



## ECOLOGICAL AND HEALTH RISK ASSESSMENT OF HEAVY METALS IN SOLID WASTE DUMPSITE SOIL IN OWODE, OGUN STATE

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### Abstract

The disposals of wastes into open dumpsites/soil tend to be the most common method of discarding wastes in Nigeria. There are presence of toxic metals which are of great concern, posing serious health threat. This study aimed at determining the ecological and health risk assessment of some heavy metals (As, Cd, Cr, Cu, Pb, Zn, Ag and V) in solid waste dumpsite in Owode Town. Five soil samples were collected from different points of the study site which are north, south, east, west and center, while the control sample was collected 500 m away from the study site from a depth of 0-15 cm. The samples were analyzed using inductively coupled plasma - optical emission spectrophotometer. The mean concentration of the heavy metals in the soil samples were  $1.60 \pm 0.87$  mg/kg,  $3.79 \pm 2.54$  mg/kg,  $9.33 \pm 4.28$  mg/kg,  $11.47 \pm 1.81$  mg/kg,  $11.54 \pm 22.92$  mg/kg,  $22.22 \pm 4.68$  mg/kg,  $40.73 \pm 31.62$  mg/kg and  $139.63 \pm 31.62$  mg/kg for Ag, Cd, As, V, Cu, Cr, Pb and Zn, respectively. All the concentrations were within the permissible limits reported by the WHO. The contamination factor, degree of contamination, geo-accumulation index (Igeo), pollution load index, and the ecological risk index were calculated and the results indicated that the soil were slightly contaminated. The health risk assessment which includes average daily dose through ingestion, inhalation and dermal; hazard quotient, hazard index and cancer risk were calculated to be less than 1, which indicated slightly low soil contamination. The results revealed that the control site was not contaminated. Hence, there is need for regular monitoring and decontamination of the dumpsite before using it for agricultural and water activities.

**Keywords:** Ecological, Health risk, Heavy metals, Owode, Solid waste dumpsite

### 1.0 Introduction

Heavy metals are defined as metallic elements that have a relatively high density compared to water. With the assumption that heaviness and toxicity are inter-related, heavy metals also include metalloids, such as arsenic, cadmium, chromium, copper, lead, vanadium, silver and zinc that are able to induce toxicity at low level of exposure (Paul, Clement, Anita & Dwayne, 2022). In Nigeria, leachates from refuse dumpsites constitute a source of heavy metal pollution to both soil and aquatic environment. In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by these metals. Also, human exposure has risen dramatically as a result of an exponential increase of their use in several industrial, agricultural, domestic and technological applications (Bradl, 2022).

There are several anthropogenic sources of heavy metals, such as; emissions from vehicle exhaust pipe, tyre wear particles, weathered street surfaces, brake lining wear particles, power plant combustion, metallurgical industry, auto repair shops, chemical plants, weathering of buildings and pavement

surfaces, atmospheric deposits, mining, smelting, waste disposal, urban effluents, pesticides, fertilizers, sawdust disposal, herbicides, pharmaceuticals, batteries, fungicides, paints, pigments and dyes, leather tanning, photographic films, fireworks, printer and photocopier toners, cement, candles, rubber, etc. (Kanayochukwu, Joel & Chidozie, 2015).

Long term exposure to heavy metals may result in slowly progressing physical muscular and neurological degenerative processes that cause muscular dystrophy, and multiple sclerosis. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. Chronic level ingestion of toxic metals have undesirable effects on humans and the associated harmful impacts become perceptible only after several years of exposure (Khan, Cao, Zheng-huang & Zhu, 2008).

Heavy metals have the tendency to persist in the environment for long. Ecological risk assessment and pollution indices are some tools used in assessing the fate of these metals in the environment



(Uzoekwe & Richard, 2020). Hence, this study is aimed at evaluating the levels or concentrations of some selected heavy metals such as arsenic, chromium, cadmium, copper, vanadium, silver and zinc around solid waste dumpsite in Owode Town, using Inductively Coupled Plasma - Optical Emission Spectrophotometer (ICP-OES) and assessing the ecological and health risk of these metals in human.

