World Applied Sciences Journal 34 (6): 720-732, 2016
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2016.34.6.46

# Evaluation of Pollution Loads in and Around Municipal Solid Waste Dumpsite.

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**Abstract:** The unscientific disposal of wastes and pollution in urban settlement has caused immense Chromium (Cr), Nickel (Ni) and Lead (Pb) all exceeded drinking water standards. Nevertheless, Chromium (Cr) exceeded the WHO tolerance limits for water bodies subjected to effluent discharge. In crop plants, Cd, Co, Cr and Ni were critical. In the soil, evaluation of contamination/pollution factor(C/P), Enrichment factor (EF), Index of Geoaccumulation (Igeo) and Pollution load index were calculated. The concentration of cadmium is demonstrated elevated contamination in all the sampling sites. The observation suggests high C/P values of the dump soil are polluted by Cd, Cr and Ni acts as a sink for heavy metals contributed from a multitude of anthropogenic sources in the study area. C/P data, EF, PLI and Geoaccumulation index values (Igeo) indicated that these heavy metals originate from anthropogenic sources. Cr had the highest plant/soil metal concentration factor even though its bioavailability in plants (4.35 mg/kg) in *Talinum triangulare* leave was lower compared to Lead (144.30 mg/kg) in *Talinum triangulare* root. This calls for immediate action to be implemented to carry out problems not only to human beings but also to the aquatic biodiversity.

**Key words:** Geo-accumulation index · Pollution load index · Water quality index · Enrichment factor · Translocation factor

## INTRODUCTION

The intensity of man's activities has led to increasing volume of solid waste worldwide despite the current level of technological advancement and industrialization. Explosive population growth is one other major factor responsible for increased municipal solid waste (MSW). Land filling of municipal solid waste is a common waste management practice and one of the cheapest methods for organized waste management in many parts of the world [1]. Studies on the pollution have been conducted by various researchers of various fields such as chemistry, biology, geography, engineering and environment. Among studies on the heavy metal pollution were those conducted by [2] . Other than general studies on heavy metal, heavy metal pollution studies also covered various sources of ecosystem such as the aquatic ecosystem [3] and terrestrial ecosystem [4].

Studies have revealed that waste dumpsites can transfer significant levels of toxic and persistent metals into the soil environment, which eventually are taken up by plant parts and transferred into the food chain [5].

Groundwater contamination is a major concern in landfill operations because of the pollution effects of landfill leachate and its potential health risks [6]. However, it has been widely reported that leachate from landfills for nonhazardous waste could as well contain complex organic compounds, chlorinated hydrocarbons and metals at concentrations which pose a threat to both surface and ground waters. Solvents and other synthetic organic chemicals constitute a significant hazard, being of environmental significance at very low concentrations and resistant to degradation. Moreover, they may be transformed in some cases into more hazardous compounds [7]. Most landfill leachate has high levels of BOD, COD, ammonia, chloride, sodium, potassium, hardness and boron. The conditions within a landfill often vary over time, from aerobic to anaerobic thus allowing different chemical reactions to take place. The presence of heavy metals in the environment is of great ecological significance due to their toxicity at certain concentrations, translocation through food chains and non-biodegradability which is responsible for their accumulation in the biosphere. These metals are

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non-biodegradable and can undergo global ecological circles. The use of dumpsites as farm land is a common practice in urban and sub-urban centers in Nigeria because of the fact that decayed and composted wastes enhance soil fertility [8]. Plants grown on a land polluted with municipal, domestic or a land polluted with municipal, domestic or industrial wastes can absorb heavy metals inform of mobile ions present in the soil through their roots or through foliar absorption. These absorbed metals get bioacumulated in the roots, stems, fruits, grains and leaves of plants [9]. The present study was carried out to assess the pollution status of the municipal solid waste environment under study, the extent to which the crop plants, soil and water were exposed to heavy metals and hence, the safety levels of the crops plants, water and soil in the environ.

