Evaluation of soil contamination status around a municipal waste dumpsite using contamination indices, soil-quality guidelines, and multivariate statistical analysis

Lekan Olatayo Afolagboye¹ · Amos Abayomi Ojo¹ · Abel Ojo Talabi¹

Received: 26 June 2020 / Accepted: 13 October 2020 / Published online: 22 October 2020
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Abstract

Indiscriminate dumping of municipal solid wastes in and around most cities in Nigeria coupled with improper waste management of the available dumpsites posed a major threat of pollution in the surrounding soils. This study assesses the concentration of heavy metals and contamination status of soils around a municipal waste dumpsite located at Arufe street, Omuooke-Ekiti, SW, Nigeria using contamination indices, soil-quality guidelines, and multivariate statistical analysis. Soil samples from different depths were taken from the center of the dumpsite and surroundings at different distances and directions. The concentration of the metals in soils taken at depth of 0–50 cm (topsoil) was significantly higher than in soils taken at depth of 50–100 cm (subsoil). The mean concentrations of heavy metals in the topsoil showed the following order $\text{Fe} > \text{Cr} > \text{Mn} > \text{Zn} > \text{Pb} > \text{Cu} > \text{Ni}$ while those of major cation followed the order $\text{Ca} > \text{K} > \text{Na} > \text{Mg}$. Exceptionally high concentration of the heavy metals compared with the background values were found at the center or close to the center of the dumpsite, which indicates an anthropogenic contribution. Compared with the adopted soil-quality guideline, only Cr and Pb showed concentrations well above the threshold value. The mean enrichment factor of all the heavy metals except Cr and Pb were < 2 . Cu, Ni, and Fe all had geo-accumulation index (I_{geo}) values less than zero, while the I_{geo} for Cr at the center of the dumpsite (topsoil) was 5. The contamination factors followed the order: $\text{Cr} > \text{Pb} > \text{Mn} > \text{Zn} > \text{Fe} > \text{Cu} > \text{Ni}$. The modified degree of contamination values was found to be mainly less than 1.5 except at the center of the dumpsite. The ecological risk index (ranged 4.37–505.55) implies low to considerable risk for the dumpsite. The significant positive correlations observed among heavy metals and the major cations indicate that these metals probably have similar sources and properties. The PCA reveals that the metals have a strong association and may have a similar source. The cluster analysis categorized the sampling points into three major groups of spatial similarities. The metals concentration combined with the contamination indices and soil-quality guidelines indicated that the soils in and around the dumpsite are polluted or being polluted because of the dumpsite.

Keywords Contamination indices · Soil-quality guidelines · Principal component analysis · Municipal solid waste · Dumpsite

1 Introduction

In most parts of Nigeria, the generation of municipal solid waste (MSW) has an increase in parallel with a rapid increase in population growth as well as urban centers.

The MSWs are heterogeneous in nature and may include used batteries, electronics waste, old clothes, plastics bags, chemical waste, organic materials, vegetables and food, syringes, automobile junks, and painting wastes [1, 2]. Consequently, the need for proper disposal and

✉ Lekan Olatayo Afolagboye, lekan.afolagboye@eksu.edu.ng; afotayour@hotmail.co.uk | ¹Department of Geology, Ekiti State University, Ado-Ekiti, Nigeria.

management of MSW is one of the major environmental and public health challenges in developing countries like Nigeria [3]. The most preferred way of dealing with this kind of environmental problem in developing countries is to discard or dispose these heterogeneous MSW in landfills and open dumpsites.

These methods of waste disposal are common in developing countries because of their advantages such as simplicity and cheaper means of managing waste and low technological barriers [4]. Consequently, landfills and open dumpsites (in particular) are common in places close to residential, groundwater recharge and in seasonal high water table designated areas [5]. Unfortunately, most of these landfills/open dumpsites are unengineered and their operations are far below acceptable or recommended standards [6, 7]. In addition, MSWs are dumped in an uncontrolled fashion and most of these landfills and open dumpsites lack leachate collection and treatment systems [8, 9]. These aforementioned inadequacies about the landfills and dumpsites facilitate the migration of the leachates and toxic gases from the landfill or dumpsite and their release into the environment [10, 11].

Migration of leachate in landfills and open dumpsites constitute a major source of pollutants in soils, surface water, and groundwater [9, 12]. The soil and groundwater under the landfills and open dumpsites can be contaminated vertically and laterally by the leachate migration. Pollutants such as trace/heavy metals released into the environment are non-biodegradable and over time bioaccumulate [13, 14]. According to Oke and Vermeulen [15], the animal, biota, and man experience the effects of long-time exposure to heavy elements discharged into the environment.

As a result of their non-biodegradable nature and ability to bioaccumulate, pollution due to heavy metals is a major challenge over the past few decades. This is owing to the fact that overaccumulation of heavy metals beyond permissible concentrations or thresholds in an organism or ecosystem can pose a serious damage or risk [16, 17]. Compared with other components of the ecosystem, heavy metals are more stable and accumulate more in soils [18]. Once in the soil, heavy metals are hard to extract/dilute, potentially dangerous to organisms, affect the functions and structure of soil ecosystem, have high tendency of transferring to the human food chain and ultimately, heavy metal pollution is an irreversible process [19, 20]. All of these, therefore, suggest that the environmental problems that may arise from the heavy metals from unengineered landfill and open dumpsite cannot be ignored. Therefore, the study of heavy metals and other pollutants in landfills/open dumpsites has been a subject of extensive discussion [21, 22]. A review of some of these works indicates that the surroundings of landfills and open

dumpsites are seriously contaminated by metals. According to Tane and Eshalomi-M [23] "heavy metal content of soils is a critical measurement for assessing the risks of refuse dumpsites and useful to assess pollution in the environment." It is therefore important to constantly monitor the soil qualities in terms of heavy metal contents around dumpsite as this will assist in recommending appropriate remedial measures [24].

Consequently, this work is carried out to assess the heavy metal and major cation concentration in soils around a local dumpsite area where the MSWs have been disposed for about 50 years to help understand the contamination situation and create a proper management strategy. This study was conducted on soil samples collected from in and around a waste dumpsite located at Arufe street, Omuooke-Ekiti, SW Nigeria to ascertain the contamination status and distribution of metals such as Cu, Cr, Ni, Cd, Fe, Mg, Pb, Na, K, Zn, Ca and Mn in soils around dumpsite and their comparison with standard soil-quality criteria. We quantify the level of contamination in the sampled dumpsite soils using different contamination indices.