## 2.0. Materials and Methods

### 2.1 Area of Study

Owode is situated in Yewa South, (formerly Egbado South), is a local Government Area in the west of Ogun State, Nigeria bordering the Republic of Benin. Its headquarters are in town of Ilaro at 6°53'00"N 3°01'00"E in the north of the area. It has an area of 629 km<sup>2</sup> and a population of 168,850 at the 2006 census. The postal code of the area is 111. The solid waste dumpsite at Owode is surrounded by residential area and garage. Due to lack of strict legislation and regulation, heavy metals and other contaminants are suspected to be released in to the environment in large quantities.

### 2.2 Sample Collection

Soil samples were collected at the main point and designated distance of 100 m apart from East, West, North and South around the dumpsite using measuring tape. The control sample was collected at about a km away from the study site. The control sample site is surrounded by industries, residential area and market area. The identified soil types were sampled using a hand trowel to collect core samples at 0-15 cm soil depths with the use of measuring tape. The soil samples were kept in a polyethylene bag and labelled accordingly.

### 2.3. Sample Treatment

Soil sample was air-dried at 25°C for 7 days, crushed using mortar and pestle and passing through 2 mm sieve mesh and labelled accordingly.

### 2.4. Sample Digestion

According to Environmental Protection Agency (EPA) 3050B method, 1 g each of the

treated soil sample was weighed and transferred into beakers, 4 ml of 50% Nitric acid and 10 ml of 20% Hydrochloric acid were added. The digestion was carried out on a heating block in a fume hood with the temperature not exceeding 90°C for about an hour. The beakers were allowed to cool and 2 ml of Hydrogen peroxide were added to each beaker and heated for 10 minutes. After digestion was completed, the digested volume of each sample was measured. The digestate was then filtered and 0.5 ml was diluted to 10 ml using ultra-pure deionized water for ICP-OES analysis. All reagent used were of analytical grade and from which standard solutions were prepared, glassware was thoroughly washed with detergent and rinsed with deionized water. Heavy metals (As, Cd, Cr, Cu, Pb, V, Ag and Zn) were determined from the filtrate using inductively coupled plasma optical emission spectrometry (ICP-OES) Agilent 720 ICP-OES.

To convert to mg/kg, multiply by

$$\text{Conc. (mg/kg)} = \frac{\text{Conc. (mg/L)} \times \text{Final Volume (L)} \times \text{Dilution Factor}}{\text{weight of sample (kg)}}$$

Conc. (mg/L) = Instrument readout concentration

Final Volume = as recorded for each sample

Dilution Factor = 20

Weight of sample = 0.001 kg or as recorded.

## 3.0. Results and Discussion

### 3.1. Results

The mean concentration of the heavy metals is presented in Table 2. The ecological risk assessment (contamination factor, degree of contamination, geo-accumulation index, pollution load index and ecological risk index) results are presented in Table 3, 4, 5 and 6, respectively. The health risk assessment (average daily dose, control for average daily dose, hazard quotient, hazard index and cancer risk) for adult and children were presented in Table 7, 8, 9, 10, and 11, respectively.

Table 1: Mean Concentration of Heavy Metals in Soil (mg/kg)



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HM	South	North	East	West	Center	Mean/SD	Control
Cd	0.97	4.22	7.75	3.62	2.41	3.79 ± 2.54	0.68
Cr	17.14	25.43	19.78	28.62	20.12	22.22 ± 4.68	21.26
As	9.18	12.14	13.59	9.27	2.45	9.33 ± 4.28	13.38
Pb	14.45	37.33	27.89	94.79	26.20	40.73 ± 31.62	19.29
V	8.79	13.58	11.71	12.45	10.81	11.47 ± 1.81	21.85
Cu	ND	1.55	7.11	48.53	0.51	11.54 ± 22.92	ND
Ag	1.93	2.68	0.29	1.41	1.71	1.60 ± 0.87	2.76
Zn	58.15	188.98	131.25	215.72	104.07	139.63 ± 63.64	14.83

Note: HM = Heavy Metals, ND = Not detected, SD = Standard Deviation

Table 2 Contamination Factor (CF)

HM	DS	CS
Cd	0.0022	0.0004
Cr	0.0127	0.0122
As	0.0053	0.0077
Pb	0.0233	0.0110
V	0.0066	0.0125
Cu	0.0066	ND
Ag	0.0009	0.0016
Zn	0.0799	0.0841