## MATERIALS AND METHODS

**Study Area Description:** Ekiti State is located between longitudes 4° $15^1$ to 5° $45^1$ East of Greenwich Meridian and latitudes 7° $15^1$ to 8° $5^1$ North of Equator. The state is mainly an upland one, about 250 meters above sea level. It lies within the area of undulating land surface with a characteristic landscape that consists of old plane broken by steep-sided outcrops of dome rocks that may occur singularly or in groups or ridges. The state enjoys tropical climate with two distinct seasons. These are the wet season (April-October) and dry season (November-March). The temperature ranges between 20° -36°C with high humidity. Tropical forest exists in the south while guinea savannah occupies the northern part of the state.

**Study Area: Ikere Ekiti:** Ikere Ekiti is the second biggest city of Ekiti State, south western Nigeria. The city is at the centre on latitude 7.32° N and longitude 5.14° E, situated in a valley 247 m above sea level. As at 2014, Ikere Ekiti had an estimated population of 537, 180 people with a total land area of about 280 $km^2$. The population in the city is unevenly distributed such that commercial, industrial and agricultural, recreational and administrative, auto-mechanic workshops and residential areas are scattered all over the city and these serve as point sources of heavy metals [10]. One sampling station was identified within Ikere Ekiti town namely: Anaye, an area well known for repairing and maintaining automobiles, centre dumpsite for market traders with a large clientele. It is located at the centre of the city. The grounds of the College of Education farm were used as a control site for this station. This site was chosen for investigation, being one of the major city dumpsite and for its sheer size, daily and frequent usage and because of its long-term waste deposition in the Ikere Ekiti Area.

**Soil Analysis:** Composite surface soil samples (0-6 cm) were collected from the four representative sites using an auger and stored in properly labeled polyethylene bags. They were air-dried at room temperature (21-27°C) for seven days and later oven-dried at 100° C for three hours to obtain a constant weight. The soil samples were mechanically ground and sieved to obtain < 2 mm fraction. A fraction of the soil was drawn from the bulk soil (< 2 mm fraction) and reground to obtain < 200 ìm fraction using a mortar and pestle and then digested using aqua-regia. Analysis of the heavy metals (Zn, Cu, As, Pb and Cd) was in duplicate, using atomic absorption spectrophotometer (AAS –bulk scientific model 210) from virgin soil. The heavy metals analyzed (Zn, Mn, Cu, Co, Ni, Pb and Cd) are among those considered most problematic in terms of environmental pollution and toxicity [11]. The level of precision of the method used for the analyzed metals ranged between ±5-10percent.

**Water Analysis:** Physical parameters such as pH, temperature, turbidity and conductivity were determined *in-situ* immediately after sampling, prior to proper calibration of the various equipment used using standard methods. Parameters such as colour, odour, clarity or the physical presence of any object were described by visual judgment of the sample like colourless, odourless, etc. The turbidity of the water samples was measured using HACH model 2100AN turbidimeter. The temperature was measured using mercury in bulb thermometer. The pH was measured using the Barnat 20 digital pH meter. Conductivity measurement was carried out using electrolytic conductivity cell HACH model CO130. Total dissolved solids (TDS) were determined by the evaporation method. Total suspended solids were determined by the filtration method [12]. Chloride was measured by the Mohr's method using silver nitrate as titrant. The method of photometric (API-RD 45, 3.17) was used in determining the oil and grease in water. This was measured by extraction with xylene. Heavy metals in the water samples were determined using buck scientific atomic absorption spectrophotometer MODEL 210 VGA.