1.1 Study Area

The studied dumpsite environment is situated at Omuooke – Ekiti, Ekiti State, SW, Nigeria (Longitude 5° 44'–5° 45'10" E and Latitude 7° 46'–7° 46'18.44" N). The area is lowland with tropical rain forest vegetation. Omuooke–Ekiti typically experiences dry season (November–March) and wet season (April–October). The mean annual rainfall and temperature are about 1800 mm and 28 °C, respectively. The relative humidity of the area is about 75%. The mean daily and annual sunshine are 5 and 2000 h, respectively.

The dumpsite is situated within residential area/buildings, and the area of the dumpsite is about 57,6000 m². The dumpsite at Arufe street, Omuooke-Ekiti has been active for more than five decades and takes waste from different parts of the community. The wastes range from household waste, market waste, agricultural waste, automobile mechanic workshop waste, and so on. The height of the dump is about 2–3 m above the ground with a depth of about 50 m. The wastes are dumped in the dumpsite without segregation or compaction and above all the dumpsite has no lining system. The dumpsite is freely accessible to all and regularly visited by scavengers and different animals scavenging for food or agricultural wastes. The only management activity at the dumpsite is burning. The geology of the dumpsite falls within the Precambrian basement complex of southwestern Nigeria. Geological mapping reveals that the main lithological unit in the area is migmatite gneiss. Hence, the area is mainly covered by

lateritic soils derived from weathered Precambrian basement complex rock.

2 Materials and method

2.1 Sample collection and analysis

Soil samples were taken in triplicates after removing the overlying waste at the center of the dumpsite, 30 m from the center of the dumpsite toward in the eastern direction, 75 m Southeast of the dumpsite, 50 m Northeast of the dumpsite, and 100 m East of the dumpsite during the month of November using soil auger. The western parts of the dumpsite are all built-up areas, and it was difficult to take samples from there. The samples were taken at two different depths of 0–50 cm and 50–100 cm. Figure 1 and Table 1 show the description of the sample locations.

The soil samples were collected in a sealed polythene bag and taken to the laboratory for further sample preparation. We air-dried the soil samples at room temperature. The air-dried samples were then crushed in an agate mortar and sieved with a 2 mm sieve. We stored the air-dried screened samples in non-reacting

Table 1 Description of sampling locations

Location	Depth (cm)	Distance and direction from the center of the dump site
H ₁	0–50 50–100	0 m (Center of the dumpsite)
H ₂	0–50 50–100	30 m from the center of the dumpsite
H ₃	0–50 50–100	75 m Southeast of the dumpsite
H ₄	0–50 50–100	50 m Northeast of the dumpsite
H ₅	0–50 50–100	100 m East of the dumpsite

polythene bags for the analysis. The TDS, temperature, pH, and electrical conductivity were determined with TDS DIST I with ART meter Hannan Instrument. For the determination of metal concentration, we digested the soil samples with a mixture of hydrofluoric–perchloric acid and then diluted with HNO₃. The concentrations of Ni, Cu, Cr, Fe, Pb, Mn, and Cd in the aliquot were then obtained using an Atomic Absorption

Fig. 1 Locations of soil sampling in the study area

Spectrophotometer Buck 210 model. All concentrations were expressed in mg/kg.

2.2 Soil quality or contamination assessment

2.2.1 Background concentration

The measured concentrations of heavy metals in the soil were used to calculate the different contamination indices. These indices were used in determining the extent or level of heavy metals contamination in the soils. Contamination indices such as contamination factor pollution load index, geo-accumulation index, and enrichment ratio were computed and used in this study. Different indices have their own advantages and weaknesses but they are all used to access soil quality using a specific underlying principle. Hence, we employed more than one pollution indices in order to avoid the shortcomings or deficiencies associated with using a single contamination index [25].

In determining these contamination indices, the choice of the background values is very important. Background value is normally used to differentiate between natural concentration and concentration of metals due to anthropogenic sources. In the past, average shale values, average concentration in the continental crust, and world average have been used as background values by different authors. Another alternative, according to Sakan et al. [26], is to compare the concentrations of contaminated soils and uncontaminated soils with similar texture and mineralogical properties. Due to the indiscriminate land use in most part of the country, it will not be appropriate to view soils in the study area as an uncontaminated soil. In addition, there is no national background value for trace metals in Nigerian soils. Most soils in Nigeria are, however, derived from in situ weathering of various crustal rocks, hence the constituent of the upper continental crust [27, 28] will be similar to the heavy metal contents of the uncontaminated soil in Nigeria. Hence, we adopted the average metal concentration by these authors as the background concentrations/values.

2.2.2 Geo-accumulation Index (I_{geo})

One way of estimating the contamination levels of heavy metal contents above the background level is to compute the I_{geo} . Muller [29] introduced the I_{geo} and used it to assess the level of metal contamination in soils. It is computed as follows:

$$I_{geo} = \log_2 \left[\frac{C_n}{1.5B_n} \right] \quad (1)$$

C_n represents the concentration of the heavy metal in the soil sample. B_n represents the background value of the heavy metal. Muller [29] stated that “the I_{geo} consists of seven classes ranging from uncontaminated to very seriously contaminated. Class 0 ($I_{geo} < 0$: practically uncontaminated); Class I ($0 < I_{geo} < 1$: uncontaminated to moderately contaminated); Class II ($1 < I_{geo} < 2$: moderately contaminated); Class III ($2 < I_{geo} < 3$: moderately to heavily contaminated); Class IV ($3 < I_{geo} < 4$: heavily contaminated); Class V ($4 < I_{geo} < 5$: heavily to extremely contaminated); Class VI ($I_{geo} > 5$: extremely contaminated).”

