Communication In Physical Sciences 2020, 5(2): 124 -135 http://journalcps.com/

Ecological Risk Assessment of Heavy Metals in Soils from Dumpsites within Umuahia, Nigeria

***Jude C. Nnaji, and E. Chukwu**
Received 15 March 2020/Accepted 28 April 2020/Published online: 29 April 2020

Abstract *Ecological risk assessment of heavy metals at five dumpsites (1 – 5) in Umuahia, Nigeria was carried out. Soil samples were collected at distances of 0, 5 and 10 m from each dumpsite and from a control site. Samples of water leaf and African Spinach leaf were also collected and analysed for heavy metal ions. Soil physicochemical parameters were determined using official and recommended methods while heavy metal ion concentrations were determined using Atomic Absorption Spectrophotometer. Results obtained indicated that the texture of soil samples were predominantly sandy loam while pH values ranged from 6.21±0.37 to 7.70±0.29. Organic matter content ranged from 1.65±0.52 to 4.15±0.36 % while electrical conductivity had a range of 98.47±7.25 – 201.57±15.86 µS/cm across the dumpsites. Mean concentrations of heavy metal ions in soils from the dumpsites were significantly higher ($P < 0.05$) than those from the control site. Average metal pollution indices showed that soils in the dumpsites are unpolluted except cadmium in Dumpsites 4 and 5. Degree of contamination values showed low degrees of contamination but enrichment factors for Pb, Cd and Cr in some Dumpsites indicated significant enrichments. All dumpsites had geo-accumulation indices less than 1.00 indicating unpolluted soil except Pb and Cr in some Dumpsites which showed moderate pollution. Ecological risk and potential ecological risk indices indicated low ecological risk. Mean concentrations of cadmium ions in the two vegetables from the dumpsites exceeded the Codex maximum limits for Cd in leafy vegetables. Although severe pollution is not pronounced for soils within the study dumpsites, it is recommended that measures should be engaged to control waste disposal in these dumpsites since heavy metals can bioaccumulate and increase in concentration to severe the environmental quality of the dumpsites in the near future.*

Key Words: *Dumpsite, metals, soil, vegetables, ecological, risk*

***Jude C. Nnaji**
Department Of Chemistry
Michael Okpara University of Agriculture
Umudike, Abia State, Nigeria
Email: judennaji30@gmail.com
Orcid Id: 0000-0002-5569-4818

E. C. Chukwu
Department Of Chemistry
Michael Okpara University of Agriculture
Umudike, Abia State, Nigeria
Email: manniechiedozie@gmail.com
Orcid Id: 0000-0003-3887-1875

1.0 Introduction

The major sources of heavy metals in the environment include increased urbanization, disposal of untreated waste, mining, smelting, burning of fossil fuels and waste disposal (Akter *et al*., 2019). Heavy metals can be leached into the environment when contaminated waste is not disposed properly. As urbanization increases and human population grows, there is need to manage waste produced from human activities and this has led to the creation of dumpsites. In most dumpsites, indiscriminate and uncontrolled wastes are disposed in such a way and manner that the environment is not protected from the detrimental effect that could be provoked by these activities (Waste Atlas 2014). Solid waste management is a major environmental challenge in Nigeria since most cities lack standard engineered landfills (Chinedu *et al.*, 2018). Open landfills are the primary means of municipal solid waste (MSW) disposal in most countries in the world, including Nigeria because the practices offer low economic cost, relative convenience, less technological involvement and have capacity to accumulate large amounts of solid waste compared to other methods such as incineration. The absence of proper engineered landfills for disposal of wastes in Umuahia, Abia State has given rise to the proliferation of open dumps that are scattered within the municipality. These practices can generate unhealthy environmental impacts. For example, leachate

formation occurs when the percolating water dissolves the soluble components out of the solid material. This is usually heavily contaminated and maybe difficult to handle within the confinement of environmental safety requirements (Ukpong *et al*., 2015).

Many factors influence the leachate composition including the types of wastes deposited in the landfill, composition of wastes, moisture content, particle size, degree of compaction, hydrology of the site, ~~the~~ climate and age of the landfill and other site specific conditions such as landfill design and type of liner used (Obasi *et al*., 2012; Okoronkwo *et al*. 2005; Zaware, 2014). Several factors can complicate risk assessment of the toxicity of heavy metals in a leachate because the toxicity of the leached heavy metals depends on factors such as pH, type of soil, presence of chelating agents or the ability of the metal to complex with some compounds in the environment (Rafizul *et al*., 2012; Tchounwou *et al.*, 2012). Accumulation of heavy metals can degrade soil quality, reduce crop yield and thus negatively impact the health of humans, animals and the ecosystem (Nagajyoti *et al*. 2010).

Ogunbanjo *et al*. (2016) investigated the concentrations of Cu, Zn, Cd, Pb, and Fe in soils at two municipal landfills in Sagamu, Ogun state, Nigeria and reported excessive contamination of the land by copper and cadmium ions. Eddy *et al*. (2006) found high concentration of heavy metals in some dumpsites within Akwa Ibom State. Although their results did not indicate imminent contamination, they concluded that if continuous disposal of waste in the studied dumpsites are not checked, future contamination of the soil by heavy metals maybe observed. Ebong *et al*. (2020) recently reported that abattoir waste can constitute significant presence of Fe, Pb, Zn, Cu, Cr and Ni. These heavy metals were identified in an old abattoir dumpsite in Akwa Ibom State, Nigeria. Some studies have also linked the primary contamination source of heavy metals to plants (which is the primary producer) cultivated in such soil and the consequence transfer to higher organism through the food chain (Azeez *et al.*, 2011; Ajiboso *et al.,* 2003; Olabanji *et al*., 2015; Umoren, *et al*., 2007)

In Umuahia, some studies on heavy metals in soil around some dumpsites have been reported. Chinyere and Madu (2015) studied concentrations of some heavy metal ions in soil around some dumpsites in Aba and Umuahia. They reported significant presence of Cu, Zn, Mn, Cd, Pb, Fe, Cr, Co, Ni, and Hg in the dumpsites compared to the control sites. They attributed the source of these heavy metal ions to anthropogenic waste. Soil samples from Ubakala and Abia Tower dumpsites in Umuahia and a nearby farm land (control site) were analysed for Cd, Cu, Mn, Pb, Zn, Fe, Ni, and Cr ions by Obasi *et al*. (2013). They found significant presence of these heavy metals in the dumpsites compared to the adjourning control sites. Since the disposal of wastes to these dumpsites is continuous and heavy metals have the tendency to bioaccumulate (since they are not biodegradable) (Eddy, *et al*., 2004; Odoemelam and Eddy, 2004), the need for continuous or routine sampling and analysis cannot be overemphasized. Also results from most of the studied dumpsites within Umuahia have not initiated comparison between dumpsites to ascertain possible correlation of the type of waste that are common to the dumpsites. Therefore, the present study was designed to analysed and compare concentrations of Cd, Cr, Co, Fe and Pb in soils and plants within some dumpsites in Umuahia metropolis.

