



Total concentration, contamination status and distribution of elements in a Nigerian State dumpsites soil

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ABSTRACT

Recent happenings (like fire outbreak and soil contamination) on Nigerian dumpsites had reiterated the need to frequently monitor and assess these dumpsites in order to avert environmental disaster. This study was conducted to determine the concentration and distribution of elements in four selected dumpsites in Ondo State, Nigeria. Soils sampled from the dumpsite were tested for their particle size distribution, cation exchange capacity and elemental concentration. The statistical relationship between the elements present was also carried out by analyzing its concentrations. The results showed that sand and clay were the main particles present in the studied dumpsite soils. The low cation exchange capacity values of the soil from the studied dumpsite showed its low retention capacity and fertility. The elements (calcium, magnesium, potassium) needed as macronutrients for plant growth on the dumpsite soil were not present in a large concentration which may be due to the low nutrient retention capacity of the soil. The heavy metals present in the dumpsite though above recommended permissible limit (with the exception of chromium) showed (through the contamination indices) no immediate risk on man and the environment. Statistical analysis showed that there was a statistically significant difference in the concentration of the elements present on the studied dumpsite soils. There was, however, no statistically significant difference in the studied dumpsites. Whatever future plans the State government may have for these dumpsites, this study had pointed out some areas of the soil that may need to be improved and/or monitored for proper remediation.

1. Introduction

The problem of environmental pollution stemming from indiscriminate waste disposal via open waste dumping has affected the human race overtimes. In developing countries like Nigeria, the majority of the cities disposed of their wastes on open dumpsites at unsuitable locations (Adewumi et al., 2019; Ajibade et al., 2019a) without a proper waste management technique (Ojuri et al., 2018; Al-Khatib et al., 2015). Consequently, these wastes then build into the pollutants with long-term adverse effects on the environment, the soil and groundwater being the major sink for contaminants (Oluwatuyi et al., 2019; Oluwatuyi and Ojuri, 2017). Although elements could spring up in small quantities from

rock minerals to soil forming process depending on its geologic structure. Open waste dumping, industrial activities and vehicle emissions had been large contributors to the contamination of soil by metals (Alsobou et al., 2018; Akinbile et al., 2016a; Ojuri et al., 2016; Kanmani and Gandhimathi, 2013). Heavy metals are immobile and harmless when in the solid state but become toxic in the aqueous state. The adverse effect of heavy metals on the environment is related to their availability in soil (Adewumi and Ajibade, 2015; Ogundiran and Osibanjo, 2009). Pollution of soil with heavy metals will undermine its properties (Ojuri and Oluwatuyi, 2014) and finally, present a menace to the human health through the food chain (Cesaro et al., 2019; Yanez et al., 2019; Aazami and KianiMehri, 2018; Ahmed et al., 2018; Welty et al., 2018; Meghea et al.,

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2009). While some of these heavy metals (like iron and zinc) function as a nutrient at a certain concentration to living organisms (Akinbile et al., 2016b). Others have led to the contamination of groundwater over time (Ilori et al., 2019; Ugya et al., 2018; Tiwari et al., 2017; Kanmani and Gandhimathi, 2013). Trace metals (like chromium) distributed indirectly at low concentrations through anthropogenic activities could be toxic. The presence of heavy metals in the soil should be closely monitored due to its toxicity at stipulated concentrations and its bioaccumulation capacity (Vaverková et al., 2019; Opaluma et al., 2012). Other elements needed as nutrients usually found on dumpsite soils are calcium, magnesium, potassium and sodium.

Previous studies had been conducted on Nigerian dumpsite soils to assess their heavy metal contamination. Ihedioha et al. (2017) reported cadmium as the only heavy metal posing a high risk to the environment at the dumpsite located in Uyo. The study by Ajah et al. (2015) investigating ten heavy metals in the dumpsite soil located in Enugu showed the need to remediate the dumpsite into a landfill because of its level of contamination. Azeez et al. (2011) suggested sorting of wastes on the dumpsite located in Abeokuta before final disposal so as to reduce/eliminate heavy metal contamination. One common conclusion from all these studies is that the study of the concentration, distribution and migration of elements (most especially heavy metals) in dumpsites could aid the concerned authorities in the removal or reduction of the contaminant(s) culminating in a safer soil (Zhang et al., 2018). Apart from understanding the concentration and distribution of elements in this region of the country. These previous studies conducted in Nigeria (unlike this study) were limited to the total concentration and distribution of elements in a single dumpsite (Ihedioha et al., 2017; Ajah et al., 2015;

Azeez et al., 2011).