2.2.3 Enrichment factor (EF)

EF is used to quantify heavy metal inputs above natural levels. The EF is calculated according to the formula

$$EF = \frac{C_x/C_b}{B_x/B_b} \quad (2)$$

where C_x and C_b represent the concentration of the heavy and reference metal, respectively. B_x and B_c are the background concentrations of the heavy and reference metals, respectively. The reference metal or element is either Al, Fe, Ti, Mn, Li, Zr, and Sc [30]. We used Fe as reference metal in this study because of the reasons provided by Bhuiyan et al. [31]. EF, according to Sakan et al. [26], is interpreted as follows: “EF < 1 indicates no enrichment; EF < 3 is minor enrichment; 3 < EF < 5 is moderate enrichment; 5 < EF < 10 is moderately severe enrichment; 10 < EF < 25 is severe enrichment 25 < EF < 50 is very severe enrichment and EF > 50 is extremely severe enrichment.”

2.2.4 Contamination factor (Cf)

The Cf [32] is employed to evaluate the level of the soil contamination with heavy metals. Cf is computed as follows:

$$Cf = \frac{C_{heavy\ metal}}{C_{background}} \quad (3)$$

where $C_{heavy\ metal}$ and $C_{background}$ represent the concentration and background concentration of the heavy metal, respectively. Cf are characterized as follows [32]: “Cf < 1 low contamination factor indicating low contamination of the soil with the examined substance, 1 ≤ Cf < 3 moderate contamination factor, 3 ≤ Cf < 6 considerable contamination factor, and 6 ≥ Cf very high contamination factor.”

2.2.5 Degree of contamination (DegC)

Cf represents a one element index which shows contamination of a single element. DegC is obtained using Eq. 4 [32].

$$\text{DegC} = \sum_{i=1}^n \text{Cf} \quad (4)$$

n is the number of analyzed heavy metals. DegC values are characterized as follows: “DegC < 8, low degree of contamination; 8 ≤ DegC < 16, moderate degree of contamination; 16 ≤ DegC < 32, high degree of contamination; DegC > 32; very high degree of contamination [32].”

2.2.6 Modified degree of contamination (MDC)

The generalized DegC equation of Hakanson [32] was modified and expressed as Eq. 5 [33].

$$\text{MDC} = \frac{\sum_{i=1}^n \text{Cf}}{n} \quad (5)$$

n is the number of analyzed heavy metals. “MDC < 1.5, nil to very low degree of contamination; 1.5 ≤ MDC < 2, low degree of contamination; 2 ≤ MDC < 4, moderate degree of contamination; 4 ≤ MDC < 8, high degree of contamination; 8 ≤ MDC < 16, very high degree of contamination; 16 ≤ MDC < 32, extremely high degree of contamination; MDC ≥ 32, ultra-high degree of contamination” [33].

2.2.7 Pollution load index (PLI)

It is mainly used to detect multi-element contamination [34]. PLI also allows a comparison of the level of pollution among sites and at different times. It is obtained as the nth root of the product of the n measured Cf of the various metals in the soil. PLI is expressed as

$$\text{PLI} = \sqrt[n]{\text{Cf}_1 * \text{Cf}_2 * \text{Cf}_3 * \dots * \text{Cf}_n} \quad (6)$$

According to Chon et al., [35], if “PLI < 1, the soil is unpolluted; if 1 ≤ PLI < 2, the soil is moderately polluted; if 2 ≤ PLI < 10, the soil is strongly polluted; if PLI ≥ 10, the soil is extremely polluted.” However according to Zarei et al., [36], “PLI can be classified as: no pollution; if PLI < 1, moderate pollution; if 1 ≤ PLI < 2, heavy pollution; if 2 ≤ PLI < 3, and extremely heavy pollution; if PLI ≥ 3.”

2.2.8 Nemerow integrated pollution index (NIPI)

We used NIPI [37] to evaluate the total contamination status of the soil by heavy metals. NIPI is expressed as

$$\text{NIPI} = \sqrt{\frac{\text{PI}_{\text{ave}}^2 + \text{PI}_{\text{max}}^2}{2}} \quad (7)$$

where PI is given as $\frac{C_{\text{heavy metal}}}{C_{\text{background}}}$. PI_{ave}^2 and PI_{max}^2 represent the mean and highest PI of each heavy metal, respectively. NIPI are characterized as follows [37]: “NIPI ≤ 0.7, non-pollution; 0.7 < NIPI ≤ 1, warning line of pollution; 1 < NIPI ≤ 2, low level of pollution; 2 < NIPI ≤ 3, moderate; and NIPI > 3, high level of pollution.”

2.2.9 Ecological risk index (RI) and ecological risk factor (E_r^i)

Hakanson [32] used the RI to evaluate the possible ecological risk due to the existence of heavy metals in the soils. The ecological risk of a given heavy metal is computed using the E_r^i and the element's reference value. It is obtained as follows:

$$E_r^i = T_r^i * C_f^i \quad (8)$$

T_r^i represents the toxic response factor. C_f^i is obtained from Eq. 3. The T_r^i of Cu, Ni, Cr, Zn, Pb, Mn, and Fe is 5, 5, 2, 1, 5, 1, and 1, respectively [38, 39]. The RI is derived using this formula:

$$\text{RI} = \sum_{i=1}^n E_r^i \quad (9)$$

The E_r^i values, according to Hakanson [32], “are classified into five degrees of ecological risk. These are $E_r^i < 40$, $40 \leq E_r^i < 80$, $80 \leq E_r^i < 160$, $160 \leq E_r^i < 320$, and $E_r^i \geq 320$ for low, moderate, considerable, high, and very high ecological risks, respectively. Similarly, the RI values are classified into four degrees of ecological risk and these include $\text{RI} < 150$, $150 \leq \text{RI} < 300$, $300 \leq \text{RI} < 600$, and $\text{RI} \geq 600$ for low, moderate, considerable, and very high ecological risks, respectively.”

2.3 Soil-quality guidelines (SQGs)

SQGs are normally used to assess soil contamination status by comparing the heavy metals concentration with standard quality guidelines. These guidelines give information on the level to which the accumulation of these metals in the soil might have affected the soil biota and assist in evaluating the level of their biological risk; hence in interpreting soil quality. In this study, we used soil-quality guidelines defined in the Finnish legislation [40] to assess the probable risk that may arise because of heavy metals present in the soils around the dumpsite. This standard, according to Awasthi [41] and Carlon et. al.,

[42], “represents a good approximation of average values of different national soil-quality guidelines in Europe and Indian.” In addition, this standard has been applied internationally for agricultural soils [43].