HM = Heavy Metals, DS = Dumpsite Soil, CS = Control Sample, ND = Not Detected

Table 3: Degree of Contamination (DC)



HM	DS	Summary	CS	Summary
Cd	0.0022	Low risk	0.0004	Low risk
Cr	0.0127	Low risk	0.0122	Low risk
As	0.0053	Low risk	0.0077	Low risk
Pb	0.0233	Low risk	0.0110	Low risk
V	0.0066	Low risk	0.0125	Low risk
Cu	0.0066	Low risk	ND	ND
Ag	0.0009	Low risk	0.0016	Low risk
Zn	0.0799	Low risk	0.0841	Low risk

HM = Heavy metals, DS = Dumpsite Soil, CS = Control Sample

Table 4: Geo-accumulation index (Igeo)

HM	DS	CS
Cd	0.0005	0.0013
Cr	0.0031	0.0030
As	0.0018	0.0023
Pb	-6.010	0.0029
V	0.0021	0.0031
Cu	0.0021	ND
Ag	0.0002	0.0000
Zn	-4.230	0.0025

HM = Heavy Metals, DS = Dumpsite Soil, CS = Control Sample

Table 5: Pollution Load Index (PLI)

Dumpsite Sample	Control Sample
13.24	8.57

Table 6: Ecological Risk Index (ERI)

HM	DS	CS
Cd	0.0651	0.0117
Cr	0.0254	0.0244
As	0.0534	0.0766
Pb	0.1165	0.0550
V	ND	ND



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Cu	0.0330	ND
Ag	ND	ND
Zn	0.0799	0.0841

HM = Heavy metals, DS = Dumpsite Soil, CS = Control Sample

Table 7: Average daily dose (ingestion, inhalation and dermal) of heavy metals concentration for Adult and Children (Dumpsite soil)

HM	MC	ADD <sub>ing</sub>	ADD <sub>inh</sub>	ADD <sub>derm</sub>	ADD <sub>ing</sub>	ADD <sub>inh</sub>	ADD <sub>derm</sub>
			Adult			Children	
Cd	3.79	5.2E-6	1.0E-6	0.2E-6	48.5E-6	1.9E-6	1.4E-6
Cr	22.22	30.4E-6	6.0E-6	0.9E-6	284.2E-6	10.9E-6	8.1E-6
As	9.33	12.8E-6	2.5E-6	0.4E-6	119.3E-6	4.6E-6	3.4E-6
Pb	40.73	55.8E-6	11.0E-6	1.6E-6	520.9E-6	20.0E-6	14.8E-6
V	11.47	15.7E-6	3.1E-6	0.4E-6	146.7E-6	5.6E-6	4.2E-6
Cu	11.54	15.8E-6	3.1E-6	0.4E-6	147.6E-6	5.7E-6	4.2E-6
Ag	1.60	2.19E-6	0.4E-6	0.1E-6	20.5E-6	0.8E-6	0.6E-6
Zn	139.63	191.3E-6	37.7E-6	5.4E-6	1785.9E-6	668.4E-6	650.8E-6

HM = Heavy metals, MC = Mean Concentration, ADD<sub>ing</sub> = Average Daily Dose Ingestion, ADD<sub>inh</sub> = Average Daily Dose Inhalation, ADD<sub>derm</sub> = Average Daily Dose Dermal

Table 8: Control Sample Concentrations for Average Daily Dose

HM	Control	ADD <sub>ing</sub>	ADD <sub>inh</sub>	ADD <sub>derm</sub>	ADD <sub>ing</sub>	ADD <sub>inh</sub>	ADD <sub>derm</sub>
			Adult			Children	
Cd	0.68	0.9E-6	0.2E-6	0.0E-6	8.7E-6	0.3E-6	0.3E-6
Cr	21.26	29.1E-6	5.7E-6	0.8E-6	291.9E-6	10.4E-6	7.8E-6
As	13.38	18.3E-6	3.56E-6	0.5E-6	171.1E-6	6.6E-6	4.9E-6
Pb	19.29	26.4E-6	5.2E-6	0.7E-6	246.7E-6	9.50E-6	7.0E-6
V	21.85	29.9E-6	5.9E-6	0.8E-6	279.5E-6	10.7E-6	7.9E-6
Cu	ND	ND	ND	ND	ND	ND	ND
Ag	2.76	3.8E-6	0.8E-6	0.1E-6	35.3E-6	1.4E-6	1.0E-6
Zn	14.82	20.3E-6	4.0E-6	0.5E-6	189.6E-6	7.3E-6	5.4E-6