This study aimed at assessing the concentration and the distribution of heavy metals alongside other essential metals present in soils from dumpsites in the central part of the State. The concentrations of these heavy metals were compared to its permissible limit in the soil as recommended by the Federal Environmental Protection Agency (FEPA) in Nigeria. Contamination statuses of these heavy metals were also determined through the evaluation of their indices. The study of the concentration and distribution of elements in dumpsite and surface soils had been investigated for the past few decades (Chaza et al., 2018; Ghazban et al., 2018; Odukoya and Laniyan, 2016; Adewumi and Ajibade, 2015). However, the study in this area is rather new, essential for the monitoring of the area and in comparison, with other areas. Above all, an in-depth analysis was conducted and the state of the dumpsites (pertaining to elemental distribution) within the specified area was fully discussed. The results of this study can help to better understand the fate of studied elements in different dumpsites.

2. Materials and methods

2.1. Study area description

The study area consists of three local government areas (Akure south, Akure north and Ifedore) located in the central part of Ondo State, Nigeria. Four dumpsites namely Igbatoro (7.084°N; 5.363°E), Iju-Itaogbolu (7.380°N; 5.253°E), Ijare (7.365°N; 5.175°E) and FUTA (7.304°N; 5.137°E) were selected from the study area. Location of the study area showing the dumpsites in the different local government areas

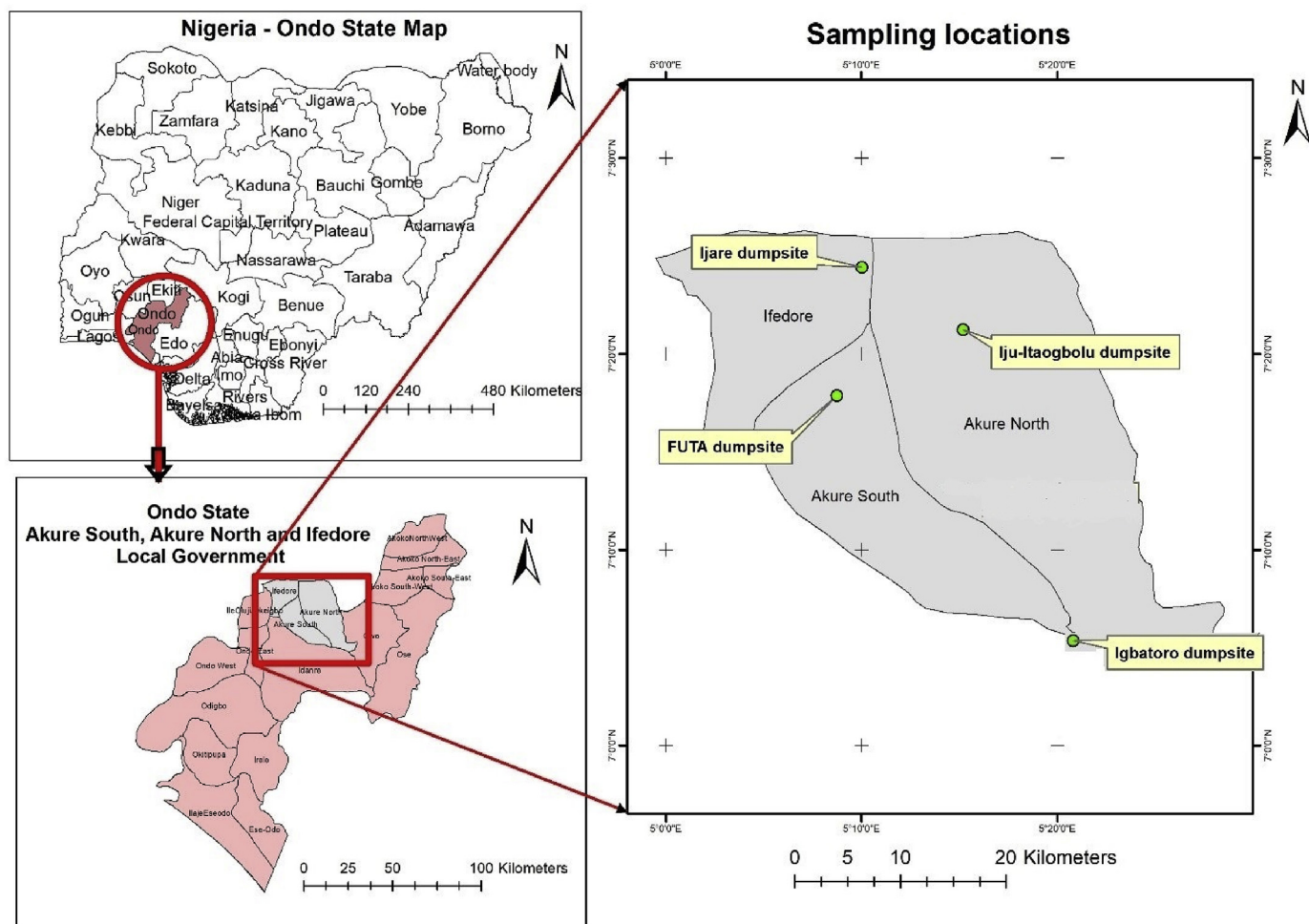


Fig. 1. Map showing study area and dumpsites location in Ondo State, Nigeria.