The standard uses the concentration level of each heavy metals to determine the soil contamination status and remediation needs. This standard consists of lower and higher concentration levels and if these concentration levels are exceeded, they indicate the need for different actions. The threshold values in the guideline are relevant for all sites and show the need for more evaluation of the area. According to the standard, if the threshold value is lower than the background concentration, background concentration is then taken as the threshold value. In addition, if the guideline value is exceeded, the contamination status of such soil presents a health or ecological risks. The “higher guideline values” are applicable to industrial and transport areas. The “lower guideline value” on the other hand is applicable to other land use. We classified the soil around the dumpsite by the heavy metal concentration using these threshold and guideline values. These include soil samples with heavy metal concentration (i) below the threshold value, (ii) above the threshold value, (iii) more than the “lower guideline value” but lower than the “higher guideline value,” and (iv) above the “higher guideline value.”

2.4 Statistical analysis

The results of the various analysis were subjected to descriptive and multivariate statistical analysis using R software. The relationships among the various metals were carried out using the Pearson correlation coefficient matrix. Multivariate statistical analysis of soil's heavy metals, major cation, and physical parameters of the soil was performed using principal component analysis (PCA) and cluster analysis (CA). We used the PCA/factor analysis to examine the association between the variables and determined the principal factors controlling their distribution [44]. The PCA was applied to all the variables (except Ni). Prior to the PCA analysis, the data were scaled or standardized using z-scaled transformation. This is to prevent miscalculation because of large variations in data dimensionality. The PCA of the standardized variables was performed to obtain the important principal components (PCs). Component(s) with eigenvalue < 1 is considered insignificant and such can be discounted. To further interpret the PCA results, we prepared the biplot with variable space and sampling points. We performed CA on the scaled variables using Ward's method with the sum of distances as a measure of similarity.

Table 2 Physical properties of the soil around the dumpsite

Location	Depth (cm)	Temperature (°C)	pH	TDS (mg/kg)	EC (μS/cm)
H ₁	0–50	27.5	6.56	3080	6150
	50–100	27.1	6.73	2930	5910
H ₂	0–50	27.1	6.47	2970	5950
	50–100	27.1	6.12	2290	4710
H ₃	0–50	27.1	5.97	1500	2950
	50–100	27.1	6.31	760	1550
H ₄	0–50	27.7	6.39	1710	3410
	50–100	27.2	6.59	960	1940
H ₅	0–50	27.2	6.36	640	1440
	50–100	27.1	6.31	640	1240

3 Results and discussion

3.1 Physical properties of the soils

The physical properties of the soil samples at different depths are shown in Table 2. The pH of the soil ranged from 5.97 to 6.73 which indicates the acidic nature of the soil samples. The mobility of metals in the soil and their availability to plants are highly affected by soil pH. In these soils, most heavy metals are likely to be in a low mobile form [45]. The pH of soils from different depths varied and showed no definite trend. The highest pH values were however found at the center of the dumpsite at both depths and with values decreasing away from the dumpsite.

The electrical conductivity (EC) of the soil samples ranged from 1240 μS/cm to 6150 μS/cm. This is an indication of high concentration of dissolved solids. This may reflect the influence of rainfall and evapo-transpiration. Higher EC was observed in samples obtained at the center of the dumpsite and with values decreasing away from the center of the dumpsite. The result also shows that EC values decreased with depth at the dumpsite. The Total Dissolved Solid (TDS) of the soils ranged from 640 mg/kg to 3080 mg/kg. The relatively high values of TDS might be attributed to the presence of large amounts of soluble ions. Like EC values, TDS recorded the highest values at the center of the dumpsite and its values decreased with increasing distance away from the center of the dumpsite. In addition, the TDS values decreased with depth.

3.2 Heavy metals and major cations concentration

Heavy metals and major cations concentrations of the dumpsite soils are shown in Table 3. The concentration of the following heavy metals Cd, Ba, Zr, Mo, Ag, U, and

Table 3 The concentrations (mg/kg) of the heavy metals and major cations in the dumpsite soils

Location	Depth (cm)	Cu	Ni	Cr	Zn	Pb	Mn	Fe	Na	K	Ca	Mg
H ₁	0–50	12.5	0.03	8450	120.5	65.5	1221	48,700	65.5	144.5	33,300	0.19
	50–100	10	ND	349.5	117.5	41.5	690	28,450	58	142.5	11,950	0.17
H ₂	0–50	3	ND	230	33	39	530	17,750	47.5	112.5	11,675	0.16
	50–100	ND	ND	113.5	19.5	36	500	10,352.5	41.5	84.5	10,175	0.15
H ₃	0–50	4	ND	60	8	14	180	5600	36	14	14.5	0.1
	50–100	2	ND	57	6	11	102	5272	35.5	13.5	10.5	0.08
H ₄	0–50	2	ND	91.5	10	33.5	480	8150	39	36.5	65	0.13
	50–100	ND	ND	68.5	9.5	27	430	7175	37.5	19	15.5	0.12
H ₅	0–50	ND	ND	43.5	5	9	78	4425	35	11	7	0.08
	50–100	ND	ND	40	4.5	7.5	56	3875	33.5	8.5	3.5	0.02
Upper continental crust ^a		25	20	35	71	20	600	35,000	28,900	28,000	30,000	13,300
World Average ^b		38.9	29	59.5	70	27	418	58,100	7100	16,900	25,900	12,600