HM = Heavy metals, MC = Mean Concentration, ADD<sub>ing</sub> = Average Daily Dose Ingestion, ADD<sub>inh</sub> = Average Daily Dose Inhalation, ADD<sub>derm</sub> = Average Daily Dose Dermal

Table 9: Hazard Quotient of Heavy Metals Concentration for Adult and Children (Dumpsite Sample)

HM	HQ <sub>ing</sub>	HQ <sub>inh</sub>	HQ <sub>derm</sub>	HQ <sub>ing</sub>	HQ <sub>inh</sub>	HQ <sub>derm</sub>
		Adult			Children	



Cd	0.0039	0.0008	0.0001	0.0370	0.0014	0.0011
Cr	0.0092	0.0020	0.0002	0.0860	0.0033	0.0025
As	0.0426	0.0084	0.0012	0.3978	0.0152	0.0113
Pb	0.1590	0.0314	0.1949	1.4884	0.0570	0.0424
V	0.0022	0.0004	0.0027	0.0209	0.0008	0.0006
Cu	0.0004	0.0000	0.0005	0.0039	0.0001	0.0001
Ag	0.0004	0.0000	0.0005	0.0040	0.0001	0.0001
Zn	0.0006	0.0001	0.0007	0.0054	0.0002	0.0001

HM = Heavy metals,  $HQ_{ing}$  = Hazard Quotient Ingestion,  $HQ_{inh}$  = Hazard Quotient Inhalation,  $HQ_{derm}$  = Hazard Quotient Dermal

Table 10: Hazard Index of Heavy Metals Concentration for Adult and Children (Dumpsite Sample)

HM	HI Adult	HI Children
Cd	0.0049	0.0395
Cr	0.0113	0.0860
As	0.0522	0.4243
Pb	0.1949	1.5878
V	0.0027	0.0223
Cu	0.0005	0.0042
Ag	0.0005	0.0044
Zn	0.0007	0.0058

HM = Heavy metal, HI = Hazard Index

Table 11: Cancer Risk of Heavy Metal Concentrations for Adult and Children (Dumpsite Sample)

CM	Adult	Children
Cd	0.0414	0.0017
Cr	0.3233	0.0129
As	0.4069	0.0164
Pb	10.0725	0.4029

CM = Carcinogenic Metals

### 3.2. Discussion

The recorded values of heavy metals concentrations of Owode municipal dumpsite were presented in Table 1. According to Twumasi et al., (2016), the composition of the disposed waste materials and the rate of microbial decomposition significantly impacted on the heavy metals concentration in the soil. The mean concentration of heavy metals at the dumpsite generally ranked as  $Zn > Pb > Cr > Cu > V > As > Cd > Ag$ .

From the result, the mean concentrations of zinc (Zn) were recorded to be 139.63 mg/kg. There was significant difference between the levels of Zn in the dumpsite soil and the control sample which was recorded to be 14.82 mg/kg. Presence of Zn within the dumpsite could be attributed to disposal of heavy metal substances which includes the presence of dry cells and burning of electronic waste (Twumasi et al., 2016). Zinc is micronutrient which plays an important role in enzymatic reactions and its presence in the soil may lead to less uptake of Cd by plants. Although, the concentration of Zn was within

the permissible concentration limit, it may however be a threat to human health if ingested in large quantities. This concentration is similar to the result observed by Odukoya et al., (2000) who reported Zn to be 10.042 mg/kg which can be attributed to domestic refuse, wastes from construction materials, motor emissions and motor vehicle wear.

