching via surface runoff, as the levels are higher than in other soil directions. Because arsenic is a strong endocrine disruptor and carcinogen, this is of the utmost importance [23]. Because of its affinity for organic stuff, mercury accumulates in the topsoil, even if its concentration is lower. There is a concern that it may volatilize and make its way into the food chain due to its persistence. This graphic highlights the southern direction as the most at-risk, calling for stringent land-use regulations.

3.2 Distribution of heavy metal concentrations in plant at 1-100m distance along East, West, North and South directions of the former waste dump site.

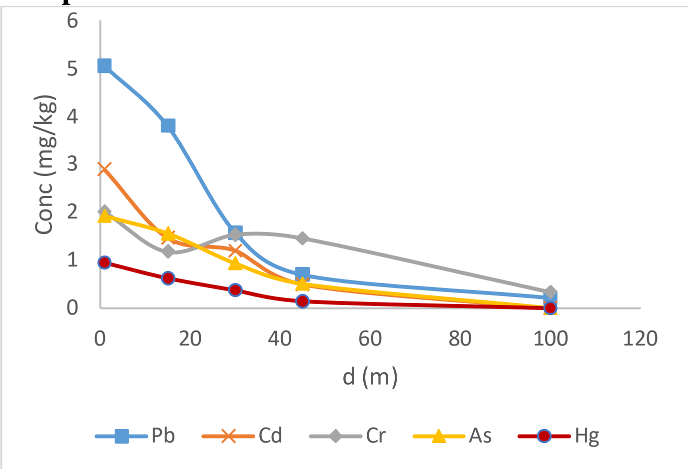


Figure v: Distribution of heavy metal concentration in the plant at the study area along the east direction (ED).

Figure v depicts the distribution of heavy metals with distance. It was noted that, for the five heavy metals studied (Pb, Cd, Cr, As, and Hg), heavy metal concentrations in the plant reduced marginally as one moved away from the dumpsite. Heavy metals are highly concentrated in plant samples collected from the eastern region. Lead builds up in the leaves, which makes veggies poisonous. Since Cd is concentrated in edible plant tissues, its great absorption is a big cause for concern [28]. While some Cr is translocated, the majority of it stays in the roots. As is found in sections that can be eaten, which increases the dangers to one's diet. Mercury bioaccumulates in plant tissues, rendering ingestion dangerous, even at minimal soil quantities [23].

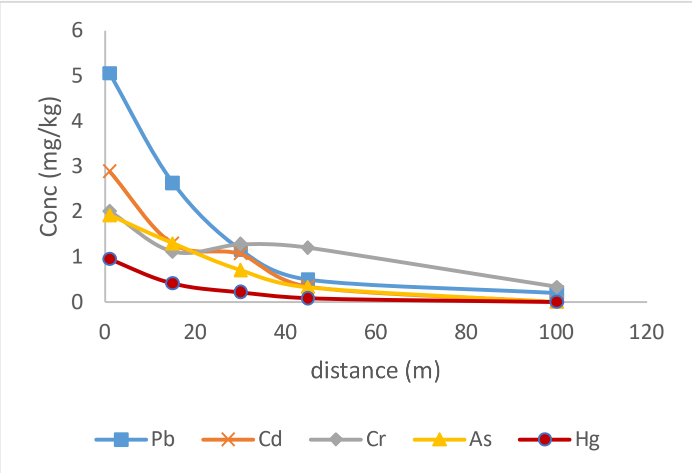


Figure vi: Distribution of heavy metal concentration in the plant at the study area along the east direction (WD).

As seen in figure vi, the amounts of heavy metals in Plants can vary. Lead, cadmium, chromium, arsenic, and mercury pollution is modest in plants found westward. Lead and cadmium remain dangerous in consumable tissues. The persistence of As and Hg in the diet highlights the dangers of long-term exposure. The majority of Cr is found in roots, therefore growing root crops is still risky. From east to west across the research region, the contaminants are ranked as follows: Pb, Cd, Cr, As, and Hg.

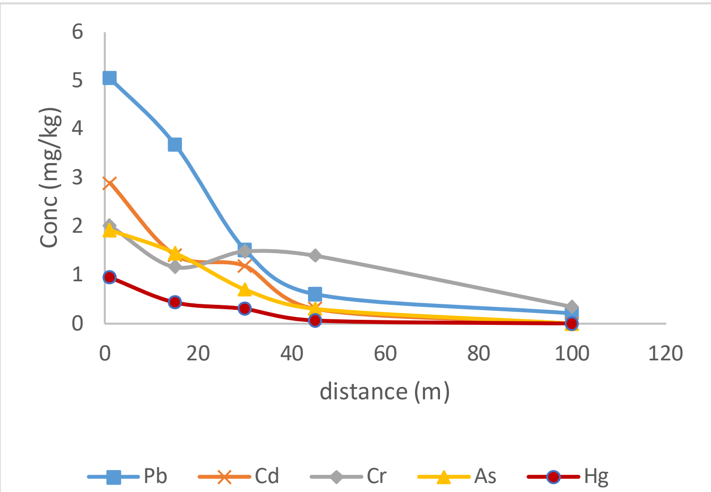


Figure vii: Distribution of heavy metal concentration in the plant at the study area along the north direction (ND).