^a[27], ^b[51] ND; Below Detection Limit

W were below detection limits in most of the soil samples. The concentrations of Cu, Cr, Zn, Pb, Mn, Fe, and Ni ranged from 2.0–12.5, 43.5–8450, 5–120.5, 9–65.5, 78–1221, 4425–48,700, and 0–0.03 mg/kg in topsoil samples (0–50 cm depth), respectively. On the other hand, they ranged from 2–10, 40–349.5, 4.5–117.5, 7.5–71.5, 56–690, 3875–28,450, and ND mg/kg in subsoil samples (50–100 cm depth), respectively. In the topsoil and the subsoil samples, the concentration of the heavy metals followed the order Fe > Cr > Mn > Zn > Pb > Cu > Ni and Fe > Mn > Cr > Zn > Pb > Cu > Ni, respectively. The concentration of heavy metals in the topsoil samples was higher than the subsoil samples in all the sampling points. The decrease of heavy metal concentration with depth was also reported by Oketola and Akpotu [46] and Shittu et al. [47] but this is in contrast to the work of Nwachukwu et al. [48] which reported that the concentration of the heavy metals increased with depth around automobile junk market. This reduction in concentration with depth can be as a result of the fact that most metals in the soil have low mobility which makes the soils to accumulate metals on a long-term term basis. It could also be as a result of an increase in clay content of the soil with depth, which affects the mobility of the metals. Similarly, their concentration decreased significantly as the distance from the center of the dumpsite increases. Among the trace metals, Fe has the highest concentrations in all locations and considerably higher compared to other heavy metals. This observation is also similar to the results presented by Arinze et al. [1], Oluwatuyi et al. [49] and Ogunbanjo et al. [50]. This may be partly due to weathering, leaching, and laterization of iron-rich rocks present in the area. The resultant lateritic soil or cap may also contribute to the reason why the heavy metals are less in abundance at the subsoil; serving as a protective layer or low permeable

layer against the deep penetration of these metals into the soil.

When the concentration of these heavy metals are compared with the background values provided by Taylor and McLennan [27] and the world soil average given by Kabata-Pendias [51] (Table 3), the concentration of Cu and Ni were lower than these averages in all the dumpsite soil. However, the concentration of Cr, Zn, Pb, and Mn in the dumpsite soils were higher than the world soil average [51] in 70%, 20%, 50%, and 60% of the samples, respectively. In addition, the concentration of Cr, Zn, Pb, Mn, and Fe in these soils exceeded the average background values [27] in 100%, 20%, 60%, 20%, and 10% of the studied samples, respectively. Exceptionally high concentration compared with the two background values were found at the center or close to the center of the dumpsite, which indicates an anthropogenic contribution along with that of lithogenic input.

The concentration of the analyzed major cations such as Ca, Mg, Na, and K ranged from 7–33,000, 0.08–0.19, 35–65.5, and 11–144.5 mg/kg in the dumpsite soils taken at depth of 0–50 cm, respectively (Table 3). The concentration ranged from 3.5–11,900, 0.02–0.17, 33.5–58, and 8.5–142.5 mg/kg, respectively in the dumpsite soils taken at depth of 50–100 cm. The average concentrations of these cations in the dumpsite soils from both depths followed the order Ca > K > Na > Mg. Similar to the trace metals, the concentrations of the major cations in the topsoil samples are greater than subsoil samples in all the dumpsite soils. The concentration of the cations also decreased as the distance from the center of the dumpsite increases. Compared with the world soil average [51] and the mean upper continental crust [27] (Table 3), Na, K, and Mg showed concentration lower than these averages in all the locations.

Table 4 Heavy metals and major cation concentration (mg/kg) in soils of different dumpsites

Dumpsite	Cu	Ni	Cr	Zn	Pb	Mn	Fe	Na	K	Ca	Mg	Reference
Arufe street, Omuooke-Ekiti	2–12.5	ND–0.03	40–8450	4.5–120.5	7.5–65.5	56–1221	3875–48,700	33.5–65.5	8.5–144.5	3.5–33,300	0.02–0.19	This study
Ilokun, Ado-Ekiti	47.33–769	32.17–57.5	323.33–1241.67	–	105–805	5.33–12.5	6676.67–41,233.33	–	–	–	–	[47]
FUTA, Akure	–	4.15	0.2000	7.280	–	119.1	2355	–	–	–	–	[49]
Apete, Ibadan	516	97.7	61.1	3030	309	–	–	–	–	23,200	4710	[46]
Sagamu	1280–2562	–	–	43.9–49.2	42.24–64.1	–	2312.5–3328	–	–	–	–	[50]
Automobile Junk Market, Nnewi	2.97–18.52	26.55–82.18	0.05–0.13	4.08–21.55	0.07–0.31	3.85–12.88	25.43–75.1	–	–	–	–	[1]

Table 4 presents the comparison between the metal concentrations in this present study and the previously published data in different dumpsite soils in Nigeria. The concentration of heavy metals in the top and sub-soils which followed the order $Fe > Cr > Mn > Zn > Pb > Cu > Ni$ and $Fe > Mn > Cr > Zn > Pb > Cu > Ni$, respectively were not compatible with any of the previous studies conducted in Nigeria states [46, 49]. Although, the concentration of Fe and Cr was the highest in this present study and the concentration recorded in the raining season in the work of Shittu et al. [47]. In addition, the concentration of the metals reported in this study showed higher mean values of Cr and Fe and lower values of Ni, Mg, and Cu in comparison with the concentrations in the previous studies [1, 46, 47]. Generally, the concentrations of the heavy metals and major cations showed noticeable variations compared with some previous studies over the dumpsite soils referenced.

3.3 Soil-quality guidelines (SQGs)

The SQGs reflect the likelihood of contaminated soil to cause adverse environmental problems. Thus, the concentration of heavy metals in this study was compared with the guidelines of the threshold value, higher guideline values, and lower guideline values (Table 5). Compared with the threshold values (Table 5) of the adopted soil-quality guideline [40], only Cr (10% of the sample) and Pb (10% of the sample) showed a concentration well above the threshold value. This implies a possible Cr and Pb pollution risk concerning the soil quality, and this calls for further assessment of the area in the future. Regarding the lower guideline values [40] in the dumpsite soils, all the concentration obtained for all the heavy metals fall below the lower guideline values, except for Cr that exceeded this concentration in 10% of the dumpsite soils and this implies ecological risk. In addition, all the concentration obtained for all the heavy metals was however smaller than the higher guideline values in all the dumpsite soil except for Cr that exceeds this concentration in 20% of the dumpsite soils. Therefore, only Cr, presently, presents an ecological risk among the heavy metals present in soils of the dumpsite. Overall, sampling points where the concentration of the heavy metals exceeded the lower and higher guideline values were either at the center of the dumpsite (H_1) or close to the center of the dumpsite (H_2).