The mean concentrations of lead (Pb) in the result were recorded to be 40.73 mg/kg. There was a significant differences between the levels of Pb in the dumpsite soil and the control sample which were recorded to be 19.29 mg/kg. Lead is considered as a lethal heavy metal (Olayiwola, Abdulawal, Adewuyi & Azeez, 2017; Yilmax, 2005). At higher concentrations, lead significantly interrupts water balances, enzyme activities and mineral nutrition. Presence of Pb at the study site was attributed to the disposal of waste materials containing batteries, food packaging material, Polyvinylchloride materials (PVC) and insecticides (Twumasi et al., 2016). In a study on leaching of heavy metal at some selected dumpsites in Nigeria, Awokunmi, Asaolu

and Ipinmoroti (2010) reported similar movement of Pb away from the center of the dumpsite down the slope. However, the Pb concentration at the various sampling locations were within the permissible limits of Bowen (2018) with the range of 2-200 mg/kg and FAO/WHO (2001) with 50 mg/kg. This result is also similar to the study of Umoh and Etim (2013) who reported Pb to be lower than the maximum tolerance levels proposed for agricultural soil (90-400 mg/kg) due to leaching.

### 3.2. Ecological Risk Assessment

**Contamination Factor (CF):** The values of the contamination factor are presented in Table 2. The contamination factor recorded for cadmium was 0.0022, 0.0127 for chromium, 0.0053 for arsenic, 0.0799 for zinc, 0.0233 for lead, 0.0066 for copper, 0.0066 for vanadium and 0.0009 for silver respectively, which falls under the classification  $CF < 1$  indicating low contamination, while in control sample, the contamination factor recorded for cadmium is 0.0004, 0.0122 for chromium, 0.0077 for arsenic, 0.0110 for zinc, 0.0841 for lead, copper is not detected which may be due to no presence of copper material in the soil, 0.0125 for vanadium and 0.0016 for silver indicating low contamination as well. This result is in line with the study done by Isaac et al., (2018) who reported lower contamination for Pb, but high contamination for Cd and Zn which could be attributed to the dumping waste materials containing high amount of Cd and Zn.

**Degree of Contamination (DC):** The degree of contamination ranged from  $DC < 8$  (low risk),  $8 \leq DC < 16$  (moderate risk),  $16 \leq DC < 32$  (considerable risk),  $DC > 32$  (very high risk) according to Bhutiani et al., (2017), from the table, both the values of the dumpsite soil sample and the control sample indicate low risk contamination.

**Geo-accumulation index (Igeo):** The values of the geo-accumulation index are presented in Table 4. The Igeo value recorded for cadmium was 0.0005, 0.0031 for chromium, 0.0018 for arsenic, 0.0021 for vanadium and copper, and 0.0002 for silver respectively, the result falls under the classification  $0 < Igeo < 1$  which indicates the study area is unpolluted or moderately polluted. Lead was recorded to be -6.010 and zinc to be -4.230 indicating that the site was not polluted with lead and zinc. While for control, cadmium was recorded to be 0.0013, 0.0030 for chromium, 0.0023 for arsenic, 0.0029 for lead, 0.0031 for vanadium, copper and silver was not detected and 0.0025 for zinc which indicates unpolluted. Ademiluyi and Chidozie (2015) reported moderate contamination of heavy

metals due to low contamination of heavy metals in the soil.

**Pollution load index (PLI):** The values of the pollution index are presented in Table 5. It was shown that 13.24 was recorded for the dumpsite soil sample while 8.57 was recorded for the control sample respectively which are greater than 1 indicating that both the study area and the control site were extremely heavy polluted.  $PLI < 1$  (no pollution),  $1 < PLI < 2$  (moderate pollution),  $2 < PLI < 3$  (heavy pollution),  $3 < PLI$  (extreme heavy pollution). Ekere et al., (2020) reported that PLI show extremely high risk, therefore this study follows the same trend as the report. Ademiluyi and Chidozie (2015) also reported high concentration of PLI values which could be sawdust and timber products dumped on the site.

**Ecological risk index (ERI):** ERI values were presented in Table 6. 0.0651 was recorded for cadmium, 0.0254 for chromium, 0.0534 for arsenic, 0.1165 for lead, 0.0330 for copper, 0.0799 for zinc, vanadium and silver was not detected indicating low contamination. While for control sample, cadmium was recorded to be 0.0117, 0.0244 for chromium, 0.0766 for arsenic, 0.0550 for lead and zinc to be 0.0841 which also indicate low contamination, copper, vanadium and silver were not detected. This work agrees with the previous finding reported by Romaric, Mary, Abimbola and Babafemi, (2019), who reported low contamination in their study area.