2.0 Materials and Methods

2.1 The Study area

Umuahia is the capital of Abia State and lies within 5° 31' 29.68" N 7° 29' 40.60" E. The city is located in the south eastern part of Nigeria with a population of 359,230 people (National Population Commission, 2006). Domestic waste, household wastes and organic wastes are disposed of in certain strategic points provided by the Abia State Environmental Protection Agency (ASEPA) within the city. However, unofficial dumpsites are littered all over the city. The dumpsites studied with their locations and GPS coordinates are shown in Table 1 and Fig. 1 respectively. They were identified and selected on the basis of factors like population density, variety of waste and magnitude of dumpsite.

Table 1. Dumpsites and GPS Coordinates

Location ID	Dumpsite	GPS Coordinates
1	Government College	05° 29' 57" N, 007° 32' 19" E
2	New Timber Shed Market	05° 30' 24" N, 007° 32' 08" E
3	Ahiaeke Market	05° 30' 40" N, 007° 31' 49" E
4	Ohokobe Market	05° 30' 59"N, 007° 30' 10" E
5	Upstair Line	05° 30' 48" N, 007° 29' 53" E

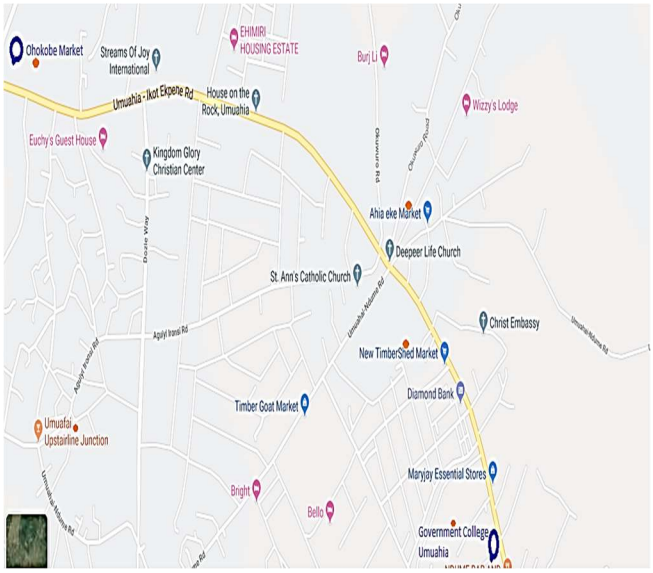

Fig. 1. Map of Umuahia showing sampling locations (source: Google map)

2.2 Sampling

Soil samples were collected in triplicate with a soil auger at soil depth of 0-15 cm and at distances of 0, 5, and 10 m from each site. Soil sample was also collected 100 m from the Government College Dumpsite and this served as the control sample. The soil samples were packed in plastic bags, labelled appropriately and taken to the laboratory with minimum delay for analysis. Two edible plant samples, water leaf (*Talinum triangulare*) and African Spinach (*Amaranthus hybridus*) were spotted near each dumpsite. The leaves on each plant were removed, labelled and also transported to the laboratory in plastic bags for analysis.

2.3 Sample pre-treatment

The soil samples for heavy metal analysis were pre-treated to remove non-soil materials using the method described by Shah *et al*. (2013). This involves air drying for 48 hours followed by gentle grinding with a wooden pestle and mortar and sieving through a 0.2 mm sieve. The dry soil samples were stored in desiccators prior to analysis. The leaves of the plants were pre-treated and thoroughly washed with distilled water to remove sand and other impurities. They were reduced to smaller pieces and air dried at room temperature to a constant weight. The dried samples were ground using wooden mortar and pestle and kept in air tight sample bottles prior to analysis.

2. 4 Physicochemical analysis

In order to determine the pH, 10 g of the air-dried sample was weighed into a 50 ml beaker containing 20 ml of distilled water. The mixture was stirred with a glass rod and allowed to stand for 30 minutes after which the probe of a pre-calibrated Hanna pH meter (model H12211) was inserted into the partly settled suspension and the pH was read out from the system meter. Moisture content was determined with oven drying method by drying 5 g of a previously ground sample at 105 ºC to constant weight. The difference in weight was recorded as the moisture content of the soil. Electrical Conductivity (EC) was determined with Hanna conductivity meter (model H1991000) after the addition of 0.1 % sodium metaphosphate to the filtrate generated from soil suspension in distilled water (Agbenin, 1995). Organic Matter (OM) content of the soil was determined by oxidation of 1 g of oven-dried sample with 50 % H_2O_2 solution followed by ignition in a muffle furnace to combust all the organic content. The difference in weight was recorded as the organic matter content of the soil (Elith and Garwood, 2001). Particle size analysis was done using the Bouyoucos hydrometer method which utilizes

50 % Calgon (sodium hexametaphosphate) as dispersing agent (Bouyoucos, 1962).

2.5 Heavy metal determination

2.5.1 Preparation of stock solutions, serial dilution and calibration curve

Stock solutions (1000 ppm) of the metals were prepared by dissolving the respective metal or its salts. (i.e. cadmium metal, lead nitrate, potassium dichromate, cobalt (II) chloride and ferric nitrate). Five working standards were prepared in triplicate for each metal by serial dilution of the stock solutions. These and blank solutions were aspirated into a digital Flame Atomic Absorption Spectrophotometer. Calibration curves were prepared using serially diluted solution of the respective metal and were used to estimate the concentrations of the heavy metal ions by extrapolations after measuring the absorbance of the heavy metal ions in the soil sample.

2.5.2 Instrument and Analytical Conditions for Metal Analysis

A PG Instruments (PG AA500) Atomic Absorption Spectrophotometer (AAS) was used for the determination of Cr, Pb, Co, Fe and Cd ions in the soil and plant samples. The wavelength was set according to the user's manual for the metal to be analyzed. The flame was put on and the flow rates of the fuel (acetylene) and oxidant (air) were regulated accordingly to optimize the flame. The burner was adjusted for stability and maximum absorption. With the standardization of the instrument using the standard

solutions and the blanks, the concentrations of the sample solutions were read on the instrument.

2.5. 3 Digestion and Heavy Metal analysis of Samples

2 g of the soil sample was placed in a 250 ml beaker. 10 ml of freshly prepared concentrated $HNO_3/HClO_4$ (1:1 V/V) solution was added into the beaker and covered with a watch glass for initial reaction to subside. The beaker containing the sample solution was placed on a hot plate and digested at a temperature below 100 °C for 2 hours to obtain a clear solution. It was cooled and diluted with 10 ml 0.1M HNO_3 followed by filtration through Whatman no. 42 filter paper into a 50 ml volumetric flask. The flask was made up to the mark with deionized water and transferred into 60 ml polyethylene bottle. In order to digest the plant samples, the homogenized plant leaves were oven dried and passed through a 2 mm sieve. 1 g of the sample was digested with 10 ml concentrated HNO_3 for 10 minutes. This procedure was repeated with additional 5 ml of concentrated HNO_3 until digestion was complete. Then 10 ml 0.1M HNO_3 was added to the cooled solution followed by filtration through a Whatman no. 42 paper into a 50 ml volumetric flask. The flask was made up to mark with distilled-deionized water. Blank digests were also digested with the same methods and kept in 60 ml polyethylene bottles for metal analysis.