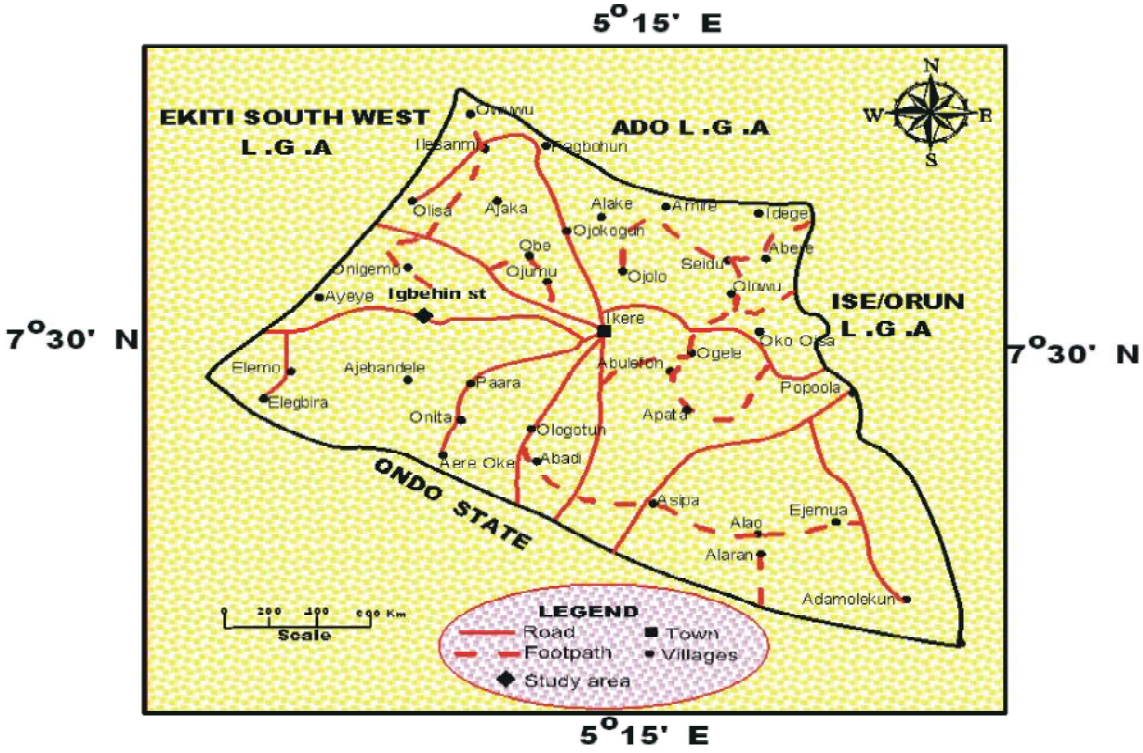


Fig. 1: The study area within Ikere Ekiti showing sampling location Anaye

**Plant Analysis:** The plant samples; tubers and leaves of cocoyam (*Xanthosoma mafaffa*), tuber and leaf of cassava (*Manihot esculenta*), plantain (*Musa sapientum*), water leaf (*Talium triangulare*) and fruit, roots and leaf of pawpaw (*Carica papaya*) and melon (*Manihot esculenta*) grown within the vicinity of the waste dumpsite were randomly collected with a stainless steel trowel and knife. The areas to be sampled in each location were divided into four quadrants, each 5 $m^2$ and crop samples were collected from each quadrant in a diagonal basis following the method of [13]. Plant samples of the same species were also collected as control from the unpolluted site chosen as control. The harvested plant parts were rinsed in distilled water and dried to a constant weight in an oven at 70ºC. These were then crushed into fine powders and then stored in polythene bags prior to further laboratory analysis [14].

**Quality Assurance:** Quality control test was conducted on soil in order to evaluate the experimental procedures and efficiency of atomic absorption spectrophotometer. This was done by spiking the pre-digested soil with multi-elemental metal standard solution [15].

**Data Evaluation:** Geoaccumulation index ($I_{GEO}$): Pollution levels of heavy metals in Ado Ekiti could be characterized by the geo-accumulation index (Igeo) [16]. This contamination assessment index has been utilized in environmental studies [17]; [18]; [19] and can be defined as the following equation:

$$Igeo = \ln \{Cn/1.5\ Bn\}.$$

where Cn is the measured content of individual heavy metal in Ado Ekiti,

Bn: the background or pristine value of individual heavy metal. The control samples were taken to represent the background and1.5 is the constant factor introduced to analyze natural fluctuations in the contents of a given substance in the environment and very small anthropogenic influences. There are seven classes of the geoaccumulation index [17] as stated in Table 1.

**Contamination/Pollution Index (C/P):** This was calculated by employing previously used method [20] with the following modifications/definitions:

C/P = Concentration of the metal in soil/Target value

Table 1: Seven Descriptive classes of Geoaccumulation index

| S/N | Class | Description |
|---|---|---|
| 1 | <0 | practically uncontaminated |
| 2 | 0-1 | uncontaminated to slightly contaminated |
| 3 | 1-2 | moderately contaminated |
| 4 | 2-3 | moderately to highly contaminated |
| 5 | 3-4 | highly contaminated |
| 6 | 4-5 | highly to very highly contaminated |
| 7 | >5 | very highly/strongly contaminated |