3.4 Contamination assessment

The values I_{geo} used for quantifying the accumulation of heavy metals in the dumpsite soils are shown in Table 6, and the variation in the results was observed based on metal type and sampling depth. Ni, Cu, and Fe have I_{geo}

Table 5 Comparison between SQGs with heavy metal concentrations (mg/kg) of all sampling points

		Cu	Ni	Cr	Zn	Pb
SQG	Threshold value ^{c, d}	100	50	100	200	60
	Lower guideline value ^c	150 ^e	100 ^e	200 ^e	250 ^e	200 ^f
	Higher guideline value ^c	200 ^e	150 ^e	300 ^e	400 ^e	750 ^e
This study	Minimum	2	–	40	4.5	7.5
	Maximum	12.5	0.03	8450	120.5	65.5
No. of samples based on the guiding values	<Threshold value	10	10	6	10	9
	≥Threshold value < Lower guideline values	0	0	1	0	1
	≥ Lower guideline values < Higher guideline values	0	0	1	0	0
	≥ Higher guideline values	0	0	2	0	0
% Samples based on the guiding values	<Threshold value	100%	100%	60%	100%	90%
	≥Threshold value < Lower guideline values	–	–	10%	–	10%
	≥ Lower guideline values < Higher guideline values	–	–	10%	–	–
	≥ Higher guideline values	–	–	20%	–	–

^c[40], ^d Area needs further assessment (if exceeded), The guideline value is defined in terms of ecological risks (^e) or health risks (^f)

Table 6 I_{geo} and EF of the heavy metals for the soils in and around the dumpsite

Location	Depth (cm)	Cu		Ni		Cr		Zn		Pb		Mn		Fe	
		I_{geo}	EF	I_{geo}	EF	I_{geo}	EF	I_{geo}	EF	I_{geo}	EF	I_{geo}	EF	I_{geo}	EF
H ₁	0–50	– 1.1	0.36	– 6.91	0.01	5.09	173.52	0.13	1.22	0.79	2.36	0.31	1.47	– 0.08	1.0
	50–100	– 1.33	0.5	–	–	1.9	12.29	0.1	2.04	0.33	2.56	– 0.27	1.42	– 0.62	1.0
H ₂	0–50	– 2.53	0.24	–	–	0.95	12.96	– 1.18	0.92	0.27	3.85	– 0.53	1.75	– 1.09	1.0
	50–100	–	–	–	–	0.78	10.97	– 1.7	0.93	0.19	6.09	– 0.59	2.82	– 1.63	1.0
H ₃	0–50	– 2.24	1.0	–	–	0.14	10.72	– 2.59	0.71	2.47	4.38	– 1.61	1.88	– 2.24	1.0
	50–100	– 2.93	0.54	–	–	0.09	10.82	– 2.88	0.57	– 1.01	3.66	– 2.18	1.13	– 2.3	1.0
H ₄	0–50	– 2.93	0.35	–	–	3.47	11.23	– 2.37	0.61	0.12	7.2	– 0.63	3.44	– 1.87	1.0
	50–100	–	–	–	–	0.27	9.55	– 2.42	0.66	– 0.11	6.59	– 0.74	3.5	– 2.00	1.0
H ₅	0–50	–	–	–	–	– 0.19	9.84	– 3.06	0.56	– 1.21	3.56	– 2.45	1.03	– 2.48	1.0
	50–100	–	–	–	–	– 0.28	10.33	– 3.17	0.58	– 1.39	3.39	– 2.78	0.85	– 2.61	1.0

less than zero at all the depths which suggest that the soil in and around the dumpsite is not contaminated by pollutants. The I_{geo} of Zn and Mn were found between less than zero and 1 indicating practically uncontaminated to uncontaminated—moderately contaminated; Pb on the other hand varied from practically uncontaminated to moderately—heavily contaminated. At the center of the dumpsite (topsoil), I_{geo} of Cr was found to be above 5 indicating extremely contaminated soil and at H₄ (topsoil), I_{geo} value indicated heavily contaminated soil. In other locations, Cr indicated uncontaminated—moderately contaminated to moderately contaminated soil quality.

Zhang and Liu [52] stated that EF “values between 0.05 and 1.5 indicate that the metal is entirely from crustal materials or natural processes, whereas EF values higher than 1.5 suggest that the sources are more likely to be anthropogenic.” The EF of heavy metals (Table 6) such as Cr, Pb, Mn (Locations H₂, H₄, and H₃ topsoil) and

Zn (Location H₁ subsoil) was > 1.5 in the dumpsite soils, suggesting anthropogenic (dumpsite) source. In addition, EF of Cu, Ni, and Zn (except in Location H₁) was found to be mainly less than 1 (Class 1; [26]) indicating no enrichment. EF of Zn and Pb in location H₁ and those of Mn (except in location H₄) were found to be mainly less than 3 (Class 2) indicating minor enrichment. The EF of Pb in other locations showed moderate enrichment—moderately severe enrichment. EF of Cr in the soils was found to be between 9.55 and 173.52 indicating severe and extremely severe enrichment.

Overall, the I_{geo} and EF show that the dumpsite soils (especially at the center and close to the center of the dumpsite) are contaminated by Cr and Pb. Although, EF and I_{geo} are used to quantify the degree of geogenic accumulation or contribution of metals in soils or sediments. They are generally referred to as single metal contamination indices and do not provide a complete

Table 7 CF, DegC, and other multi-metal contamination indices of the dumpsite soil

Location	Depth (cm)	CF							DegC	MDC	PLI	NIPI
		Cu	Ni	Cr	Zn	Pb	Mn	Fe				
H ₁	0–50	0.5	0.01	241.43	1.7	3.28	2.04	1.4	250.36	35.77	1.53	244.06
	50–100	0.4	–	9.99	1.66	2.08	1.15	0.82	16.1	2.3	1.53	10.34
H ₂	0–50	0.12	–	6.58	0.47	1.95	0.89	0.51	10.52	1.51	0.83	6.81
	50–100	–	–	3.25	0.28	1.8	0.84	0.3	6.47	0.93	0.84	3.5
H ₃	0–50	0.16	–	1.72	0.12	0.7	0.3	0.16	3.16	0.46	0.32	1.8
	50–100	0.08	–	1.63	0.09	0.55	0.17	0.16	2.68	0.39	0.24	1.69
H ₄	0–50	0.08	–	2.62	0.15	1.68	0.8	0.24	5.57	0.8	0.47	2.78
	50–100	–	–	1.96	0.14	1.35	0.72	0.21	4.38	0.63	0.56	2.15
H ₅	0–50	–	–	1.25	0.08	0.45	0.13	0.13	2.04	0.3	0.24	1.31
	50–100	–	–	1.15	0.07	0.38	0.1	0.12	1.82	0.26	0.21	1.21

pollution status for all the heavy metals in each sampling point. Hence, multi-metal contamination indices are also required to access the heavy metal pollution status of the dumpsite soils [53]. The results of the multi-metal contamination indices such as DegC, MDC, PLI, and NIPI are presented in Table 7.