3.0 Results and Discussions

3.1 Physicochemical parameters

The results obtained for the analysis of particle size and physicochemical parameters in the soil samples are recorded in Table 2. The texture of soil was predominantly sandy loam. The sand fraction was higher than the silt and clay fractions. A high percentage of sand on the topsoil represents an advantage because it encourages seepage (Uba *et al*., 2008). However, soil of clay texture is recommended for waste disposal sites, since they are highly impermeable. Excessive drainage of sandy soil can encourage leaching of major cations and anions to the deeper layers which would increase the possibility of groundwater pollution. Ogbonna *et al*. (2007) reported that soils with very low fractions of sand (< 40%) are not suitable for dumpsites since they are highly permeable and allow large quantities of leachates from the wastes to infiltrate into groundwater resources. The mean sand content of the dumpsites ranged from 75.12 ±7.35 to 84.44±9.60 %. This could imply that they are suitable for waste land filling. The mean sand, silt and clay contents of control soil sample were 72.44 ±2.05, 16.42 ±0.84 and 11.14 ±3.49 % respectively.

Organic matter, pH and electrical conductivity values of the soil samples are shown in Table 2. Soil pH is one of the several properties which affect the mobility, availability, retention of nutrients and heavy metals in soils (Wang *et al.*, 2006; Ikpe *et al*., 2019). The pH values in this study ranged from acidic (6.21±0.37) in the soil sample collected 10 m from Dumpsite 5 (Upstair Line) to alkaline (7.70±0.29) in the sample collected 5 m from Dumpsite 1 (Government College). The pH of the control sample was also acidic at 6.33±0.54. Alkaline soil encourages soil fertility and plant growth. The soil pH values obtained in this study are similar to the values for dumpsites by Elaigwu *et al*. (2007). The degree of acidity and/or alkalinity of soil is a significant parameter that can influence several soil properties including physicochemical properties. At low pH, metals are known to be more bioavailable to plants, and hence could pose severe toxicity problems compared to alkaline soils (Oluyemi *et al*., 2005).

The values obtained from this study shows that the highest organic matter content of the soil was recorded at Dumpsite 4 (Ohokobe Market) as 4.15±0.36 % while the lowest value of 1.65±0.52 % was recorded at Dumpsite 5 (Upstair line). Low organic matter contents of the dumpsite soils could be due to the lower soil moisture contents which reduces the activities of the micro-organisms involved in the decomposition of organic matter.

The organic matter contents of the soil also play an important role in adsorption reaction in the soil; if it is high, it prevents the pollutants from reaching the groundwater sources (Parameswari, 2015).

The values of electrical conductivity varied significantly across the dumpsites; ranging from 92.58±7.41 μScm^{-1} at Dumpsite 5 (Upstair Line) to 201.57±15.86 μScm^{-1} at Dumpsite 1 (Government College). EC value of the control sample was significantly lower ($P<0.05$) than values recorded for the dumpsites at all distances. The variation observed in electrical conductivity between the dumpsites could be attributed to the presence of soluble salts that might have leached out from the waste. Also, the high electrical conductivity of soils is an indicator of high or significant presence of ions. EC values for this study were generally lower than the values obtained by Obasi *et al*. (2013) for major dumpsites in Umuahia.

Table 2. Mean (±SD) particle size and physicochemical parameters of soils in the dumpsite

Sample ID	Distances (m)	Sand (%)	Silt (%)	Clay (%)	Texture Class	**Soil pH**	**OM (%)**	**Moisture (%)**	**EC (µS/cm)**
Dumpsite 1	0	75.12 ±7.35	20.66.±0.74	4.22 ±0.63	Sandy loam	7.31 ±0.45	3.90 ±0.45	2.60 ±0.21	185.32 ±7.11
	5	78.97±5.29	16.93±2.89	4.10±1.31	Sandy loam	7.70 ±0.29	3.11 ±0.46	1.93 ±0.15	201.57 ±15.86
	10	81.46±8.37	14.72±3.50	3.82±0.95	Sandy loam	7.48 ±0.83	2.84 ±0.65	1.66 ±0.28	140.39 ±10.55
Dumpsite 2	0	78.55 ±3.22	17.11 ±0.97	4.34 ±0.76	Sandy loam	6.84 ±0.34	3.79 ±0.14	2.20 ±0.13	171.28 ±9.57
	5	80.93±8.49	15.60±1.88	3.47±0.51	Sandy loam	6.29 ±0.74	2.63 ±0.50	2.44 ±0.17	163.48 ±12.35
	10	80.40±10.26	14.37±2.91	5.23±0.66	Sandy loam	7.09 ±0.57	2.79 ±0.62	2.86 ±0.09	136.73 ±9.22
Dumpsite 3	0	82.61 ±5.81	13.34 ±1.55	4.05 ±0.82	Sandy loam	6.27 ±0.26	2.40 ±0.63	1.40 ±0.12	118.54 ±5.26
	5	84.44±9.60	10.17±2.42	5.39±1.06	Sandy loam	5.99 ±0.73	1.92 ±0.68	3.11 ±0.57	98.47 ±7.25
	10	81.74±10.13	11.45±1.97	6.81±0.95	Sandy loam	6.92 ±0.58	2.13 ±0.24	2.08 ±0.26	110.93 ±8.78
Dumpsite 4	0	78.20 ±6.12	17.63 ±2.70	4.17 ±0.65	Sandy loam	7.53 ±0.26	4.15 ±0.36	3.16 ±0.08	170.62 ±8.39
	5	79.48±9.55	15.39±2.24	5.13±1.08	Sandy loam	7.79 ±0.83	3.47 ±0.28	2.45 ±0.33	182.51 ±11.94
	10	77.54±7.28	13.80±1.75	8.66±1.30	Sandy loam	6.54 ±0.27	2.11 ±0.60	1.82 ±0.04	152.77 ±10.48
Dumpsite 5	0	81.67 ±4.13	14.04 ±0.92	4.29 ±0.93	Sandy loam	6.91 ±0.11	1.65 ±0.52	1.50 ±0.01	115.94 ±8.22
	5	82.57±6.99	11.25±2.30	6.18±1.22	Sandy loam	7.50 ±0.85	2.44 ±0.36	2.08 ±0.51	103.76 ±6.93
	10	83.64±	11.46±1.84	4.90±0.75	Sandy loam	6.21 ±0.37	3.22 ±0.89	1.79 ±0.30	92.58 ±7.41
Control		72.44 ±2.05	16.42 ±0.84	11.14 ±3.49	Sandy loam	6.33 ±0.54	1.21 ±0.04	2.48 ±0.32	78.23 ±2.36