Figure vii displays the distribution of heavy metals in plants. The image clearly shows that the concentration of heavy metals reduced as one moved northward from the dumpsite. Plants farther north show lower contamination levels, which is causing this downward trend; yet, their high bioavailability is still a matter for concern. As persists in edible tissues, while Hg stays detectable in low but worrisome concentrations. The risk from long-term usage is still there, even though levels are lower.

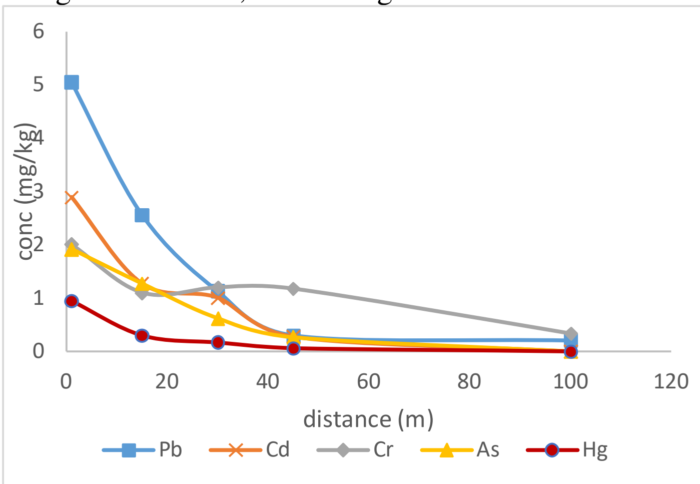


Figure viii: Distribution of heavy metal concentration in the plant at the study area along the west direction (WD).

Figure viii displays the changes in heavy metal concentrations in plants as one moves southward. According to data on soil and water, this orientation indicates the most polluted plants. Edible portions contain dangerous amounts of lead and cadmium. There is a marked increase in as well as nutritional hazards due to mercury. Cr adds to the contamination load even after it leaves roots. Avoid eating crops that grow in this direction.

3.3 Directional variation of pollution index (PI) in the soil at 1-100m distance along east, west, north and south directions of the waste dump site.

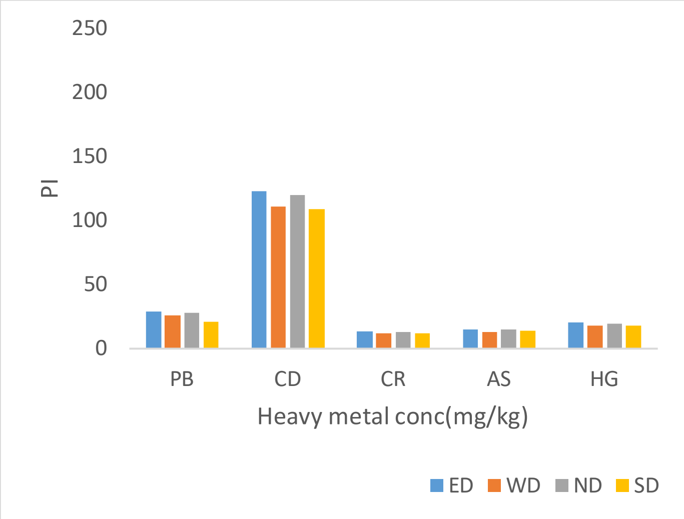


Figure ix: Directional variation of pollution index (PI) in the soil at the study area.