in Ondo State and map of Nigeria is displayed in Fig. 1. In terms of land area covered, the volume of waste deposited and the number of people using it, the dumpsites were grouped into major and minor. The major dumpsites were the Igbatoro and Iju-Itaogbolu dumpsites while the Ijare and FUTA dumpsites were minor dumpsites. Igbatoro dumpsite is the recognized dumping ground for more than 350,000 people (as at the year 2008), receiving more than 100,000 metric tons of wastes per year (Ojuri et al., 2018; Akinbile, 2012). While solid wastes (of about 5000 metric tons of wastes per year) from about 15,000 people staying in and around the Federal University in Akure is brought to the FUTA dumpsite. The study area was selected because of its centrality, proximity and accessibility. The climate of the study area which is tropical consists of the dry and wet seasons (Ajibade, 2013). The rainfall varies about 1500 mm and 3000 mm every year (Ajibade et al., 2014a). The atmospheric temperature ranges between 25 °C and 32 °C and a mean annual relative humidity of about 80 percent. The dumpsites soil parent materials are more of crystalline acid rocks which is made up of ferruginous tropical soils (Akinbile et al., 2016; Ajibade et al., 2014b) which encourage the growth of crops like maize, cassava and yam in enormous amount that is economically sustainable (Adewumi and Ajibade, 2019).

2.2. Soil sampling and testing

The soil was randomly sampled from each dumpsite using the hand auger (2.5 cm diameter) and a spatula in a logical array (100 × 100 m grid) (Kodirov et al., 2018). Overlying wastes in form of plant materials (roots and leaves) and other forms of wastes on the topsoil were manually removed. The soil was sampled from three vertical layers to depict distribution in the vertical profile, they were at depths: 0–10 cm (hereafter referred to as v1 layer in this study), 10–20 cm (hereafter referred to as v2 layer in this study) and 20–30 cm (hereafter referred to as v3 layer in this study). Three (3) samples were collected from each vertical layer, making a total of nine (9) samples from each dumpsite. A control sample was obtained at a distance of 20 m away from each dumpsite as means of comparison in the analysis and also to depict distribution in the horizontal profile. The distance at which control samples were taken was limited to 20 m, as it could not be extended further in order not to encroach the government reserved areas surrounding these dumpsites. The multiple samples collected were moved to the laboratory for analysis in an appropriately labelled non-reacting polyethylene bags. Particle size distribution which includes the sieve (to determine the coarse portion of the soil) and sedimentation (to determine the fine portion of the soil) analysis were performed on each soil sample in accordance to ASTM D6913 (2017) and ASTM D7928(2017) respectively. The samples for each zone were air-dried at room temperature, sieved through 2 mm mesh, ground, and homogenized in an agate mortar. Concentrations of chromium, iron and manganese in the dumpsite soils were determined using the X-ray fluorescence spectrometer (XRF, AS - 4000, USA). The standard reference material (SRM) 2709 available from the National Institute of Standards and Technology (NIST) was used. The percentage recovery was in the range of 80–90%. For the remaining heavy metals, to disconnect inhibiting components and enable actual measurement, acid digestion was done on soil samples weighing 0.2 g. It is done in open vessels with convection or microwave heating, reagents used are nitric acid and hydrogen peroxide. The digest was thereafter diluted to 10 ml with distilled deionized water. The concentrations of nickel and zinc in the digested liquid were measured using the atomic absorption spectrophotometer (AAS, AA-6300C, Japan). Flame absorption spectrometry (FAAS) was used for the direct analysis of most elements including nickel and zinc in solid soil samples. Other elements (alkali and alkaline earth metals) present in the soil include magnesium (Mg) and calcium (Ca) were determined using the Versenate or ethylene diamine tetra-acetic acid (EDTA) method. Potassium (K) and sodium (Na) were also determined using the FAAS technique (Pansu and Gautheyrou, 2007). Triplicate samples of dumpsite soil were each tested for the concentration of heavy, alkali and alkaline metals present in them. The mean and standard

deviation of each were reported in the results and discussion section. The cation exchange capacity (CEC) which is a measure of cations that can be withheld on the soil particle was determined in accordance with ASTM D7503(2018). Other bio-physicochemical data from the dumpsites soil can be found in Ajibade et al. (2019b).

2.3. Statistical analysis

The metals concentration values were statistically analyzed using a one-way non parametric analysis of variance (ANOVA) also known as Kruskal-Wallis Test at 5% level of significance. The concentration data was assigned as the dependent variable (test fields) while the metal type was assigned as the independent variable (groups). The test of between-subjects effect was obtained between the concentrations and the metals. The correlation coefficients between concentrations of the metals at the different dumpsites and sampling points were also determined using the non-parametric Spearman correlation test at 5% level of significance. Data did not have a normal distribution and the assumption of equality of variance was not fulfilled, hence the need to use non-parametric test.