****Dumpsite 1 = Government College; Dumpsite 2 = Timber Market; Dumpsite 3 = Ahiaeke Market; Dumpsite 4 = Ohokobe Market; Dumpsite 5 = Upstair Line**

3.2 Heavy metal ions in the soil

The results of the mean metal ion concentrations in soils from the five dumpsites are presented in Table 3. The results obtained indicated that mean concentration of lead ions in the soil ranged from 8.72 to 12.47 mg/kg at a distance of 0 m from Dumpsites 1 to 5 then 3.45 to 6.06 mg/kg and 1.11 to 2.01 mg/kg at 5 m and 10 m respectively from the dumpsites. The high levels of lead in the soils could be attributed to the leaching of Pb from the Dumpsite. Lead has the potential of forming complexes with some soil radicals such as trioxocarbonate (IV) and tetraoxosulphate (VI) and therefore becomes bound in the soil. It can also displace some cation from their salts and persist in the soii (ATSDR, 2007). The levels of Pb obtained in this study were much lower than the range, 3.00 – 117.50 mg/kg obtained by Ukpong *et al*. (2013) and 45.00 – 624.50 mg/kg obtained by Adelekan and Abegunde (2011). Opaluwa *et al*. (2012) recorded a lower range of 0.90 – 4.20 mg/kg in their study. Mean concentrations of iron (Fe) ranged from 66.67 to 713.27mg/kg across the three distances (0, 5 and 10 m). Dumpsite 3 had the highest mean concentration of iron ion, which ranged from 221.53 to 713.27mg/kg. Studies carried out by Akaeze (2001) and Udume (2001) for soils along Aba-Ikot Epkene road in Uyo metropolis using different methods

at different sample locations indicated mean concentration of iron ions ranged from 3,000 to 5000 mg/kg which is higher than the range of the present findings. However, it has been confirmed that natural soils contain significant concentration of iron. Eddy *et al*. (2004) also suggested that the pollution of the environment by iron cannot be conclusively linked to waste materials alone but other sources of iron must be taken into consideration.

Mean concentration of cadmium ions within the study zone had ranges of 0.29 – 0.37, 0.15 – 0.27 and 0.10 – 0.21 mg/kg for distance of 0, 5, and 10 m from the dumpsites. The observed mean values are lower than those reported by Omoniyi *et al.* (2013) and Ukpong *et al*. (2013) for some dumpsites at Kaduna and Uyo respectively. However, they were within the range of values (0.06-0.20 mg/kg) reported by Adamcová *et al*. (2016).

Table 3. Mean (±SE) metal concentrations (mg/kg) in Dumpsite and Control Soils

Metal	Distance	Dumpsite 1	Dumpsite 2	Dumpsite 3	Dumpsite 4	Dumpsite 5	Control
Pb	0 m	12.47± 1.21	10.62±0.53	10.53±0.06	10.53±1.02	8.72±0.84	0.45±0.01
	5 m	6.06±0.51	4.01±0.09	4.69±0.03	5.88±0.23	3.45±0.02	
	10 m	1.71±0.10	1.85±1.85	2.01±0.03	1.11±0.04	1.98±0.06	
Fe	0 m	124.13±5.31	289.10±2.65	713.27±16.62	107.40±4.25	213.40±8.61	58.00±2.86
	5 m	94.43±1.37	138.8±4.33	503.13±13.71	90.77±1.76	183.23±5.71	
	10 m	66.67±2.81	84.73±2.95	221.53±6.07	87.23±3.75	83.87±1.27	
Cd	0 m	0.29±0.02	0.29±0.03	0.27±0.02	0.37±0.02	0.33±0.05	0.11±0.01
	5 m	0.18±0.04	0.17±0.02	0.15±0.01	0.27±0.06	0.15±0.03	
	10 m	0.14±0.00	0.12±0.16	0.10±0.03	0.21±0.02	0.11±0.01	
Cr	0 m	3.85±0.18	5.11±0.03	4.64±0.14	2.91±0.23	6.10±0.82	0.29±0.03
	5 m	1.25±0.05	2.81±0.06	1.42±0.05	1.29±0.04	2.99±0.13	
	10 m	0.70±0.04	0.89±0.03	1.11±0.03	0.63±0.05	0.95±0.08	
Co	0 m	0.60±0.04	0.51±0.04	0.42±0.51	0.47±0.08	0.37±0.11	0.21±0.02
	5 m	0.40±0.03	0.32±0.02	0.15±0.02	0.22±0,04	0.17±0.01	
	10 m	0.35±0.02	0.22±0.01	0.11±0.01	0.17±0.01	0.11±0.01	

Dumpsite 1 = Government College; Dumpsite 2 = Timber Market; Dumpsite 3 = Ahiaeke Market; Dumpsite 4 = Ohokobe Market; Dumpsite 5 = Upstair Line

The mean concentrations of Cr ions in soils within the dumpsite soils ranged from 2.91 to 6.10 mg/kg. Background concentrations of soil in chromium in some soils has been reported to be significantly high. However, in this study, if reference is made to chromium ion concentration at the control sites, it can be stated that the dumpsites have witnessed entrance of chromium rich waste such as coloured polythene bags, discarded plastic materials, empty paint containers and electronic waste (Jung and Casher, 2006). The observed concentrations for chromium ions are within the range of values reported by Ukpong *et al*. (2013) with range (1.00 – 4.50 mg/kg) but below those reported by Awokunmi *et al*. (2010) (212.00 – 2020.00 mg/kg) and Oluyemi *et al*. (2008) (107.50 - 181.25 mg/kg) for soils in dumpsites at Ado-Ekiti and Ile-Ife respectively.

Concentration range for Co ions in soils within the dumpsites was 0.37 – 0.60 mg/kg at a distance of 0 m from the dumpsites. The highest concentration was recorded at Dumpsite 1 (Government College). Mean concentration of cobalt ions in the studied dumpsites were lower than the range reported by Adefemi and Awokunmi (2009) for some dumpsites in Ado Ekiti metropolis; theirs might be due to the indiscriminate disposal of cobalt containing waste on the dumpsite. In general, the observed trend for the concentration of the studied heavy metal ions within the dumpsites is Fe>Pb>Cr>Co>Cd. All the metal ion concentrations in the soils within and around the dumpsites were higher than those recorded for the control site and tend to decrease as the distance away from the dumpsites increases.

3.3 *Heavy metal ions in plants*

Mean concentrations of heavy metal ions in plants taken from the vicinity and off the vicinity of the studied dumpsites are presented in Figs. 2 and 3 for water leaf and African spinach. Mean cadmium concentration in plants from the dumpsite ranged from 0.21 mg/kg in

Dumpsite 4 (Ohokobe market) to 0.40 mg/kg in Dumpsite 3 (Ahiaeke).