Soil samples were taken at different distances from the old dump site, and the Pollution Index (PI) is shown in Figure ix. Soil quality assessment tools like the PI are crucial, since PI values over 1 indicate pollution levels that are significantly higher than the natural background [30]. In particular, the chart demonstrates that the east and south directions have the highest PI values, indicating that these areas are the most affected. As for lead (Pb), the PI shows that there is a lot of enrichment close to the dump, which proves that it binds strongly to organic matter and soil colloids. Soil lead pollution is dangerous because the metal does not break down over time and does not easily drain (Alloway, 2013). Lead exposure, whether through soil contact or dust inhalation, can cause hypertension in adults and neurological impairment in children [24]. Because of its mobility and solubility in soils, cadmium (Cd) exhibits consistently high PI values across all directions. Because it is so easy for Cd to move to crops cultivated in polluted soil, Cd contamination is a major reason for concern. Chronic consumption of Cd through food has been associated with renal disease and bone deterioration [26]. Despite having moderate PI values, chromium (Cr) is nonetheless a cause for concern. Cr in its hexavalent form (Cr VI) is extremely harmful and carcinogenic [27]. Its presence could be explained by industrial waste inputs, although it is less mobile than Cd. Arsenic (As) is associated with the breakdown of organic waste, and its elevated PI levels in the south and east reflect this. Skin blemishes, cardiovascular problems, and malignancies can result from long-term exposure to As in soil transfer [23]. Although its PI values are lower than those of Pb and Cd, the toxicity of mercury (Hg) makes it a very important element. Mercury, even at low amounts, can permeate crops and cause developmental delays and neurological harm in the long run [29]. According to Figure 4.13, the soil surrounding the Ugwuaji dump site is mildly to severely polluted in all directions. The most common contaminants are Cd, Pb, As, and Cr, in that order. This poses a substantial risk to future residential and agricultural uses of the land.

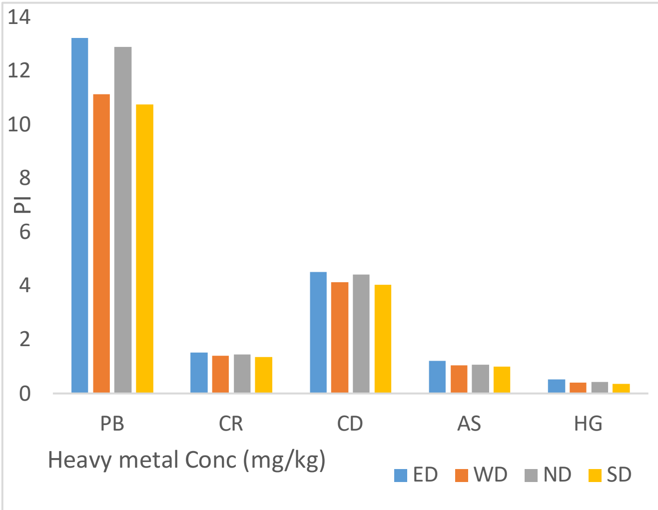


Figure x: Directional variation of pollution index (PI) in the plant at the study area.

In Figure x, we can see how different directions of plant sampling affected the PI. Heavy metal accumulation by plants is indicated by elevated PI values, particularly in the south and east directions, where contamination is most prevalent. Plants exhibit the greatest PI values for Pb, indicating that edible portions of plants, such as leaves, undergo substantial bioaccumulation. Because they can hold Pb in their tissues and on their surfaces, leafy greens pose a special threat because of the large levels of food exposure they cause [24]. Because of its mobility and solubility, Cd is able to be easily absorbed by roots and translocated to edible plant tissues; it also has one of the highest PI values of the metals that were studied. Ingesting Cd-contaminated crops on a regular basis causes kidney problems and skeletal issues like Itai-Itai disease [26]. Although Cr is mainly found in plant roots, some worry about consuming root crops because of its presence. Food insecurity may result from stunted plant development and decreased harvest yields caused by Cr toxicity [29]. The east and south have notably high PI values, indicating a substantial transport of soil and water to plant tissues. Multiple cancers and developmental abnormalities have been related to dietary as exposure [23]. Although mercury is present at lower PI values, it can accumulate in edible plant tissues and cause major problems. Neurological function and prenatal development can be negatively affected by the chronic eating of crops polluted with Hg [27]. There have to be stringent agricultural controls in place, and this figure shows that crops grown near the dump site are not safe to eat. Pb > Cd > Cr > As > Hg is the PI order, therefore.

3.4 Directional variation of Geoaccumulation index (Igeo) in the soil (0.60m depth) at 1-100m distance along east, west, north and south directions of the waste dump site.

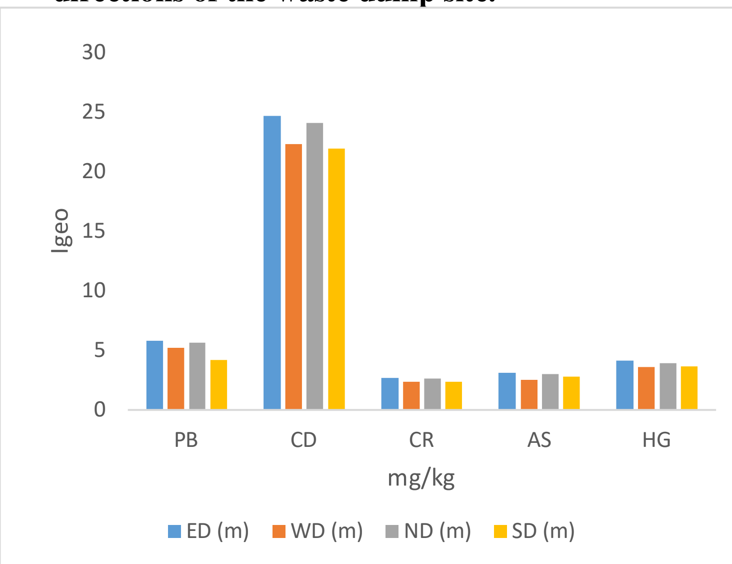


Figure xi: Directional variation of geoaccumulation index (Igeo) in the soil.