The highest CF (Table 7) for the metals was found at the center of the dumpsite, which is likely to be the area receiving the highest amount of leachate from the dumpsite. The CF for Cr was > 6 in soil samples taken at H₁ and H₂ (topsoil). This indicates a very high contamination by this heavy metal. The CF of Cr in other locations showed a moderate contamination. For Zn, Pb, Mn, and Fe, CF ranged from low contamination to moderate contamination in the dumpsite soils. The CF of Cu and Ni in the soils showed low contamination. The CF for the pollutants followed the order: Cr > Pb > Mn > Zn > Fe > Cu > Ni.

The DegC ranged from 1.82 to 250.36 (Table 7), indicating low to moderate and very high degree of contamination. Generally, higher DegC values were observed in the topsoil than the subsoil. Cr and Pb are the main metals contributing to the DegC of these soils. The MDC ranged from 0.26 to 35.77. Similar to DegC, MDC values

at the topsoil were higher than the subsoil. The MDC values were found to be mainly less than 1.5 except at location H₁ indicating zero to very low degree of contamination. The MDC value for location H₁ (topsoil) was found to be above 32 indicating ultra-high degree of contamination while H₁ (subsoil) was found to be 2.3 indicating moderate degree of contamination. Most of PLI values for the soil samples were less than 1 except in location H₁ (Table 7), which means most of these samples are unpolluted [35, 36]. Location H₁ had the highest PLI (1.58 for both topsoil and subsoil samples), indicating that the soils at the locations were moderately polluted by these pollutants. The values of the calculated NIPI for each location are shown in Table 7. The NIPI of samples of H₁ and H₂ were > 3, which means that these samples are highly polluted. On the contrary, the NIPI values for soil samples of H₃, H₄, and H₅ were between 1–3, which means the soil at these sites is lowly to moderately polluted.

Table 8 summarizes the E_rⁱ and RI of the dumpsite soils. The E_rⁱ for all the heavy metals except Cr were less than 40 in all the sampling points, which indicate that these heavy metals present a low ecological risk to the dumpsite

Table 8 E_rⁱ and RI of the dumpsite soils

Location	Depth (cm)	E _r ⁱ						RI
		Cu	Ni	Cr	Zn	Pb	Mn	
H ₁	0–50	2.5	0.05	482.86	1.7	16.4	2.04	505.55
	50–100	2	–	19.98	1.66	10.4	1.15	35.19
H ₂	0–50	0.6	–	13.16	0.47	9.75	0.89	24.87
	50–100	–	–	6.5	0.28	9	0.84	16.62
H ₃	0–50	0.8	–	3.44	0.12	3.5	0.3	8.16
	50–100	0.4	–	3.26	0.09	2.75	0.17	6.67
H ₄	0–50	0.4	–	5.24	0.15	8.4	0.8	14.99
	50–100	–	–	3.92	0.14	6.75	0.72	11.53
H ₅	0–50	–	–	2.5	0.08	2.25	0.13	4.96
	50–100	–	–	2.3	0.07	1.9	0.1	4.37

soil. E_r^i values for Cr were less than 40 in most sampling points except in the at the center of the dumpsite (top-soil) which means Cr poses low to very high ecological risk. The average E_r^i for the heavy metals followed the order: $Cr > Pb > Mn > Cu > Zn > Ni$. RI values (ranged 4.37–505.55) imply low to considerable risk for the dumpsite. The RI of sampling points close to the center of the dumpsite is higher compared with those points away from the center.

3.5 Statistical analyses

3.5.1 Correlation matrix

To determine the relationships between the major cations, heavy metals, and the physical parameters of the soil, and to establish the source of these metals in the dumpsite soils, the Pearson correlation coefficients were calculated for these parameters. According to Rollinson [54] correlation coefficients between 0.9–1, 0.7–0.9, 0.5–0.7, 0.3–0.5, and < 0.3 are termed very high, high, moderate, low, and very low respectively. According to Zhai et al. [55], high correlation coefficients point to the same geochemical processes/reactions, which may influence the distribution of the metals. The results of correlation coefficients are presented in Table 9. There exists a different degree of correlation between the metals and physical properties of the soil samples. In addition, positive correlations were observed between all the analyzed parameters.

There was a high to very high positive correlation between all the metals. However, K and Mg both show a moderate correlation with Cr. The observed correlation coefficients (> 0.7) for most of the metals suggested that these metals have common source or similar characteristics which may be due to the leachates emanating

from the dumpsite. There was no significant correlation between the metals and both the pH and temperature of the soil. The investigated metals (except Cr) however showed a high to very high positive correlation with TDS and EC.

3.5.2 Principal component analysis (PCA)

PCA was carried out on the standardized data to further establish the relationships among the variables

Table 10 The result of principal component analysis of the soils around the dumpsite

	Coefficients of PC1	Coefficients of PC2
Cu	0.27	0.06
Cr	0.24	0.42
Zn	0.29	– 0.05
Pb	0.29	0.06
Mn	0.3	0.13
Fe	0.3	0.1
Na	0.3	– 0.03
K	0.29	– 0.27
Ca	0.29	0.05
Mg	0.27	– 0.15
Temp	0.1	0.71
pH	0.17	0.09
TDS	0.28	– 0.29
EC	0.28	– 0.3
Standard deviation	3.26	1.11
Proportion of Variance (%)	75.69	8.86
Cumulative Proportion (%)	75.69	84.54

Table 9 Correlation matrix of the tested metals and physical parameters of the soil