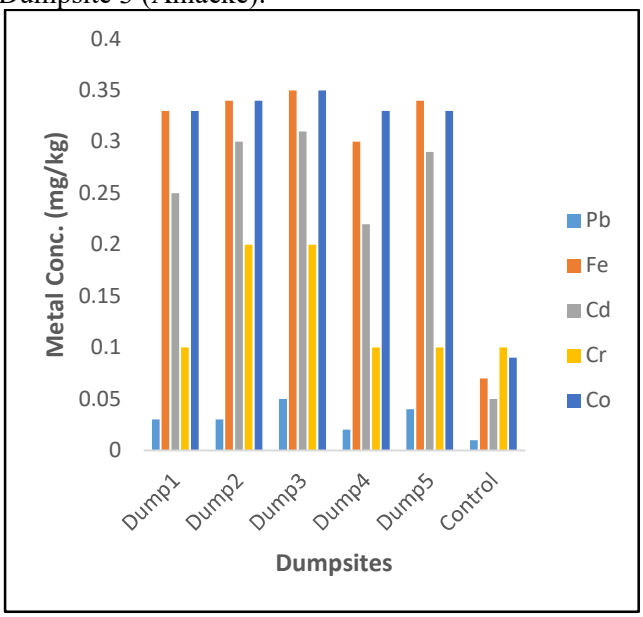

Fig. 2. Mean Metal Concentrations Water leaf (*Talinum triangulare*)

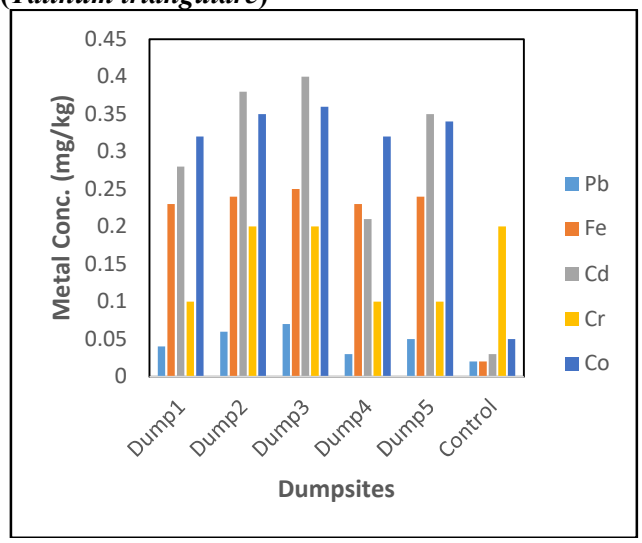

Fig. 3. Mean Metal Concentrations African Spinach (*Amaranthus hybridus*)

The levels of concentration of cadmium recorded in this study were higher than the range, 0.01 – 0.03 mg/kg reported by (Fatoba *et al*., 2012) and 0.08 mg/kg reported by (Amusan *et al*., 2005). Toxic effects of cadmium on plants include reduced shoot growth and inhibition of root growth (Ahmad *et al*., 2012). The Codex maximum limits for Cd in leafy vegetables is 0.2 mg/kg (Codex, 2015). This value was exceeded in all vegetable samples from the dumpsites but lower values were recorded in plants taken from the Control site.

Mean concentrations of Cr ion in plants from the dumpsites ranged from 0.10 to 0.20 mg/kg while lead ion concentrations ranged from 0.02 to 0.07mg/kg. The range for lead ion concentrations are higher than the range (0.01 – 0.03 mg/kg) reported by Fatoba *et al*. (2012) at Ilorin and much lower than the range reported (1.50 – 3.40 mg/kg) by Amusan *et al*. (2005) at Ile-Ife. The Codex maximum limits for Pb in leafy vegetables is 0.3 mg/kg (Codex, 2015) which was not exceeded in any of the vegetable samples from the sites. Lead has no beneficial biological function and is known to accumulate in the body and can generate lead poisoning in humans as well as chronic neurological disorders in children and foetus (Yargholi *et al*., 2008).

Mean iron concentrations in edible plant samples in this study ranged from 0.23 mg/kg in spinach leaf samples in Dumpsite 1 (Government college) to 0.35mg/kg in waterleaf samples in Dumpsites 2 and 5 (Timber market and Upstair line). Mean cobalt concentrations recorded in leaves of the two plant samples had a range of 0.32 to 0.35mg/kg. Mean Pb, Fe, Cd and Co concentrations were significantly higher ($P < 0.05$) in vegetable samples from the dumpsites compared to the control samples.

In general, the concentrations of the metals found in the plants at the study areas were higher than those observed at the control site.

3.3 Heavy metal contamination indices

3.3.1 Metal pollution index (MPI)

This indicates the relationship between metals in a studied soil and in a reference (control) soil. It was determined using the equation of Lacatusu (2000),

$$\text{MPI} = \frac{(Concentration\ of\ metal\ in\ dumpsite\ soil)}{Concentrati\quad of\ metal\ in\ Control\ soil} \qquad (1)$$

MPI is classified as unpolluted if MPI<1, slightly polluted if 1<MPI<2, moderately polluted if 2<MPI<3, severely polluted if 3<MPI<5 and heavily polluted if 6<MPI<10.

3.3.2 Degree of contamination (Cdeg)

This is the sum of the MPI for all metals at a particular location:

$$Cdeg = \sum_{I=1}^{I=n} CF \qquad (2)$$

The classification of Cdeg includes: Cdeg<6 = low degree of contamination; 6<Cdeg<12 = moderate degree of contamination; 12<Cdeg<24 = considerable

degree of contamination and Cdeg>24 = high degree of contamination (Hakanson, 1980).

3.3.3 Enrichment factor (EF)

This identifies the source of trace metals in dumpsite soils and it was calculated using the equation of Rubio *et al*. (2000):

$$EF = \frac{(M/Fe)_{Dumpsite}}{(M/Fe)_{Controlsite}} \quad (3)$$

[$(M/Fe)_{\text{Dumpsite soil}}$ is the ratio of a metal and iron concentration in dumpsite soil and $(M/Fe)_{\text{Control soil}}$ is the ratio of the metal and iron concentration in control soil]. EF index <2 indicates deficiency to minimal enrichment, 2<EF<5 indicates moderate enrichment, 5<EF<20 significant enrichment, 20<EF<40 very high enrichment EF>40 extremely high enrichment (Rubio *et al*., 2000).