Table 2: Standard formulated by the Department of Petroleum Resources of Nigeria (DPR), for maximum allowed concentration of heavy metals in soils.

| S/N | Heavy metal in soil | Maximum allowed concentration (ppm) |
|---|---|---|
| 1 | Cd | 0.8 |
| 2 | Cr | 100.0 |
| 3 | Pb | 85.0 |
| 4 | Ni | 35.0 |
| 5 | Zn | 140.0 |
| 6 | Co | 20.0 |
| 7 | Hg | 0.30 |
| 8 | Cu | 36.0 |
| 9 | Mn | 476.0 |
| 10 | Fe | 5000.0 |

Table 3: The significance of interval of contamination/pollution index

| S/N | Class | Significance |
|---|---|---|
| 1 | <.1 | Very slight contamination |
| 2 | 0.10-0.25 | slightly contamination |
| 3 | 0.26-0.5 | Moderate contamination |
| 4 | 0.51-0.75 | Severe contamination |
| 5 | 0.76-1.00 | Very severe contamination |
| 6 | 1.10-2.0 | Slight pollution |
| 7 | 2.1-4.0 | Moderate pollution |
| 8 | 4.1-9.0 | severe pollution |
| 9 | 9.1-16.0 | Very severe pollution |
| 10 | >16.0 | Excessive pollution |

The target value was obtained by using the standard formulated by the Department of Petroleum

Resources of Nigeria (DPR), for maximum allowed concentration of heavy metals in soils.

The significance of interval of contamination/ pollution index [21], are given below.

The values less than 1 define contamination range while greater than 1 defines pollution range.

**Enrichment Factor (EF):** By following established method [22], EF was employed to assess the degree of contamination and to understand the distribution of the elements of anthropogenic origin from sites by individual elements in sediments. Fe was chosen as the normalizing element when determining EF-values, since in wetlands it is mainly supplied from sediments and is one of the widely used reference element [23]; [24]; [25]; [26]. Other widely used reference metal elements are Al, Mn [27]; [28]; [29]. The EF is defined as follows:

Enrichment factor = (Cn/Fe) sample/ (Cn/Fe) background,

where, Cn is the concentration of element "n". The background value is that of control sample. An element qualifies as a reference one if it is of low occurrence variability and is present in the environment in trace amounts [22]. Elements which are naturally derived have an EF value of nearly unity, while elements of anthropogenic origin have EF values of several orders of magnitude.

Six categories are recognized [30], as stated bellow:

Table 4: Descriptive classes of Enrichment factor index

| S/N | Class | Description |
|---|---|---|
| 1 | <1 | background concentration |
| 2 | 1-2 | depletion to minimal enrichment |
| 3 | 2-5 | moderate enrichment |
| 4 | 5-20 | significant enrichment |
| 5 | 20-40 | very high enrichment |
| 6 | >40 | extremely high enrichment |

Pollution load index (PLI): Pollution load index for each site was evaluated as indicated by [45].

Pollution load index= $(CF1 * CF2 *.....* CFn)^{1/n}$

where, n is the number of metals (six in the present study). The PLI value > 1 is polluted whereas PLI value < 1 indicates no pollution [25], [26].

**Quantification of Soil Contamination (QoC):** The third approach using the quantification of anthropogenic concentration of metal employs the concentration in the control samples to represent the lithogenic metal. This is calculated as:

Quantification of anthropogenic metal

$$\text{Anthropogenic metal } \frac{X - Xc}{X} x00$$

where X = average concentration of the metal in the soil under investigation and Xc = average concentration of the metal in the control samples [32]. All the indices were employed to assess the impact of the auto mechanic works on the surrounding soils.

**Calculation of WQI:** The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method Ramakrishnaiah *et al*. [33]. The quality rating scale for each parameter qi was calculated by using this expression:

$$qi = (Ci / Si) \times 100$$

A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100. Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter:

$$Wi = 1/Si$$

The overall Water Quality Index (WQI) was calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly as shown below:

$$WQI = \sum_{n=1}^{i=n} wiqi$$

where:
qi : The quality of the ith parameter,
wi : The unit weight of the ith parameter and.
n : The number of the parameter considered.