2.4. Contamination/pollution status determination

The contamination statuses which include metal pollution index (MPI), geo-accumulation index (Igeo), ecological risk factor (ERF) and contamination factor (CF) of the heavy metals present in the dumpsites soil were determined. MPI is the concentration of heavy metal in studied soil divided by the concentration of heavy metal in the control soil. Igeo is the logarithm base two of the concentration of heavy metal in studied soil divided by the one and a half of concentration of heavy metal in the control soil. ERF is equal to the toxic response factor multiplied by metal pollution index. The toxic response factors were 2, 0, 1, 5 and 1 for chromium, iron, manganese, nickel and zinc respectively (Hakanson, 1980). The methodology, classifications and remarks for the MPI, Igeo and ERF statuses can be found in the literature (Ebong et al., 2018; Ojuri et al., 2016). CF was determined in accordance with the methodology of Ihedioha et al. (2017).

3. Results and discussion

3.1. Trace metals composition, concentration and distribution in dumpsite soil

Distribution and migration of elements in the soil depend on its different particle sizes (Qiao et al., 2017). The particle sizes detailing the percentages of gravel, sand, silt and clay present in the Igbatoro, Iju-Itaogbolu, Ijare and FUTA dumpsite soils is shown in the supplementary file (Figs. S1-4) respectively. Concentration of chromium, iron, manganese, nickel and zinc is shown in the supplementary file (Figs. S5-9) respectively. The concentrations of chromium, iron, manganese, nickel and zinc in the various dumpsite locations ranged from below the limit of quantification to 1.9 ± 0.08 mg/kg, 434.0 ± 72.0 to 3484.5 ± 180.0 mg/kg, 11.0 ± 7.2 to 119.8 ± 13.0 mg/kg, 0.9 ± 0.2 to 10.2 ± 0.5 mg/kg respectively. The Igbatoro dumpsite soil consists of mainly sand particles, about 64%, 61%, 65% and 62% of the soil in the v1, v2, v3 layers and control samples respectively were sand particles. This percentage of sand in dumpsite soil were in the range of previous studies (Yahaya et al., 2010; Okoronkwo et al., 2006). For the clay particles, it was about 27%, 25%, 25% and 27% of the soil in the v1, v2, v3 layers and control samples respectively. In the Igbatoro dumpsite, the sample from the v1 layer (topsoil upon which wastes were dumped) had the highest chromium, iron, nickel concentration. While the highest manganese and zinc concentration were tested in the v3 and v2 layered soil samples. The lowest concentrations for the metals were detected in the control sample. Igbatoro dumpsite had a Cation exchange capacity (CEC) of 2.90 cmol/kg. The low CEC values in the studied dumpsite was an indication of a poor soil fertility and nutrient retention capacity in the

Table 1

Estimated mean concentration and standard deviation of heavy metals in the studied dumpsite soils in mg/kg.

Dumpsites	Heavy metals				
	Chromium	Iron	Manganese	Nickel	Zinc
Igbatoro	0.2250 ± 0.287	1194 ± 800.0	82.90 ± 48.29	2.050 ± 0.939	15.28 ± 11.86
Iju-Itaogbolu	0.5500 ± 0.911	1646 ± 1096	93.63 ± 33.22	4.025 ± 4.127	18.88 ± 7.463
Ijare	0.6500 ± 0.656	1876 ± 658.8	118.3 ± 1.915	3.875 ± 1.448	8.050 ± 2.398
FUTA	0.2000 ± 0.216	2355 ± 1139	119.1 ± 0.645	4.150 ± 1.066	7.280 ± 0.940
FEPA PERMISSIBLE LIMIT	2.000	400.0	50.00	0.020	3.000

soil. The low CEC values may be attributed to the fact that organic wastes in some of these studied dumpsites are recycled into compost (Elemile et al., 2019). Soils with low CEC also have low ability to retain water.

The Iju-Itaogbolu dumpsite soil had more of clay particles with about 51%, 54%, 49% and 47% of the soil present in the v1, v2, v3 layers and control samples respectively. About 32%, 33%, 36% and 36% of the soil present in the v1, v2, v3 layers and control samples respectively in the Iju-Itaogbolu dumpsite soil were sand particles. The dumpsite CEC value was 3.40 cmol/kg. Soil samples from the v3 layer of the Iju-Itaogbolu dumpsite had the highest trace metal concentration. This could be attributed to the clay percentage (being lower in comparison to other layers) and its sand percentage (being higher in comparison to other layers). The percentage of clay present in the Iju-Itaogbolu dumpsite soil was enough to act as hydraulic barriers for metal adsorption (Ojuri et al., 2017) and material for waste containment structures (Akosile et al., 2020; Ajibade et al., 2019c; Ojuri and Oluwatuyi, 2017, 2018). The Ijare dumpsite soil had more of sand than clay particles, about 37%, 59%, 52% and 48% of the soil present in the v1, v2, v3 layers and control samples respectively were sand particles. About 31%, 27%, 31% and 43% of the soil present in the v1, v2, v3 layers and control samples respectively in the Ijare dumpsite soil were clay particles. The dumpsite CEC value was 2.99 cmol/kg. Ijare dumpsite had chromium below the quantification limit on the control sample, the highest concentration of chromium (1.5 ± 0.1 mg/kg) detected was at the v2 layer. Iron and zinc had their highest concentration in the v3 layer while manganese and nickel were in the v1 layer.

