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Heavy Metal Contamination in Soils from Urban and Rural Dumpsites of Ebonyi State, Southeastern Nigeria

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Abstract

Use of soils around dumpsites in rural and urban areas is common for food production especially vegetables. However, most people use such soils without knowledge of the risk of heavy metal uptake by plants. Therefore, the assessment of heavy metal contamination is an important component of risk assessment at waste dumpsites. This study was conducted at Ahiaofu Market dumpsite Abakaliki and Emezaka Ngbo market in Ohaukwu LGA of Ebonyi State, to determine the risk of heavy metal pollution of soils at a waste dumpsite. Soil samples were collected from a depth of 0–20 cm depth. Heavy metals such as lead, zinc, cadmium, chromium and copper were analysed using atomic absorption Spectrophotometer (AAS). Their concentrations at the two (2) dumpsites generally followed the trend: Concentration of metals in sample A (Ahiaofu Market dumpsite Abakaliki): Zn > Cu > Pb > Cd > Cr, while the concentration of metals in sample B (Emezaka Ngbo market in Ohaukwu LGA) Zn > Cr > Pb > Cu > Cd. The results revealed that the soil samplesfrom the dumpsiteswere slightly contaminated with Zn, as opposed to the remaining heavy metals (Cr, Cd, Pb and Cu). However, heavy metals contamination at the two dumpsites were within the permissible limits recommended by FAO/WHO. There is the need for regular monitoring and decontamination of the dumpsite before use for agricultural activities. At 100 and 150 mg/kg body weight, histopathological plates show that rats in groups II and III were tolerant to E. senegalensis leaf extract.

Keywords: Heavy metals, dumpsite; pollution; risk-assessment; monitoring

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Introduction

Increase in world population with its associated high industrial activities has led to the production of large volumes of domestic, municipal and industrial wastes (Otomewo et al., 2020). The increased waste generation is, however, not commensurate with capacity in waste management, especially in developing countries. The result of this is wide instances of improper waste disposal and management which have posed serious threats to the environment and development of major cities around the world especially Africa (Agbeshie et al., 2020). Contamination of soils because of uncontrolled dumping of industrial, municipal and agricultural solid waste, as well as hazardous waste such as e-waste, has become a matter of public health concern in Nigeria (Kolawole et al., 2023). Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leading gasoline and paint, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition. Heavy metals can migrate from surface soil to subsoil and contaminate ground water (Zhang & Far, 2014; Twumasi *et al.*, 2016). They can also bio-accumulate in the food chain, posing health risks at high concentrations. In addition to precious metals such as gold, silver, and platinum, waste contains toxic metals such as lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg) (Gupta *et al.*, 2017). Informal contact can result in acute and chronic toxicity. These metals can damage the central and peripheral nervous systems, result in blood abnormalities, impair the lungs, kidneys, and liver, and even lead to death (Jaishankar et al., 2014).

Humans can be exposed to soil contaminants from waste dumpsites through accidental soil ingestion or direct dermal exposure.One problem of improper waste disposal practice that has been widely observed is the issue of leachates (water which passes through a solid and leached some of its constituents) from improperly cited or managed waste dumping sites. These sites which are known to be responsible for toxic leachates from waste have been found to significantly impact on all forms of life. Inhabitants around sites which are somehow rich in nutrients usually grow some vegetables and other arable crops (e.g. maize) for sustenance. These heavy metal leachates from dumpsites could end up in the food chain by plant uptake, surface water bodies, underground water, soils and other biophysical components of the environment resulting in adverse effects on humans, aquatic organisms, plants and animals. People around such dumpsites may not be aware of the extent and dangers such heavy metals pose.A heavy metal is a metallic element which is toxic and has a high density, specific gravity more than 5 gcm $^{-1}$or atomic weight(El-Kady & Abdel, 2018). However, the term means something slightly different in common usage, referring to any metal capable of causing health problems or environmental damage.Such metals include lead (Pb), mercury (Hg), arsenic (As), cadmium (Cd), chromium (Cr), and higher levels of micronutrient (e.g. iron (Fe), copper (Cu), nickel (Ni) and zinc (Zn)). In metallurgy, for example, a heavy metal may be defined on the basis of density, whereas in physics the distinguishing criterion might be atomic number, while a chemist would likely be more concerned with chemical behavior. Some heavy metals are either essential nutrients (typically iron, cobalt, and zinc), or relatively harmless (such as ruthenium, silver, and indium), but can be toxic in larger amounts or certain forms. Heavy metals tend to be less reactive than lighter metals and havefar
fewer soluble sulfides and hydroxides.