WQI for the drinking water is taken from the overall WQI given as:

$$\text{Overall WQI} = \Sigma qi\ wi / \Sigma wi$$

Water quality classification based on WQI value.

Table 5: Descriptive classes of water quality index

| S/N | Class | Description |
|---|---|---|
| 1 | <50 | Excellent |
| 2 | 50-100 | Good water |
| 3 | 100-200 | Poor water |
| 4 | 200-300 | Very poor water |
| 5 | >300 | Unsuitable for drinking |

## RESULTS AND DISCUSSION

The results for concentrations of heavy metals in water, plants and soil are represented on Tables 6, 11 and 12 respectively. For soil geo-accumulation index and the classification table are represented on Tables 7 and 1 respectively; contamination factor and the classification table are represented on tables 8 and 3 respectively; enrichment factor and the classification table are represented on tables 9 and 4 respectively. For water quality index, the results are presented on Table 14. While for translocation factor, the results are presented on Table 13.

**Cadmium:** Cadmium is a non-essential element that causes kidney damage in humans and negatively affects plant growth and development. It is released into the environment by power stations, heating systems, metal working industries or urban traffic. It is also used in electroplating, pigment, plastic stabilizers and Nickel-Cadmium batteries. The common source of contaminants is due to corrosion of galvanized pipes, erosion of natural deposits, discharge from metal refineries, run-off from waste batteries and paints. The concentration of Cd was 0.06mg/kg in well water. This exceeded drinking water standards of USEPA and WHO. In plants, Cd accumulates in several tissues and complexes with amino acids, organic acids and other major parts of plant metabolism [34]. In the study, the concentration of Cd in plants ranged from 1.02mg/kg in leaves of *Carica papaya* to 4.43mg/kg in *Musa sapientum* fruit. The normal range for cadmium in plants is between 0.1 - 2.4 mg/kg [35]. The concentration of Cd in soil ranged from 5.13 to 6.12mg/kg. This was above the probable effect level of 3.5mg/kg [36] and above the control 0.01mg/kg. However, in this study area, Cd content in soil was falling in class and classified as highly contaminated with Igeo ranging from 3.60 to 3.78. In the current work, the source appears to be due anthropogenic contribution of Cd in soil. The C/P indicated severe pollution with content ranging from 6.41 to 7.65. The EF indicated depletion to minimal enrichment with a mean content of 1.00

**Lead:** The species of Pb vary considerably with soil type; it is mainly associated with clay minerals, Mn oxides, Fe and Al hydroxides and organic matter. Allowable limits of Pb concentrations vary widely with countries [20]. However, in the study area Pb content in the soil was falling into moderately contaminated with Igeo ranging from 1.39 to 1.53. Additionally the C/P ranging from 0.82 to 0.92 indicated very severe contamination in most of the samples. The EF values ranging from 2.18 to 2.55 (mean value= 2.33) showed moderate enrichment in most of the samples. The values of Pb obtained in this study were lower than the 1162 mg/kg reported by [37] for auto mechanic workshop area in Owerri, South-East Nigeria.

Table 6: Metal concentration of soil close to Anaye dumpsite

| Parameter | Distance 0<br>Depth 0 – 30cm | Distance 10m<br>Depth 0 -30cm | Distance 20m<br>Depth 0 – 30cm | Control<br>0 – 30cm |
|---|---|---|---|---|
| Pb (mg/kg) | 78.36 ± 0.12 | 70.74 ± 0.23 | 68.22 ± 0.10 | 11.35 ± 0.05 |
| Ni (mg/kg) | 65.20 ± 0.05 | 60.00 ± 0.00 | 57.32 ± 0.04 | 9.85 ± 0.02 |
| Cr (mg/kg)) | 90.14 ± 0.10 | 74.31 ± 0.07 | 78.52 ±0.02 | 6.20 ± 0.02 |
| Cd (mg/kg) | 6.12 ± 0.01 | 5.81 ± 0.01 | 5.13 ± 0.01 | 0.01 ± 0.01 |
| Cu (mg/kg) | 445.62 ± 0.12 | 423.11 ± 0.06 | 403.82 ± 0.10 | 34.14 ± 0.02 |
| Fe (mg/kg) | 3115.40 ± 4.12 | 2995.45 ± 2.32 | 2422.14 ± 1.14 | 1006.35 ± 2.15 |
| Zn (mg/kg) | 218.10 ± 0.02 | 211.23 ± 0.04 | 198.47 ± 0.01 | 63.02 ± 0.01 |
| Mn (mg/kg) | 239.10 ± 0.00 | 220.42 ± 0.02 | 223.46 ± 0.06 | 73.46 ± 0.03 |