3.3.4 Geoaccumulation index (Igeo)

The Igeo of trace metals was calculated using the equation of Lu *et al*. (2009):

$$Igeo = Log_2\left(\frac{C_n}{1.5B_n}\right) \quad (4)$$

(Cn = measured concentration of metal in dumpsite soil, Bn = concentration of metal in control site, 1.5 is a constant which allows for fluctuations of a given metal in the environment in addition to small anthropogenic influences. Classes of geo-accumulation index (Huu *et al*., 2010) are Igeo < 0 = unpolluted, 0–1 = unpolluted to moderately polluted, 1–2 = moderately polluted, 2–3 = moderately to strongly polluted, 3–4 = strongly polluted, 4–5 = strongly to extremely polluted and > 5 = extremely polluted

3.3.5 Ecological risk Index (Er)

This expresses the potential ecological risk for a particular metal at a dumpsite soil and was calculated using the equation:

$$E_r = T_r \times MPI \quad (5)$$

(Tr = toxic-response factor for a particular metal, MPI = metal pollution index)

According to Hakanson (1980), Tr for metals are: Co (5.00), Pb (5.00), Cr (2.00) and Cd (30.00).

3.3.6 Potential ecological risk Index (PERI)

Potential ecological risk factor (PERI) estimates the sum of potential risk of individual metals. It was calculated for all the metals determined in dumpsite soil with the equation:

$$PERI = \sum_{I=1}^{I=n} E_r \quad (6)$$

Grading of the studied dumpsites environmental status based on calculated Ecological and Potential Ecological Risk Indices are recorded in Table 4 while metal contamination indices are presented in Table 5.

Metal pollution index (MPI) indicates the relationship between metals in a studied soil and in a reference (Control) soil. It can also be calculated as the contamination factor (Lacatusu, 2000). The calculated MPI recorded in Table 6 shows range of 0.900 - 1.233 for cadmium (average = 1.03); 0.436 – 0.624 for lead (Pb) (average = 0.53); 0.002 – 0.015 for Fe (average = 0.01); 0.019 – 0.027 for Co (average = 0.03) and 0.012 – 0.068 Cr (average = 0.04). Based on the calculated metal pollution index, the dumpsite soils are unpolluted with the exception of cadmium in Dumpsites 4 and 5 which were slightly polluted.

Calculated values of degree of contamination ranged from 0.03 for Fe to 2.64 for Pb, with the highest value of 5.17 for Cd. With reference to calculated values of Cdeg, all the heavy metals Pb, Fe, Cd, Cr and Co in this study showed low degrees of contamination.

Enrichment factor (EF) identifies the source of trace metals in dumpsite soils. The results calculated in this study show values of 6.00 and 7.00 for Pb in Dump 4 and Dumpsite 1 respectively indicating significant enrichments by lead ions in these dumpsites. Cd also showed high values of 5.00 and 10.00 in Dumpsites 1 and 2 respectively, which also implies significant enrichments, Cr showed values of 5.00 and 8.50 in Dumpsites 1 and 2 indicating significant enrichments, while Co showed lower values ranging from 0.86 to 1.50 indicating minimal enrichment.

Table 4. Categories of the Environment based on Ecological and Potential Ecological Risk Factors or Indices (Yang *et al*., 2009)

Grade	Er value	ERI grading	PERI	PERI grading
A	Er < 40	Low ecological risk	PERI < 150	Low ecological risk
B	40 < Er < 80	Moderate ecological risk	150 < PERI < 300	Moderate ecological risk
C	80 < Er < 160	Appreciable ecological risk	300< PERI < 600	High ecological risk
D	160 < Er < 320	High ecological risk	PERI> 600	Significantly high ecological risk
E	Er > 320	Serious ecological risk		

Table 5. Metal Contamination indices

Metal	Dumpsite	MPI	Ave MPI	Cdeg	EF	Igeo	Er
Pb	1	0.624	0.53	2.64	7.00	1.78	3.12
	2	0.531			3.00	1.58	2.66
	3	0.527			1.00	0.86	2.64
	4	0.527			6.00	0.98	2.64
	5	0.436			3.00	0.91	2.18
Fe	1	0.003	0.01	0.03	1.00	0.28	–
	2	0.006			1.00	0.34	–
	3	0.015			1.00	0.54	–
	4	0.002			1.00	0.37	–
	5	0.005			1.00	0.40	–
Cd	1	0.967	1.03	5.17	5.00	0.29	29.01
	2	0.967			10.00	0.53	29.01
	3	0.900			0.80	0.75	27.00
	4	1.233			0.75	0.28	36.99
	5	1.100			1.00	0.29	33
Cr	1	0.012	0.04	0.22	5.00	0.67	0.02
	2	0.057			8.50	0.11	0.11
	3	0.052			2.50	0.89	0.10
	4	0.032			2.43	0.58	0.06
	5	0.068			3.00	1.61	0.14
Co	1	0.032	0.03	0.13	1.25	0.71	–
	2	0.027			1.00	0.36	–
	3	0.022			0.86	0.29	–
	4	0.025			1.50	0.33	–
	5	0.019			1.08	0.31	–

Calculated values of geo-accumulation index (Igeo) indicated a highest value of 1.78 for lead ion in Dumpsite 1, while Cr had the lowest index of 0.11 for Dumpsite 2. Igeo values for heavy metal ions in all the dumpsites (except lead and chromium ions) were less than 1.00 indicating unpolluted to moderately polluted. The values for lead at Dumpsites 2 and 1 were 1.58 and 1.73 respectively. Chromium had Igeo value of 1.61 at Dumpsite 5 hence, lead and chromium pollutions in these dumpsites are graded as moderate.

The ecological risk index (Er) is a significant tool for assessing heavy metal ions contamination of soils in a given environment. Calculated Er value for all the studied heavy metal ions in soils ate the dumpsites indicated low ecological risk as defined by Yang *et al*. (2009). The results of the potential ecological risk index (PERI) calculated as the sum of the ecological risk factor are presented in Table 6.

It is evident from results resented in Table 6 that all the dumpsites witnessed low ecological risk at present. Calculated PERI values were within the range, 30.64 to 39.69. The highest value of PERI was calculated for Dumpsite 5 while the least was for Dumpsite 3

Table 6. Potential Ecological Risk Index (PERI) for the Dumpsites

Location	PERI	Risk Grade
Dumpsite 1	32.15	Low ecological risk
Dumpsite 2	31.78	Low ecological risk
Dumpsite 3	30.64	Low ecological risk
Dumpsite 4	39.69	Low ecological risk
Dumpsite 5	35.32	Low ecological risk

4.0 Conclusion

The average metal pollution indices obtained in this study indicated that the soils in the dumpsites are unpolluted except cadmium in Dumpsites 4 and 5. Degree of contamination values also indicated low degrees of contamination but enrichment factors for Pb, Cd and Cr indicated significant enrichments in three Dumpsites. Geo-accumulation indices (Igeo) for lead at Dumpsites 2 and 1 and for chromium at Dumpsite 5

indicated moderate pollutions while values of ecological risk and potential ecological risk indices indicated low ecological risk. However, continuous disposal of waste in these dumpsites may lead to high ecological risks of heavy metal contamination in future. The edible plants grown near the dumpsites showed traces of heavy metal which were leached into the soil from the dumpsites and the consumption of the leaves of the plants may cause health problems for humans since the recommended maximum limits for cadmium was exceeded. Cultivation of vegetables near dumpsites should be discouraged by public health authorities and adequate plans should be made create modern waste management facilities.