While it is relatively easy to distinguish a heavy metal such as tungsten from a lighter metal such as sodium, a few heavy metals, such as zinc, mercury, and lead, have some of the characteristics of lighter metals; and lighter metals such as beryllium, scandium, and titanium, have some of the characteristics of heavier metals. Heavy metals are relatively scarce in the Earth's crust but are present in many aspects of modern life. They are used ingolf clubs, cars, antiseptics, self-cleaning ovens, plastics, solar panels, mobile phones, and particle accelerators.

Since these metals affect environmental quality, regular monitoring has become imperative to recommend appropriate remediation strategies. Remediationusing chemical, physical, and biological methods has been adopted to solve the problem of recovering soils contaminated by heavy metals. Phytoremediation has proven to be a promising alternative to conventional approaches as it is cost effective and environmentally friendly. Evaluation of dumpsite soils to determine the levels of heavy metals is of critical importance in risk assessment, as such metals could be harmful and persistent in the soils for several years

Therefore, this study was undertaken to specifically determine the extent of heavy metals contamination of soils at the waste dumpsite and their influence on soil physicochemical properties. It is anticipated that data obtained from the study will be used by environmental regulators, residents and farmers to broaden their knowledge on the risk accompanying waste dumpsites.

Sampling was carried out at Ahia Ofu Market dumpsite Abakaliki and Emezaka Ngbo market dumpsite in Ohaukwu LGA Ebonyi State. Ebonyi state is in the South-eastern geopolitical zone of Nigeria, bordered to the north and northeast by Benue State, Enugu State to the west, Cross river state to the east and southeast, and Abia State to the southwest. Ebonyi State covers an area of 5,532 square kilometers. It lies at latitude 6°15′ North and longitude 8°05′ East and has a humid tropical climate with one rainy season and one dry season lasting for 8 and 4 months, respectively. The temperature typically ranges from 20 to 38 degrees Celsius during the dry season and from 16 to 28 degrees Celsius during the rainy season. Harmattan winds are common between December and January. These dumpsites are the largest of all the dumpsites in Ebonyi state and it is about 20 hectares each. The quantity of waste disposed of into these areas is estimated at 92, 345 t per annum. Waste generated from residential, industrial and commercial areas are dumped into the facilities with trucks by commercial operators from different parts of the city, and is covered with big mounds of municipal waste, garbage, industrial waste, plastic, and other materials. Approximately 80% of the total waste generated in the city is dumped in the facility, which includes waste from educational, residential, hospital, minor industrial, and commercial regions.

Movement of garbage to and from the facility, off-loading and compaction of waste, open burning of waste, and wind scouring of waste surfaces are some of the processes that generate particulate matter which circulates in the air

Fig.1. Activities in the study area (a) Scavengers picking different materials from the waste at dumpsites (b) machines used for concentration of wastes and people ingesting food in the dirty environment (c) open burning of dumps in the environment.

2. Materials & Methods

I. Collectionandpreparation of Soil Samples

Ten (10) samples were taken from the dumpsites of urban part of Ebonyi state in AbakalikiAhiaofu market (sample A) and rural part of Ebonyi state Emezakamgbo of OhaukwuLGA (sample B) at a depth of 0–20cmusing a stainless-steel scoop, which is corrosion resistant and could not interact with the metals in the soil. The samples were combined with a composite sample and air-dried, crushed into fine dust, and sieved using a 2 mm sieve. It waskept in a polyethylene bag and labelled accordingly. Thereafter,stored in a refrigerator at 4°C prior to analysis to inactivate bacteria and prevent any change in volume that may be caused due to evaporation.

II.Digestion

Sample A: 2g Soil from urban area
Sample B: 2g Soil from rural area

III. Reagents: 20ml of concentrated Nitric acid {HNO3}, 10ml of concentrated perchloric acid, 100ml of distilled water, acetone.
2g of sample A was measured into the conical flask followed by the addition of 20ml of concentrated HNO_3 and10ml of concentrated perchloric acid. The mixture was shaken and heated on an electric heater at temperature of 60^{O}C for three hours until the sample became clear. This was repeated for sample B. Then both samples were diluted with 100ml of distilled water and shaken, after which they were subjected to flame atomic absorption spectroscopy (AAS).