Table 7: Geoaccumulation index of soil close to Anaye dumpsite

| Parameter | Distance 0<br>Depth 0 – 30cm | Distance 10m<br>Depth 0 -30cm | Distance 20m<br>Depth 0 – 30cm | Mean<br>Igeo |
|---|---|---|---|---|
| Pb | 1.53 | 1.42 | 1.39 | 1.45 |
| Ni | 1.48 | 1.40 | 1.36 | 1.41 |
| Cr | 2.27 | 2.08 | 2.12 | 2.16 |
| Cd | 3.78 | 3.73 | 3.60 | 3.70 |
| Cu | 2.16 | 2.11 | 2.07 | 2.11 |
| Fe | 0.73 | 0.69 | 0.47 | 0.63 |
| Zn | 0.84 | 0.80 | 0.74 | 0.79 |
| Mn | 0.78 | 0.69 | 0.71 | 0.73 |

Table 8: Contamination /pollution index of soil close to Anaye dumpsite

| Parameter | Distance 0<br>Depth 0 – 30cm | Distance 10m<br>Depth 0 -30cm | Distance 20m<br>Depth 0 – 30cm | Mean<br>C/P |
|---|---|---|---|---|
| Pb | 0.92 | 0.82 | 0.82 | 0.85 |
| Ni | 1.86 | 1.71 | 1.64 | 1.74 |
| Cr | 0.91 | 0.74 | 0.79 | 0.81 |
| Cd | 7.65 | 7.26 | 6.41 | 7.11 |
| Cu | 12.38 | 11.75 | 11.22 | 11.78 |
| Fe | 0.62 | 0.60 | 0.48 | 0.57 |
| Zn | 1.56 | 1.51 | 1.42 | 1.50 |
| Mn | 0.50 | 0.46 | 0.47 | 0.47 |

Table 9: Enrichment factor index of soil close to Atikankan dumpsite.

| Parameter | Distance 0<br>Depth 0 – 15cm | Distance 10m<br>Depth 0 -15cm | Distance 20m<br>Depth 0 – 15cm | Mean<br>EF |
|---|---|---|---|---|
| Pb | 2.27 | 2.18 | 2.55 | 2.33 |
| Ni | 2.10 | 2.00 | 2.40 | 2.17 |
| Cr | 4.83 | 4.17 | 5.33 | 4.78 |
| Cd | 2.00 | 2.00 | 2.00 | 2.00 |
| Cu | 4.21 | 4.15 | 4.91 | 4.42 |
| Fe | 1.00 | 1.00 | 1.00 | 1.00 |
| Zn | 1.11 | 1.13 | 1.30 | 1.18 |
| Mn | 1.06 | 1.01 | 1.26 | 1.11 |

However, the levels are in line with those reported by [38] in South-South Nigeria and those in industrial areas in North-West Nigeria, but above that reported by [39] in central Nigeria. The concentration of Pb ranged from 0.14 to 0.21mg/kg in well water. This exceeded drinking water standards of FEPA and WHO. In plants, Pb accumulates in several tissues and complexes with amino acids, organic acids and other major parts of plant metabolism. In the study, the concentration of Pb in plants ranged from 10.35mg/kg in root of *Musa sapientum* to 144.30mg/kg in *Talinum triangulare* root. The critical range for Pb as described by [40] and [35] is 30 – 300mg/kg.