### 3.3. Health Risk Assessment

**Average daily dose (ingestion, inhalation and dermal):** These parameters are presented in Table 7. **Ingestion value** for adult were recorded as follows; cadmium to be 5.19E-6, 30.44E-6 for chromium, 12.78E-6 for arsenic, 55.79E-6 for lead, 15.71E-6 for vanadium, 15.81E-6 for copper, 2.19E-6 for silver and 191.29E-6 for zinc respectively indicating low contamination which is less than 1. While control sample were also recorded to be 0.93E-6 for cadmium, 29.136E-6 for chromium, 18.33E-6 for arsenic, 26.43E-6 for lead, 29.93E-6 for vanadium, 3.78E-6 for silver, 20.30E-6 for zinc which are below the reference dose value and also indicates low contamination whereas copper was not detected. For children, the values were also less than 1 indicating low contamination as well. This report goes in line with a study done by Vincent et al., (2018) who reported their average daily ingestion to be of low contamination due to the low contamination of heavy metals present in the study site.

**Inhalation value** for adult were recorded as follows; cadmium to be 1.02E-6, 30.44E-6 for chromium, 5.99E-6 for arsenic, 2.52E-6 for lead, 10.99E-6 for vanadium, 3.09E-6 for copper, 0.43E-6 for silver and 37.70E-6 for zinc respectively indicating low contamination which is less than 1. While the control samples were also recorded to be 0.18E-6 for cadmium, 5.74E-6 for chromium, 3.61E-6 for arsenic, 5.21E-6 for lead, 5.89E-6 for vanadium, 0.75E-6 for silver, 4.00E-6 for zinc which are below the reference dose value and also indicates low contamination whereas copper was not detected. For children, the values were also less than 1 indicating low contamination as well.

**Dermal value** for adult were recorded as follows; cadmium to be 0.15E-6, 0.85E-6 for chromium, 0.36E-6 for arsenic, 1.56E-6 for lead, 0.44E-6 for vanadium and copper, 0.06E-6 for silver and 5.36E-6 for zinc respectively indicating low contamination which is less than 1. While control sample (table 4.10) were also recorded to be 0.03E-6 for cadmium, 0.82E-6 for chromium, 0.51E-6 for arsenic, 0.74E-6 for lead, 0.84E-6 for vanadium, 0.11E-6 for silver, 0.45E-6 for zinc which are below the reference dose value and also indicates low contamination whereas copper was not detected. For children, the values were also less than 1 indicating low contamination as well.

**Hazard quotient (HQ):** The hazard quotient value was presented in Table 9. All the heavy metals calculated indicated low contamination for both adult and children; likewise, the control sample for adult and children also indicates low contamination. A similar report was reported by Vincent et al., (2018) who reported moderate contamination of heavy metals in the study site due to low activities done on the site.

**Hazard Index (HI):** These values are presented in Table 10 for both adult and children which indicate no adverse effect ( $HI < 1$ ) reported by USEPA (2001). The control sample was also in the same trend aside for copper which was not detected. It could be concluded that all measured metals in surface soil had insignificant non-cancer risks to adults and children. This report collaborates with the study of Ismat, Abubakr and Saif, (2019) who reported low contamination in khamees-mushait dumpsite, Saudi Arabia.

**Cancer risk (CR):** The cancer risk values were presented in Table 11 for both adult and children. The values for Cd, Cr and As were less than 1 which indicates low contamination, while Pb (10.0725 mg/kg) was high for adult which indicates high contamination. This report was in line with the study

by Ismat et al., (2019). A similar result was reported by Vincent et al., (2018) who specified cancer risk to be of low value which may be due to low activities done on the site.

## Conclusion

This study assessed the ecological and health risk assessment of heavy metals in soils around solid waste dumpsite in Owode Town Ogun State. The study revealed that the concentration varied at different point for each metal. The pollution load index indicated that the sample area was extremely polluted while geo-accumulation indicated low pollution. All the ecological risk assessment indicated low contamination for all the heavy metals assessed in both adult and children which were lower than the World Health Organization and Lagos State Environmental Protection Agency threshold limits for soil. Hazard quotient and hazard index were less than 1, indicating low contamination. The cancer risk suggests high contamination in lead for both adult and children; therefore, urgent measures are needed to reduce the contamination of lead (Pb) in the dumpsite soil.

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