3. Results and Discussion

The recorded values of heavy metals concentrations at sample A (Ahia Ofu market dumpsite) and B (Emezaka Ngbo market dumpsite) are presented in table 1. According to Twumasi *et al.* 2016, the composition of the disposed waste materials and the rate of microbial decomposition significantly impacts on the heavy metals concentration in the soil. The concentration of heavy metals at the 2 dumpsites generally follows the trend: Concentration of metals in sample A: Zn >Cu >Pb> Cd>Cr, while that of metals in sample B: Zn>Cr>Pb>Cu>Cd.

Table 1: Result ofMean Concentration of heavy metals in Sample A and Sample B (in mg/l)

Sample	Cu	Zn	Pb	Cr	Cd
A (Ahia Ofu Market dumpsite)	0.19	3.87	0.06	0.05	0.06
B (Emezaka Ngbo market dumpsite)	0.03	3.91	0.08	0.19	0.02
WHO (2006) values for sediments	0.05-0.15	≤ 1	5.00	0.03-0.3	0.1

Zinc concentration of sample A was 3.87 mg kg $-^{1}$, while sample B was 3.91 mg kg $-^{1}$. The relatively high concentration of Zn within the dumpsites may be linked to disposal of heavy metal substances which includes presence of dry cells and the burning of electronic waste (Twumasi *et al.* 2016). Zn is a micronutrient which plays an important role in enzymatic reactions and its presence in the soil may lead to less uptake of Cd by plants (Chahab*et al.*,2010). The concentration of Zn was higher than WHO permissible concentration limit for soil which is ≤ 1, which may pose severe threat to human health if ingested in large quantities.

Cadmium is an uncommon heavy metal but perceived as one of the most injurious heavy metals on the health of mankind(Kumar*et al.*, 2015). Results from this study revealed that cadmium concentrations in samples A and B were 0.06 mg kg $-^{1}$ and 0.02 mg kg $-^{1}$, respectively, which were found to be higher than the WHO permissible limits (0.1 mg kg $-^{1}$). The slightly high concentration of Cd at the study site may be associated with high inputs of cadmium materials from sludge, batteries, PVC materials, coatings and motor oils, and if not properly checked may be hazardous to the ecosystem.

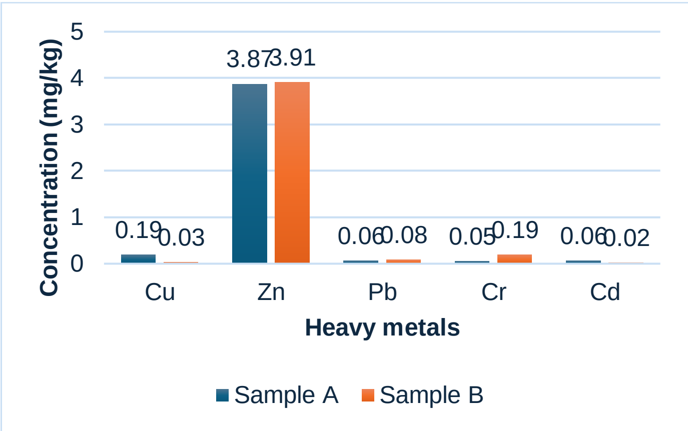

Figure 2 Pictorial representation of the concentrations of heavy metals in samples A and B.

Lead (Pb) is considered a toxic heavy metal and affects humans if ingested into the body (Olayiwola*et al.*, 2017). At higher concentrations, Pb significantly interrupts water balances, enzyme activities and mineral nutrition. Pb at sample A was 0.06 mg kg $-^{1}$, while sample B was 0.08 mg kg $-^{1}$ comparatively lower than WHO permissible limit. The presence of Pb may be linked with the disposal of waste materials containing batteries, food packaging material, PVC materials and insecticides (Twumasi *et a*l. 2016). In a study on leaching of heavy metal at some selected dumpsites in Nigeria, Awokunmi *et a*l, (2010). reported similar movement of Pb away from the center of the dumpsite down the slope. However, the Pb concentration at the two sampling locations was far less than the permissible limits WHO.