5.0 References

Adamcová, D., Vaverková, M. D., Barton, S., Havlícek, Z. & Broušková E. (2016). Soil contamination in landfills: a case study of a landfill in Czech Republic. *Solid Earth*, 7, pp. 239–247.

Adefemi, S. O. & Awokunmi, E. E. (2009). The impact of municipal solid waste disposal in AdoEkiti metropolis, Ekiti-State, Nigeria. *African Journal of Environmental Science and Technology*, 3, pp. 186-189.

Adelekan, B. & Abegunde, K. (2011). Heavy metal contamination of soil and ground water at automobile mechanic village in Ibadan, Nigeria. *International Journal of the Physical Sciences*, 6, 5, pp. 1045-1058.

Agbenin, J. O. (1995). *Laboratory Manual for Soil and Plant Analysis*. Dept. of Soil Science, Ahmadu Bello University, Zaria, pp. 30-72.

Ahmad, I., Akhtar, M. J., Zahir, Z. A. & Jamil A. (2012). Effect of cadmium on seed germination and seedling growth of four wheat (*Triticum aestivum* L.) cultivars. *Pakistan Journal of Botany*, 44, 5, pp. 1569–1574.

Ajiboso, T., Olayinka, K. O. & Alo, B. I. (2003). Speciation of heavy metal contaminants at metal dumpsites by improved sequential fractionation technique. *Journal of Nigerian Environmental Society*, 1, pp. 178-186.

Akaeze, C.S. (2001). Solid wastes analysis characterization and management along Abak/Ikot Ekpene roads of Uyo metropolis. A research project. Dept. Chemistry, University of Uyo, Nigeria.

Akter, S., Islam, S. M. A., Rahman, M. O., Mamun, K. M. & Jolly Y.N. (2019). Toxic Elements Accumulation in Vegetables from Soil Collected from the Vicinity of a Fertilizer Factory and Possible Health Risk Assessment. *Open Access Journal of Biomedical Engineering and Biosciences*, 3, 2, pp. 277-288.

Amusan, A. A., Ige, D.V. & Olawale, R. (2005). Characteristics of Soils and Crops' Uptake of Metals in Municipal Waste Dump Sites in Nigeria. *Journal of Human Ecology*, 17, 3, pp. 167-171.

APHA (2012). *Standard Methods for the Examination of Water and Wastewater*, 22nd Edition. American Public Health Association, American Water Works Association, Water Environment Federation, Washington DC.

Agency for Toxic Substances and Disease Registry. (2007). Public Health Statement: Lead. *ATSDR Report* CAS#: 7439-92-1.

Awokunmi, E.E., Asaolu, S.S. & Ipinmoroti, K.O. (2010). Effect of leaching on heavy metals concentration of soil in some dumpsites. *African Journal of Environmental Science and Technology*, 4, 8, pp. 495-499.

Azeez, J. O., Hassan, O. A. & Egunjobi, P. O. (2011). Soil contamination at dumpsites: implication of soil heavy metals distribution in municipal solid waste disposal system: a case study of Abeokuta, Southwestern Nigeria. *Soil and sediment contamination International Journal*, 20, 4, pp. 370-386.

Bouyoucos, G. J. (1962). Improved hydrometer method for making particle size analysis of soils. *Agronomy Journal*, 54, pp. 464-465.

Chinedu, I., Ezeibe, C., Anijiofor, S. C. & Daud, N. N. (2018). Solid Waste Management in Nigeria: Problems, Prospects, and Policies. *Journal of Solid Waste Technology and Management*, 44, 2, pp.163-172.

Chinyere, G. C. & Madu, F. U. (2015). Physicochemical characteristics and heavy metal constituents of five dumpsite soils and edible vegetables grown in two major metropolises of Abia State, Nigeria. *International Research Journal of Biochemistry and Biotechnology*, 2, 2, pp. 014-027.

Codex Alimentarius Commission. (2015). *General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995)* - Amended 2015. FAO/WHO, Geneva.

Ebong, G. A, Ettesam, E. S. & Dan, E. U. (2020). Impact of abattoir wastes on trace metal accumulations, speciation and human health-related problems in soil within Southern Nigeria. *Air Soil and Water Research*, 13, pp. 1-14.

Eddy N. O. (2004). *Physicochemical parameter of water and heavy metal content of water, sediment and fishes from Qua Iboe River Estuary*. M.Sc Thesis, Michael Okpara University of Agriculture, Umudike, Nigeria. Retrieved from: https://www.researchgate.net/publication/267934661_Effect_of_leaching_on_heavy_metals_concentration_of_soil_in_some_dumpsites.

Eddy, N. O., Ndibuke, M. O. & Ndibuke, E. O. (2004). Heavy metals in sediment from Cross River at Oron. *African Journal of Environmental Pollution and Health*, 3, 5, pp. 21-26.

Eddy, N. O., Odoemelam, S. A. & Mbaba, A. (2006). Elemental composition of soil in some dumpsites. Electronic *Journal of Environmental, Agriculture and Food Chemistry*, 5, 3, pp. 1349-1363.

Elaigwu, S.E., Ajibola, V.O. & Folaranmi, F.M. (2007). Studies on the Impact of Municipal Waste Dump on Surrounding Soil and Air Quality of Two Cities in Northern Nigeria. *Journal of Applied Sciences,* 7, 3, pp. 421-425.

Elith, M & Garwood, S. (2001). *Investigations into the levels of Heavy metals within Manly Dam catchment*. Freshwater Ecology Report 2001. Department of Environmental Sciences, University of Technology, Sydney.

Fatoba, P.O., Adepoju, A.O. & Okewole, G.A. (2012). Heavy metal accumulation in the fruits of tomato and okra irrigated with industrial waste effluents. *Journal of Industrial Pollution and Control*, 28, 2, pp. 103-107.

Hakanson, L. (1980). Ecological risk index for aquatic pollution control, a sedimentological approach. *Water Research*, 14, pp. 975–1001.

Huu, H.H., Rudy, S. & Damme, A.V. (2010). Distribution and contamination status of heavy metals in estuarine sediments near Cau Ong Harbor, Ha Long Bay, Vietnam. *Geologica Belgica*, 13, pp. 37–47.

Ikpe, A. E., Ebunilo, P. O. & Sadjere, G. E. (2019). Effects of waste dumpsites on geotechnical properties of the underlying soils in wet season. *Environmental Engineering Research*, 24, 2, pp. 289-297.

Jung, H.G. & Casler, M.D. (2006). Maize stem tissues: impact of development on cell wall degradability. *Crop Science*, 46, 4, pp. 1801.