FUTA dumpsite soil also had more of sand than clay particles, about 64%, 59%, 52% and 52% of the soil in the v1, v2, v3 layers and control samples respectively were sand particles. For the clay particles, it was about 25%, 23%, 28% and 27% of the soil in the v1, v2, v3 layers and control samples respectively. The percentage of sand and clay in this dumpsite were in the range of previous studies (Nava-Martinez et al., 2012). The FUTA dumpsite soil had a CEC value of 2.97 cmol/kg. Chromium was not detected at the v2 layer while the highest concentration (0.5 ± 0.2 mg/kg) was detected at the v1 layer of the dumpsite. Iron, manganese and nickel had its highest concentration measured from the control samples. This may be attributed to the scrap metals and corroded vehicle dumped/sorted out around the point where the control sample was taken. Also, the high percentage of sand particles in the control sample may have led to high pollutant leaching potentials. Table 1 presents the average concentration of the metals at each dumpsite with the permissible limit. The chromium concentration from soil samples in these dumpsites were lower than those from previous studies in Nigerian states (Luter et al., 2011; Oyelola and Babatunde, 2008). None of the samples collected from the dumpsites exceeded the permissible limit for chromium in soil as recommended by FEPA (1991). The average concentration of iron and zinc in this study was greater than the one obtained from a previous study in Akwa Ibom state (Ebong et al.,

Table 2

Pairwise comparison between concentrations of heavy metals using the Kruskal-Wallis Test.

Pairwise comparison	Test Statistic	Significance	Adjusted Significance*
Chromium–Nickel	16.312	0.047	0.470
Chromium–Zinc	31.312	0.000	0.001
Chromium–Manganese	–47.375	0.000	0.000
Chromium–Iron	63.750	0.000	0.000
Nickel–Zinc	–15.000	0.068	0.678
Nickel–Manganese	–31.062	0.000	0.002
Nickel–Iron	47.438	0.000	0.000
Zinc–Manganese	–16.062	0.051	0.505
Zinc–Iron	32.438	0.000	0.001
Manganese–Iron	16.375	0.046	0.462

*Significance values have been adjusted by the Bonferroni correction for multiple tests.

2008). The average concentration of nickel was however, in the range of what was measured from studies in Abia (Okoronkwo et al., 2006) and Lagos state (Oyelola and Babatunde, 2008). All samples collected from the dumpsites exceeded the permissible limit for iron, manganese, nickel and zinc in soil as recommended by FEPA (1997).

3.2. Statistical analysis of heavy metals concentration in dumpsite soil

A one-way non-parametric ANOVA analysis (also known as Kruskal-Wallis Test) was carried out on the concentration of heavy metals present in the studied dumpsites. The test involve comparison between groups in terms of the mean rank on the dependent variable (concentration). The null hypothesis stated that the distribution of concentration is the same across categories of heavy metals in dumpsite soil. In the independent samples Kruskal-Wallis test, the null hypothesis was rejected because the obtained asymptotic significance level (0.00) was less than alpha level (0.05). The pairwise comparisons between the earth metals is shown in Table 2. There was statistically significant difference ($p < 0.050$) between the following pairs: chromium and zinc, chromium and manganese, chromium and iron, nickel and manganese, nickel and iron, zinc and iron. There was no statistically significant difference ($p > 0.050$) between the following pairs: chromium and nickel, nickel and zinc, zinc and manganese, manganese and iron. Mean concentration of heavy metals in dumpsite soil (Table 1), showed that only the concentration of chromium was below the permissible limit for heavy metal in soil. In terms of mean rank, iron had the highest (72.50) and chromium the lowest (8.75). The Spearman's correlation coefficient showed that there was a negative correlation between the heavy metal types and its concentration $r_s = -0.301$ at a p-value of $0.007 < 0.010$.

3.3. Contamination status of studied dumpsites

The concentration of the heavy metals present in the dumpsite soil was used in determining their contamination status (Table 3). The MPIs ranged from 0.000 to 7.536 with a significance ranging from 'very slight contamination' to 'severe pollution'. For the Igbatoro dumpsite soil, the MPI for chromium was 0.000 while that of manganese was 7.536. The MPI of chromium in Igbatoro dumpsite soil showed that it won't have any negative effect on the environment. The MPIs of other heavy metals present in Igbatoro dumpsite soil was, however, greater than 1 an indication they (the heavy metals) may pose a negative effect on the environment. Iju-Itaogbolu dumpsite soil also had a MPI (0.329) less than 1 for chromium while MPIs of other heavy metals were higher than 1. Heavy metals in the soil from the Ijare dumpsite all had their MPIs greater than 1 while heavy metals in the soil from FUTA dumpsite all had their MPIs lower than 1. The Igeo which ranged from -2.189 to 2.329 with classes ranging from 'uncontaminated' to 'moderately to strongly contaminated'. The Igbatoro dumpsite soil had an Igeo class that was 'uncontaminated' for chromium and 'moderately to strongly

Table 3
Contamination status of the heavy metals present in the studied dumpsite soils.