Copper (Cu) is one of the eight essential plant nutrients and is required for many enzymatic activities in plants and for chlorophyll and seed production. Increase soil Cu concentrations causes toxic effects in plants and microorganisms (Koen *et a*l., 2012), and its deficiency can lead to increased exposure to diseases like ergot, which can cause significant yield loss in grains. Results from this study revealed that Cu concentrations in samples A and B were 0.19 mgkg $-^{1}$ and 0.03 mgkg $-^{1}$, respectively.

Table 2: Classes of I_{geo}

Class	Value	Sediment & water quality
0	$I_{geo} \leq 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated 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

This implied that sample A had a higher concentration than WHO permissible limit, while the concentration of sample B was less than the WHO permissible limit (0.5-0.15 mg kg $-^{1}$). The high concentration of Cu at sample A may be associated with influx of copper materials from fertilizers, animal manures, biosolids, and pesticides.

The presence of chromium (Cr) in the soil can be linked to various sources which include contamination from human activities like the application of pesticides and fertilizers that contain chromium, improper disposal of industrial waste, and the disposal of fossil fuels. Its negative effects include reduced growth and development of plant tissues (Xu *et al.*, 2023). Cr concentration in sample A was 0.05 mgkg $-^{1}$, while that of sample B was 0.19 mgkg $-^{1}$,which was higher than the WHO permissible limits (0.03-0.3 mg kg $-^{1}$).

Table 3: Result of geo-accumulation (I_{geo}) index

Sample	metals	I_{geo}values	interpretation
Sample A	Cd	-1.32	uncontaminate
	Cr	0.15	uncontaminate
	Pb	-6.96	uncontaminate
	Cu	1.34	Moderately contaminated
	Zn	1.37	Moderately contaminated
Sample B	Cd	-2.91	uncontaminate
	Cr	-0.58	uncontaminate
	Pb	-6.55	uncontaminate
	Cu	-1.32	uncontaminate
	Zn	1.38	Moderately contaminated

Result of the geo-accumulation index (I_{geo}) for sample A and B are as shown in table 3 above. The result indicated that sample A was uncontaminated by Cd, Cr and Pb but moderately contaminated by Cu and Zn. Sample B was uncontaminated by all the heavy metals except Zn which was moderately contaminated.

Analyzed soils at the two dumpsites exhibited the presence of heavy metals including zinc (Zn), cadmium (Cd), lead (Pb), chromium (Cr) and copper (Cu), and their concentrations ranked as: sample A: Zn > Cu > Pb > Cd > Cr, while sample B follows the trend: Zn > Cr > Pb > Cu

>Cd. Zinc has the highest concentration in both soils at the dumpsites as opposed to the remaining heavy metals (Cu, Cd, Pb and Cr). It was observed that concentrations of Cd, Cr, Zn and Cu in sample A were all higher than WHO (2006) permissible limits for sediments, while for sample B, Cd, Cr and Zn only had concentrations above the permissible limits, Pb and Cu were found to be below the recommended limits. The presence of Pb and Cd could be linked to the high quantity of used batteries, paint materials, pipes, etc. deposited in the dumpsite. Main sources of Cu and Zn could be from burning of tyres, disposal of metal scraps, lubricating oils and various environmental and industrial wastes. This can cause severe side effects such as allergies, cardiovascular and kidney diseases, lung and nasal cancer, lung fibrosis and so on. High concentrations of zinc may also rise from the disposal of smelter slag wastes and commercial products such as fertilizers and wood preservatives containing zinc.

Conclusion

Result of the geo-accumulation factor for sample A indicated that soil from the urban dumpsite was uncontaminated by Cd, Cr and Pb but moderately contaminated by Cu and Zn. While the soil from the rural dumpsite (sample B) was uncontaminated by Cd, Cr, Pb and Cu, but moderately contaminated by Zn. The findings from this research suggest that the soil around the dumpsitesis suitable for agricultural activities but activities such as burning of tyres, disposal of metal scraps and lubricating oils which may lead to an influx in the concentration of Zn must be put in check. There is the need for regular monitoring and awareness creation by the Environmental Protection Agency to ensure segregation of waste before dumping to reduce increased levels of the contaminants (heavy metals) at the dumpsite, which may pose serious health risks. Alternatively, remediation technologies (e.g. phytoremediation) could be introduced at the site to help decontaminate the dumpsites, especially of Zn.

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Conflict of interest

The authors declared that there is no conflict of interest. All the co-authors approved their participation.