Lacatusu R. (2000). Appraising levels of soil contamination and pollution with heavy metals. *European Soil Bureau Research Report*, 4, pp. 393-402.

Lu, X., Wang, L., Lei, K., Huang, J. & Zhai, Y., (2009). Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China. *Journal of Hazardous Materials*, 161, pp. 1058–1062.

Mohajeri, S., Aziz, M., Zahed, M.A. & Adlan, M.N. (2010). Statistical optimization of process parameters for landfill leachate treatment using electro-Fenton technique. *Journal of Hazardous Materials*, 176, pp.749–758.

Nagajyoti, P. C., Lee, K. D. & Sreekanth, T. V. M. (2010). Heavy metals, occurrence and toxicity for plants: a review. *Environ. Chem. Lett,* 8, pp. 199–216.

National Population Commission (NPC). (2006). Population and Housing Census, "Population distribution by Sex, State, LGA, and Senatorial district". Retrieved from: Retrieved from: http://www.population.gov.ng/images/ SDistrict-PDF.pdf.

Obasi, N. A., Akubugwo, E. I., Kalu, K. M. & Ugbogu, O. C. (2013). Speciation of Heavy Metals and Phyto-accumulation Potentials of Selected Plants on Major Dumpsites in Umuahia, Abia State, Nigeria. *International Journal of Current Biochemistry Research*, 1, 4, pp. 16- 28, 18.

Odoemelam, S. A. & Eddy, N. O. (2009). Studies on the use of oyster, snail and periwinkle sheels as adsorbent for the removal of Pb^{2+}. Journal of Chemistry, 5, 1, pp. 213-222.

Ogbonna, D N, Igenijie, M. & Isirimah, N. O. (2007). Microbiological and Physicochemical Characteristics of the soils of waste collection sites in Port Harcourt city, Nigeria. *Nigerian Journal of Soil Science*, 16, pp. 162 – 167.

Ogunbanjo, O., Onawumi, O., Gbadamosi, M., Ogunlana, A. & Anselm, O. (2016). Chemical speciation of some heavy metals and human health risk assesse,ent in soil around two municipal dumpsites in Sagamu, Ogun State, Nigeria. *Chemical Speciation and Bioavailability*, 28, -4, pp. 142-151.

Olabanji, I. O., Oluyemi, E. A. & Obianjuwa, E. I. (2015). Nondestructive analysis of dumpsite soil and vegetable for elemental composition. *Journal of Environmental Chemistry and Ecotoxicology,*7, pp. 1-10.

Oluyemi, E. A., Feuyit, G., Oyekunle, J. A. O. & Ogunfowokan, A. O. (2008). Seasonal variations in heavy metal concentrations in soil and some selected crops at a landfill in Nigeria. *African Journal of Environmental Science and Technology*, 2, 5, pp. 89-96.

Omoniyi, K. I., Ekwumemgbo, P. A, & Sanni, H. A. (2013). An evaluation of the As, Cd, Mn and Hg contamination in soils and plants (Amaranthus spinusis) of Kaduna Metropolis dumpsites. *Physical Review and Research International*, 3, 4, pp. 541-555.

Opaluwa, O., D., Aremu, M. O., Ogbo, L., O., Abiola, K., A., Odiba, I.,E., Abubakar, M. M. & Nweze, N. O. (2012). Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria. *Advances in Applied Science Research*, 3, 2, pp. 780-784.

Parameswari, K., Padmini, T. K. & Mudgal, B. V. (2015). Assessment of Soil Contamination around Municipal Solid Waste Dumpsite. *Indian Journal of Science and Technology*, 8, 36, pp. 1-5.

Rafizul, M., Alamgir, I. M. & Shahed-Sharif, S. M. (2012). Analysis and Selection of Appropriate Aggregation Function for Calculating of Leachate Pollution Index of Landfill Lysimeter. *Iranica Journal of Energy and Environment*, 3, pp. 370-379.

Rubio, B., Nombela, M. A. & Vilas, F. (2000). Geochemistry of major and trace elements in sediments of the Ria de Vigo (NW Spain) an assessment of metal pollution. *Marine Pollution Bulletin*, 40, pp. 968–980.

Shah, A., Niaz A., Ullah N., Rehman A., Akhlaq M., Zakir M. & Khan M. S. (2013). Comparative study of Heavy Metals in Soil and Selected Medicinal Plants. *Journal of Chemistry*, 2013, pp. 1-6.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K. & Sutton D. J. (2012). Heavy Metals Toxicity and the Environment. *EXS*, 101, pp. 133–164.

Uba, S., Uzairu, A., Harrison, G. F. S., Balarabe, M. L. & Okunola, O. J. (2008). Assessment of heavy metals bioavailability in dumpsites of Zaria metropolis, Nigeria. *African Journal of Biotechnology*, 7, 2, pp. 122-130.

Udeme, A.E. (2001). *Solid waste analysis and characterization*. Department of chemistry, University of Uyo.

Ukpong, E. C., Antigha, R. E. & Moses, E. O. (2013). Assessment of heavy metals content in soils and plants around waste dumpsites in Uyo Metropolis, Akwa Ibom State. *International Journal of Engineering and Science*, 7, 2, pp. 2319 – 1805.

Ukpong, E. C; Udo, E. A. & Umoh, I. C. (2015). Characterization of Materials from Aba Waste Dumpsites. *International Journal of Engineering and Applied Sciences*, 6, 3, pp. 1-10.

Umoren, I. U., Udoh, A. & Udousoro, I. I. (2007). Concentration and chemical speciation for the determination of Cu, Zn, Ni, Pb and Cd from refuse dump soils using the optimized BCR sequential extraction procedure. *Environmentalist*, 27, pp. 241-252.

Wang, A. S., Angle, J. S., Chaney, R. L., Delorme, T. A. & Reeves, R. D. (2006). Soil pH effects on uptake of Cd and Zn by *Thlaspi caerulescens*. *Plant and Soil*, 281, 1-2, pp. 325–337.

Waste Atlas. (2014). The World's 50 biggest Dumpsites. Retrieved from: http://nswai.com/docs/World's%20Fifty%20biggest%20dumpsites,Waste%20Atlas%202014.pdf.

Yang, Z., Ying, W. & Shen, Z. (2009). Distribution and speciation of heavy metals in sediments from the mainstream, tributaries, and lakes of the Yangtze River catchment of Wuhan, China. *Journal of Hazardous Materials*, 166, pp. 1186–1194.

Yargholi, B., Azimi, A. A., Baghvand, A., Liaghat, A. M. & Fardi, G. A. (2008). Investigation of cadmium absorption and accumulation in different parts of some vegetables. *American–Eurasian Journal of Agriculture and Environment Science*, 3, pp. 357–364.

Zaware, S. G. (2014). Environmental impact assessment on soil pollution issue about human health. *International Research Journal of Environment Sciences*, 3, pp. 78-81.