Dumpsite	Heavy metal	Metal pollution index (MPI)	Significance of MPI	Remarks on MPI	Geo-accumulation index (Igeo)	Igeo class	Ecological risk factor (ERF)	ERF grade
Igbatoro	Chromium	0.000	Very insignificant contamination	No adverse consequence on environment	0.000	Uncontaminated	0.000	Low ecological risk
	Iron	3.336	Bearable pollution	May proffer adverse consequence on environment	1.153	Moderately contaminated	0.000	Low ecological risk
	Manganese	7.536	Stern pollution	May proffer adverse consequence on environment	2.329	Moderately to strongly contaminated	7.536	Low ecological risk
	Nickel	2.278	Bearable pollution	May proffer adverse consequence on environment	0.603	Uncontaminated to moderately contaminated	11.389	Low ecological risk
	Zinc	3.182	Bearable pollution	May proffer adverse consequence on environment	1.085	Moderately contaminated	3.182	Low ecological risk
Iju-Itaogbolu	Chromium	0.329	Bearable contamination	No adverse consequence on environment	−2.189	Uncontaminated	0.658	Low ecological risk
	Iron	2.909	Bearable pollution	May proffer adverse consequence on environment	0.956	Uncontaminated to moderately contaminated	0.000	Low ecological risk
	Manganese	2.071	Bearable pollution	May proffer adverse consequence on environment	0.466	Uncontaminated to moderately contaminated	2.071	Low ecological risk
	Nickel	2.012	Bearable pollution	May proffer adverse consequence on environment	0.424	Uncontaminated to moderately contaminated	10.063	Low ecological risk
	Zinc	1.547	Insignificant pollution	May proffer adverse consequence on environment	0.045	Uncontaminated to moderately contaminated	1.547	Low ecological risk
Ijare	Chromium	2.889	Bearable pollution	May proffer adverse consequence on environment	0.945	Uncontaminated to moderately contaminated	5.778	Low ecological risk
	Iron	1.820	Insignificant pollution	May proffer adverse consequence on environment	0.279	Uncontaminated to moderately contaminated	0.000	Low ecological risk
	Manganese	1.023	Insignificant pollution	May proffer adverse consequence on environment	−0.553	uncontaminated	1.023	Low ecological risk
	Nickel	1.614	Insignificant pollution	May proffer adverse consequence on environment	0.106	Uncontaminated to moderately contaminated	8.073	Low ecological risk
	Zinc	1.278	Insignificant pollution	May proffer adverse consequence on environment	−0.231	uncontaminated	1.278	Low ecological risk
FUTA	Chromium	0.833	Very stern contamination	No adverse consequence on environment	−0.848	uncontaminated	1.667	Low ecological risk
	Iron	0.568	Stern contamination	No adverse consequence on environment	−1.401	uncontaminated	0.000	Low ecological risk
	Manganese	0.995	Very stern contamination	No adverse consequence on environment	−0.592	uncontaminated	0.995	Low ecological risk
	Nickel	0.830	Very stern contamination	No adverse consequence on environment	−0.854	uncontaminated	4.150	Low ecological risk
	Zinc	0.933	Very stern contamination	No adverse consequence on environment	−0.684	uncontaminated	0.933	Low ecological risk

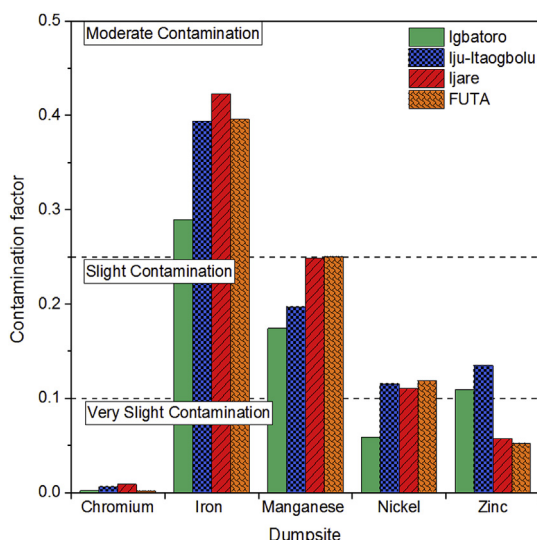


Fig. 2. Contamination factor and status of the heavy metals present in the studied dumpsite soils.