Soil Geoaccumulation Index (Igeo) is shown in Figure xi. When it comes to heavy metals, Igeo can assist you tell the difference between their natural and man-made sources [31]. According to the findings, the soils facing south and east are moderately to severely contaminated. The results show that there is considerable anthropogenic enrichment from the dump site, since Pb and Cd dominate the Igeo values. Since Pb is immobile and cannot be remedied, it will remain in the environment for decades, while Cd poses a constant threat of plant absorption due to its high solubility [24]. The moderate contribution of Cr indicates that metallic and industrial wastes from waste streams are likely sources. The southern region has higher Igeo values, which are in line with the paths taken by surface runoff and leachate. Although Hg is not as noticeable, its persistence and possible methylation make it a long-term concern. The soils are not suitable for agricultural usage, according to the Igeo data, thus remediation is necessary before they can be turned into residential.

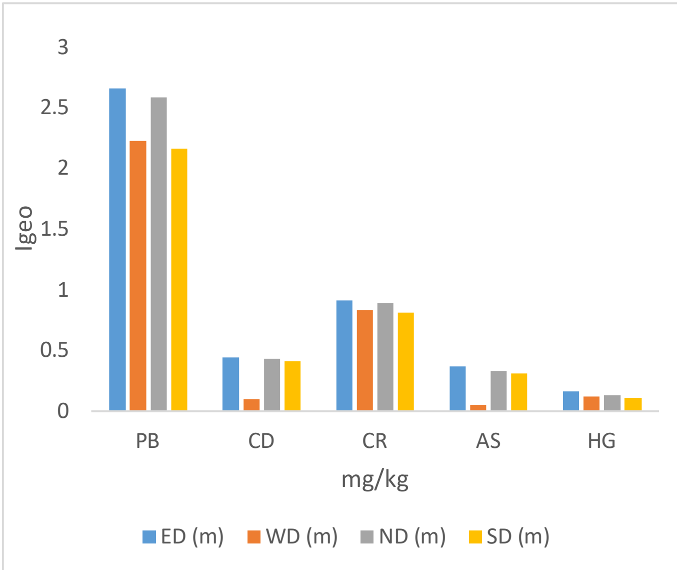


Figure xii: Directional variation of geoaccumulation index (Igeo) in the plant.

The plant Igeo values are shown in Figure xii. Plant tissues, especially those facing east or south, exhibit a considerable enrichment of Pb, Cd, and As, according to the results. Pb enrichment proves that eating crops cultivated close to the landfill is extremely dangerous for your health. As a result of its efficient bioaccumulation and translocation within plants, Cd displays the highest Igeo values among the metals. The findings of Singh et al. (2010) are likewise consistent with this. The danger of food exposure causing chronic diseases is highlighted by enrichment. Even in tiny concentrations, mercury poses long-term health hazards owing to bioaccumulation, and cadmium, which mostly stays in roots, reduces plant productivity. According to Igeo, the following is the sequence of heavy metal pollution in the area's plants: Pb > Cr > Cd > As > Hg. The findings are consistent with those of [32]. With this number, it's clear that the plants around the Ugwuaji dump site aren't fit for human consumption, and that unchecked cultivation in the area would be bad for everyone's health.

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4.0 Conclusion

Common practice in Nigeria involves converting dumpsites into residential and agricultural areas without doing adequate rehabilitation assessments. Due to their high toxicity, persistence, and bioaccumulation, Pb and Cd stand out as the most concerning contaminants from the analysis of the Ugwuaji converted dumpsite. Soil and plants are major reservoirs for Cr, whereas even at low concentrations, As and Hg are known to cause cancer and neurological damage, respectively, and offer serious long-term health hazards. Heavy metal pollution (Pb, Cd, Cr, As, and Hg) was determined by evaluating the area's pollution level using the pollution and geoaccumulation index. Cd > Pb > Hg > As > Cr in soil and Pb > Cr > Cd > As > Hg in plants, correspondingly, according to the geoaccumulation index. Due to leachate flow, the land is unfit for agricultural or residential use in the north and east directions of the research area, necessitating substantial rehabilitation.

This work was funded by Tetfund via SUMAS IBR 2023/ 2024.

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