Table 10: Physicochemical properties of hand dug well water close to Anaye dumpsite

| | Distance from dumpsite | | |
|---|---|---|---|
| Parameter | 50m | 100m | Control |
| pH | 7.17 ± 0.03 | 7.21 ± 0.07 | 7.23 ± 0.01 |
| Turbidity (NTU) | 4.84 ± 0.02 | 5.86 ± 0.04 | 1.62± 0.02 |
| Conductivity ($\mu$s/cm) | 487.06 ± 8.42 | 521.93 ± 8.33 | 188.04± 2.04 |
| TDS (mg/L) | 390.94 ± 1.42 | 492.75 ± 2.55 | 231.10 ± 3.20 |
| BOD (mg/L) | 20.28 ± 0.02 | 29.79 ± 0.03 | 1.86± 0.00 |
| COD (mg/L) | 35.90 ± 0.01 | 33.06 ± 0.01 | 10.02± 0.10 |
| $SO_4^{2-}$ (mg/L) | 59.69 ± 0.03 | 64.26 ± 0.04 | 8.44 ± 0.04 |
| DO (mg/L) | 4.40 ± 0.01 | 4.12 ± 0.06 | 2.03± 0.01 |
| Chloride (mg/L) | 24.18 ± 0.06 | 33.10 ± 0.01 | 4.94 ± 0.02 |
| $NO_3^-$ (mg/L) | 17.33 ± 1.11 | 17.84 ± 0.23 | 3.08± 0.02 |
| $PO_4^{3-}$ (mg/L) | 0.61 ± 0.01 | 0.64 ± 0.01 | BDL |
| CN (mg/L) | 0.12 ± 0.02 | 0.09 ± 0.01 | BDL |
| Total Alkalinity (mg/L) | 39.97 ± 2.03 | 44.32 ± 3.28 | 37.46± 0.04 |
| Ca (mg/L) | 23.20 ± 1.10 | 26.14 ± 1.22 | 7. 15± 0.01 |
| Mg (mg/L) | 12.14 ± 0.20 | 11.84 ± 2.12 | 0.36± 0.00 |
| Na (mg/L) | 5.36 ± 0.60 | 5.48 ± 0.62 | 0.52± 0.02 |
| Fe (mg/L) | 1.98 ± 0.02 | 2.01 ± 0.31 | 0.91± 0.01 |
| Cu (mg/L) | 0.18 ± 0.01 | 0.21 ± 0.07 | 0.03± 0.01 |
| Mn (mg/L) | 0.03 ± 0.01 | 0.04 ± 0.01 | BDL |
| Zn (mg/L) | 1.22 ± 0.04 | 0.89 ± 0.21 | 0.38± 0.01 |
| Pb (mg/L) | 0.21 ± 0.07 | 0.14 ± 0.02 | 0.01± 0.00 |
| Cd (mg/L) | 0.06 ± 0.01 | 0.06 ± 0.01 | BDL |
| Ni (mg/L) | 0.02 ± 0.01 | 0.01 ± 0.01 | BDL |
| Cr (mg/L) | 0.01 ± 0.01 | 0.01 ± 0.01 | BDL |

Table 11: Metal concentration (mg/kg) of crop plants from Anaye dumpsite

| PLANT TYPE | PARTS | Cd | Cr | Cu | Fe | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|
| Pawpaw (*Carica papaya*) | Root | 1.10 ± 0.00 | 1.12 ± 0.01 | 14.72 ± 0.03 | 20.32 ± 0.01 | 0.03 ± 0.03 | 39.04 ± 0.01 | 16.53 ± 0.02 |
| | Fruits | 1.06 ± 0.03 | 1.34 ± 0.01 | 4.15 ± 0.01 | 30.00 ± 0.00 | ND | 31.29 ± 0.01 | 13.11 ± 0.02 |
| | Leaves | 1.02 ± 0.01 | 1.20 ± 0.00 | 6.08 ± 0.01 | 16.16 ± 0.01 | ND | 27.67 ± 0.01 | 17.70 ± 0.01 |
| Water leaf (*Talinum triangulare*) | Roots | 3.20 ± 0.00 | 3.18 ± 0.01 | 6.08 ± 0.02 | 23.07 ± 0.01 | 1.19 ± 0.01 | 144.30 ± 0.00 | 34.27 ± 0.01 |
| | Leaves | 2.16 ± 0.01 | 4.35 ± 0.01 | 3.55 ± 0.01 | 17.63 ± 0.01 | 1.99 ± 0.01 | 110.44 ± 0.02 | 36.28 ± 0.02 |
| Plantains (*Musa sapientum*) | Root | 3.75 ± 0.01 | 1.42 ± 0.01 | 1.50 ± 0.01 | 24.50 ± 0.01 | ND | 10.35 ± 0.01 | 11.35 ± 0.01 |
| | Fruits | 4.43 ±0.01 | 0.62 ± 0.01 | 0.66 ± 0.03 | 52.70 ± 0.01 | ND | 17.85 ± 0.02 | 89.94 ± 0.01 |
| Cocoyam (*Xanthosoma mafaffa*) | Tuber | 2.74 ± 0.01 | 1.20 ± 0.00 | 8.22 ± 0.00 | 20.30 ± 0.00 | ND | 29.72 ± 0.02 | 88.01 ± 0.01 |
| | Leaves | 4.32 ± 0.01 | 2.30 ± 0.00 | 4.75 ± 0.00 | 16.12 ± 0.02 | 3.00 ± 0.01 | 31.13 ± 0.01 | 33.47 ± 0.01 |