contaminated' for manganese. For the Iju-Itaogbolu dumpsite soil, Igeo class was 'uncontaminated' for chromium and 'uncontaminated to moderately contaminated' for the rest of the heavy metals. Ijare dumpsite soil could be classified according to Igeo as 'uncontaminated' for manganese and zinc while other heavy metals are 'uncontaminated to moderately contaminated'. The Igeo classification for FUTA dumpsite soil showed that it was 'uncontaminated' despite the heavy metals present in it. The ERF on the heavy metals present in the soil from the four studied dumpsites was of low ecological risk. The CF (Fig. 2) showed that iron on the four studied dumpsites was classified as moderate contamination (which is the highest form in this study). Chromium on the four studied dumpsites, nickel at Igbatoro dumpsite, zinc at Ijare and FUTA dumpsite were classified as slight contamination. In terms of the contamination level from the least to the most, the studied dumpsites could be ranked in the order: FUTA < Iju-Itaogbolu < Igbatoro < Ijare.

3.4. Alkali and alkaline earth metals composition and distribution in dumpsite soil

The concentrations of calcium in various dumpsite soil samples ranged from 120.0 ± 29.2 to 460.0 ± 20.5 mg/kg (supplementary file Fig. S10). On the dumpsite, sources of calcium include bone, eggshell (Oluwatuyi et al., 2018) and pozzolanic materials used in construction that were later deposited as waste. In the Igbatoro dumpsite, calcium concentration was 120.0 ± 29.2 mg/kg in the control sample and 280.0 ± 15.0 mg/kg in the v3 layer sample. Distribution of calcium in the Iju-Itaogbolu dumpsite showed a concentration of 140.0 ± 18.4 mg/kg in the control sample and 460.0 ± 20.5 mg/kg in the v3 layer sample. Ijare dumpsite had a calcium concentration of 220.0 ± 21.6 mg/kg in the v2 layer sample and 340.0 ± 13.0 mg/kg in the v1 layer sample. FUTA

Table 4
Pairwise comparison between concentrations of earth metals using the Kruskal-Wallis Test.

Pairwise comparison	Test Statistic	Significance	Adjusted Significance*
Magnesium–Sodium	−5.562	0.398	1.000
Magnesium–Calcium	31.938	0.000	0.000
Magnesium–Potassium	−37.250	0.000	0.000
Sodium–Calcium	26.375	0.000	0.000
Sodium–Potassium	31.688	0.000	0.000
Potassium–Calcium	−5.312	0.419	1.000

*Significance values have been adjusted by the Bonferroni correction for multiple tests.

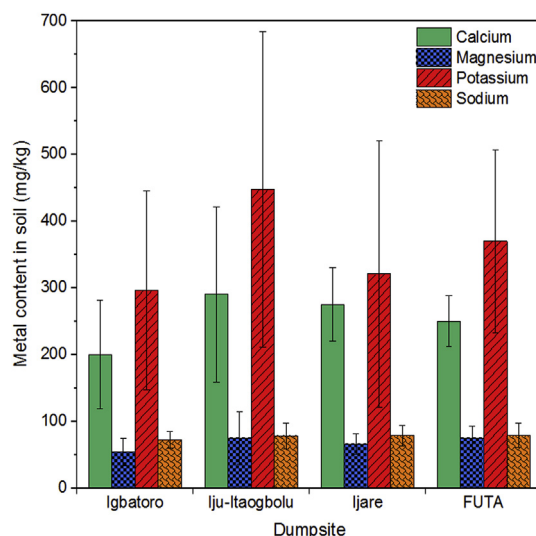


Fig. 3. Estimated mean concentration and standard deviation of metals in the studied dumpsite soils.

dumpsite had a calcium concentration of 220.0 ± 21.1 mg/kg in the v2 layer sample and 300.0 ± 29.0 mg/kg in the v1 layer sample.

The concentrations of magnesium in various dumpsite soil samples ranged from 36.0 ± 12.2 to 132.0 ± 18.5 mg/kg (supplementary file Fig. S11). Magnesium is one of the macronutrients needed for plant growth, its sources include decomposed rocks and clay minerals. Distribution of magnesium in Igbatoro dumpsite showed a concentration of 36.0 ± 12.2 mg/kg in the control sample and 72.0 ± 13.3 mg/kg in the v1 layer. Distribution of magnesium in Iju-Itaogbolu and Ijare dumpsites were similar. Both dumpsites had their highest magnesium concentration in the v3 layer soil while the lowest was in the v2 layer soil. FUTA dumpsite had a magnesium concentration of 60.0 ± 12.8 mg/kg in the v3 layer sample and 96.0 ± 20.9 mg/kg in the v1 layer sample.