	Cu	Ni	Cr	Zn	Pb	Mn	Fe	Na	K	Ca	Mg	Temp	pH	TDS	EC
Cu	1														
Ni	–	1													
Cr	0.77	–	1												
Zn	0.96	–	0.69	1											
Pb	0.78	–	0.73	0.8	1										
Mn	0.85	–	0.8	0.85	0.99	1									
Fe	0.93	–	0.87	0.94	0.89	0.93	1								
Na	0.93	–	0.76	0.97	0.91	0.93	0.98	1							
K	0.8	–	0.56	0.89	0.89	0.87	0.88	0.94	1						
Ca	0.86	–	0.88	0.85	0.89	0.91	0.96	0.93	0.87	1					
Mg	0.77	–	0.5	0.72	0.92	0.88	0.76	0.83	0.86	0.75	1				
Temp	0.1	–	0.46	0.18	0.45	0.47	0.32	0.26	0.12	0.26	0.31	1			
pH	0.59	–	0.3	0.63	0.51	0.53	0.55	0.6	0.53	0.39	0.43	0.23	1		
TDS	0.7	–	0.49	0.78	0.89	0.84	0.8	0.87	0.96	0.81	0.9	0.17	0.36	1	
EC	0.7	–	0.49	0.78	0.89	0.84	0.8	0.87	0.96	0.81	0.91	0.16	0.36	1	1

used and factors contributing to the metal enrichment/source apportionment. The results of PCA on all the metals (except Ni) and soil physical properties are shown in Table 10. The PCA (Table 10) revealed two Principal Components (PCs) with standard deviation (eigenvalues) greater than one that accounted for 84.54% of total cumulative variances in the soil data. The biplot of the factor loadings of these components is shown in Fig. 2. The biplot shows how the sample is related to one another in our PCA and how the variables contribute to the PCs. The first PC (PC-1) accounts for 75.69% of the total cumulative variance and contained variable such as Na, Fe, and Pb. The factor loadings show that most of the variables roughly contributed equally to the first PC since all the variables have more or less the same weight (except temperature and pH). From the biplot, we also observed that the variables (as shown by the arrows) contributed more or less equally to the PC - 1 since they virtually have the same length and in addition they are quite correlated because

most of the variables have virtually the same direction and low angles between the arrows. This implies that these metals have a strong association and may have a similar source which may be anthropogenic and/or natural.

The second PC (PC 2) accounts for 8.86% of the variance and the factor loadings, however, show that only Cr and temperature are the main variables that contributed to this PC. The biplot shows that only temperature and Cr have any real contribution to the PC-2. The Cr having positive loadings in PC-1 and PC-2 suggests that it might be coming from more than one pollution source. On the 2D diagram depicting the relationship between Factors 1 and 2 (Fig. 2), three distinct groups can be identified, relating to the sampling points. Group 1 consists of a sampling point situated at the center of the dumpsite and a sampling depth of 0–50 cm. This location is the most polluted region among the sampling point which may be due to the fact that it receives more leachate discharges from the dumpsite. Group 2 consists of sampling

Fig. 2 Factor loading plot for the measured variables

points located at the center of the dumpsite (sampling depth of 50–100 cm) and H_2 . These points were also polluted but not as high as that of Group 1. Group 3 comprised other sampling points. These points correspond to regions of relatively low pollution.

3.6 Cluster analysis (CA)

CA was performed on all the metals and soil physical properties to group related sampling point together. The CA produced a dendrogram (Fig. 3) where the sampling points in and around the dumpsite were classified into three clusters. The cluster analysis also classified the sampling points into three groups. Cluster 1 comprised sampling point H_1 (0–50 cm depth) located at the center of the dumpsite, which is expected to receive the highest amount of leachate from the dumpsite. Cluster 2 comprised locations H_1 (50–100 cm depth) and H_2 (both depths). These locations are located at the center of the dumpsite but at a greater depth and just out the dumpsite. Cluster 3 comprised other sampling points.

Likewise, CA was carried out to group the metals and physical parameters. The dendrogram in Fig. 4 shows that the analyzed metals and physical parameters were grouped into three distinct clusters. Cluster 1 comprised variables such as Zn, Cu, Fe, Pb, Na, Mn, Ca, K, TDS EC, and

Mg. Cluster 1 was further grouped into three sub-clusters: (A) Cu, Zn, Fe, and Na; (B) Pb, Mn, and Ca; (C) K, TDS, EC, and Mg. Cluster 2 comprised pH while Cluster 3 was made up of temperature and Cr. Overall, the results obtained from Pearson's correlation and the PC are the same as the cluster analysis, which helped in interpreting the data.

4 Conclusions

Contamination indices, soil-quality guidelines, and statistical analysis were used for evaluating contamination status in soils around a local dumpsite area at Arufe street, Omuooke-Ekiti, SW Nigeria. The highest concentrations of the major cations and heavy metals were found in soils obtained from the center of the dumpsite and decreased as the distance from the center of the dumpsite increases. The concentrations of the major cations and heavy metals in the topsoil samples are higher than the subsoil. The mean concentration of heavy metals in the topsoil samples and major cations in the dumpsite soils followed the order: $Fe > Cr > Mn > Zn > Pb > Cu > Ni$ and $Ca > K > Na > Mg$, respectively. Compared with the threshold values of the adopted soil-quality guideline, only Cr and Pb showed concentration well above the threshold value. The result also

Fig. 3 Dendrogram displaying clustering of sampling points in the dumpsite

Fig. 4 Dendrogram showing clustering of all the parameters

indicated that the concentrations of Cr in some samples are likely to result in ecological risk. The highest values of CF, DegC, MDC, PLI, EF, I_{geo} and NIPI for the heavy metals were found at the center of the dumpsite, which receives the largest amount from the dumpsite. The PCA reveals that the metals have a strong association and may have a similar source which may be anthropogenic and/or natural. The CA categorized the sampling points into three similar groups. A strong positive correlation between the heavy metals and the major cation showed that they were derived from the same source(s) and have similar properties. Although the results from this study reveal that the soil at the center or close to the center of the dumpsite is polluted, it can also be used as a guide for planning of public policies to investigate the impact of indiscriminate citing of dumpsite on the environment.

Compliance with ethical standards

Conflict of interest There are no conflicts of interest with regard to this manuscript.

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