The concentrations of potassium in various dumpsite soil samples ranged from 120.0 ± 29.2 to 460.0 ± 20.5 mg/kg (supplementary file Fig. S12). In plants, potassium is a required element for growth and reproduction. On the dumpsite soil, sources of potassium include organic waste and wood ash. Igbatoro dumpsite had its lowest potassium concentration of 101.0 ± 21.0 mg/kg in the v1 layer sample and the highest concentration of 429.0 ± 20.5 mg/kg in the v3 layer sample. Iju-Itaogbolu dumpsite had a potassium concentration of 109.0 ± 15.0 mg/kg in the v3 layer sample and 651.0 ± 29.2 mg/kg in the control sample. Ijare dumpsite had a potassium concentration of 140.0 ± 21.6 mg/kg in the v2 layer sample and 581.0 ± 19.3 mg/kg in the v3 layer sample. FUTA dumpsite had a potassium concentration of 211.0 ± 21.1 mg/kg in the v2 layer sample and 519.0 ± 22.0 mg/kg in the control sample.

The concentrations of sodium in various dumpsite soil samples ranged from 51.0 ± 6.9 to 99.0 ± 7.8 mg/kg (supplementary file Fig. S13). Sodium is a silver-white highly malleable element that reacts explosively in water and found abundantly in common salts. It is not a plant nutrient and, in a concentration, greater than 230 mg/kg result in high salinity and poor soil structure. In the Igbatoro dumpsite, sodium concentration was 81.0 ± 12.2 mg/kg in the control sample and 53.0 ± 12.0 mg/kg in the v3 layer. Distribution of sodium in Iju-Itaogbolu and Ijare dumpsite soils were similar. Both had the same mean concentration of sodium on the control and v3 layer samples which were the highest. The lowest concentration of sodium for Iju-Itaogbolu (51.0 ± 6.9 mg/kg) and Ijare (62.0 ± 8.0 mg/kg) dumpsite soils was in the v1 layer. FUTA dumpsite also had the highest concentration of sodium in the control sample (99.0 ± 7.8 mg/kg) and the lowest in the v3 layer sample (56.0 ± 11.8 mg/kg).

3.5. Statistical analysis of alkali and alkaline earth metals in dumpsite soil

A one-way non-parametric ANOVA analysis (also known as Kruskal-Wallis Test) was also carried out on the concentration of alkali and alkaline earth metals present in the studied dumpsites. The test involves comparison between groups in terms of the mean rank on the dependent variable (concentration). The null hypothesis stated that the distribution of concentration is the same across categories of alkali and alkaline earth metals in dumpsite soil. In the independent samples Kruskal-Wallis, the null hypothesis was rejected because the obtained asymptotic significance level (0.00) was less than alpha level (0.05). The pairwise comparisons between the earth metals is shown in Table 4. There was statistically significant difference ($0.000 < 0.050$) between the following pairs: magnesium and calcium, magnesium and potassium, sodium and calcium, sodium and potassium. There was however, no significant difference ($0.398 > 0.050$) between magnesium and sodium and between potassium and calcium ($0.419 > 0.050$). The estimated mean concentration of the metals in dumpsite soil (Fig. 3), showed that the mean concentration of potassium was the highest. This was also confirmed by the Kruskal-Wallis Test, potassium had the highest mean rank of 51.06 and magnesium the lowest rank of 13.81. The Spearman's correlation coefficient revealed that there was a weak negative correlation between the earth metal types and its concentration $r_s = -0.254$ at a p-value of $0.043 < 0.050$.

4. Conclusions

The study was conducted in order to monitor and assess the elemental concentration and contamination status of dumpsite soil in a Nigerian State. Four dumpsites named after their locations (Igbatoro, Iju-Itaogbolu, Ijare and FUTA) were selected from the central part of the State for this study. Multiple soil samples were collected for testing from the dumpsites at three depth levels and 20 m away from the dumpsite. The particle size distribution test showed that soils on the dumpsites studied were more of sand and clay particles. The concentrations of heavy metals present in the studied dumpsite soils followed the sequence: $Fe > Mn > Zn > Ni > Cr$. All these heavy metal except chromium were above the permissible limit recommended by FEPA in Nigeria. Heavy metal contamination status of the studied dumpsite was also determined through various indices. Remarks (on these indices) showed that despite the presence of heavy metals in the studied dumpsite soil, their concentration was not at an alarming rate and therefore may pose none or less risk to man and the environment. However, there is need by the State government (through the waste management agency) to constantly monitor and assess this dumpsite as the contamination levels could elevate easily due to accumulated heavy metals present in the soil. Speciation of these metals to know the various forms by which they occur in the dumpsite soil is also important. The contamination level in the studied dumpsite followed the sequence: Ijare > Igbatoro > Iju-Itaogbolu > FUTA. The alkali and alkaline earth metals present in the studied dumpsite soil (apart from sodium) were macronutrients needed for plant growth. These metals were, however, not present in large concentration and they followed the sequence: $K > Ca > Na > Mg$. Despite the notion that dumpsite soils will be fertile because of the organic waste dumped on it (which could serve as organic fertilizer). The obtained CEC values from the studied dumpsite soils were low, an indication of soil with low fertility.

Declaration of competing interest

No potential conflict of interest was reported by the Authors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.indic.2020.100021>.

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