Table 12: Translocation factor of crop plants from Anaye dumpsite

| Plant Type | Samples | Cd | Cr | Cu | Fe | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|
| Pawpaw (*Carica papaya*) | SITE | 1.89 | 2.27 | 0.69 | 2.27 | 0 | 1.51 | 1.86 |
| | CONTROL | 1.07 | 0 | 0.46 | 2.01 | 0 | 2.20 | 4.31 |
| Water leaf (*Talinum triangulare*) | SITE | 0.68 | 1.37 | 0.58 | 0.76 | 1.67 | 0.77 | 1.06 |
| | CONTROL | 0.48 | 0 | 1.71 | 4.88 | 0 | 0.50 | 0.78 |
| Plantains (*Musa sapientum*) | SITE | 1.18 | 0.44 | 0.44 | 0.28 | 0 | 1.73 | 7.92 |
| | CONTROL | 1.35 | 0 | 0.24 | 0.66 | 0 | 0.79 | 0.45 |
| Cocoyam (*Xanthosoma mafaffa*) | SITE | 1.58 | 1.92 | 0.58 | 0.79 | 0 | 1.05 | 0.38 |
| | CONTROL | 2.13 | 0 | 0.73 | 1.53 | 0 | 1.92 | 1.40 |

Table 13: Water quality index of Anaye well water

| Parameters | Mean (Ci) | Si | qi | Wi = 1/Si | wi qi |
|---|---|---|---|---|---|
| pH | 7.19 | 7.5 | 95.87 | 0.133 | 12.750 |
| Turbidity | 5.35 | 1.00 | 535.00 | 1.000 | 535.000 |
| Conductivity | 504.50 | 1000 | 50.45 | 0.001 | 0.051 |
| TDS | 441.85 | 500 | 88.37 | 0.002 | 0.177 |
| TSS | 3.23 | 10 | 32.30 | 0.100 | 3.230 |
| TS | 445.08 | 1000 | 44.51 | 0.001 | 0.045 |
| BOD | 25.04 | 10 | 250.40 | 0.100 | 25.04 |
| COD | 34.48 | 10 | 344.8 | 0.100 | 34.48 |
| $SO_4^{2-}$ | 61.98 | 400 | 15.50 | 0.003 | 0.047 |
| DO | 4.26 | 5 | 85.20 | 0.200 | 17.04 |
| $CL^-$ | 28.64 | 400 | 7.16 | 0.003 | 0.022 |
| $NO_{3-}$ | 17.59 | 10 | 175.9 | 0.100 | 17.59 |
| $PO_4^{3-}$ | 0.63 | 50 | 1.26 | 0.020 | 0.025 |
| CN | 0.21 | 0.05 | 420.00 | 20.000 | 8400 |
| Total Alkalinity | 42.15 | 100 | 42.15 | 0.010 | 0.42 |
| Ca | 25.60 | 150 | 17.11 | 0.007 | 0.120 |
| Mg | 11.99 | 100 | 11.99 | 0.010 | 0.120 |
| Na | 5.42 | 200 | 2.71 | 0.005 | 0.014 |
| Fe | 2.00 | 0.10 | 2000 | 10.000 | 20000 |
| Cu | 0.20 | 1.0 | 20.00 | 1.000 | 20.00 |
| Mn | 0.04 | 0.05 | 80.00 | 20.000 | 1600 |
| Zn | 1.06 | 5.00 | 21.20 | 0.200 | 4.240 |
| Pb | 0.18 | 0.05 | 360.00 | 20.000 | 7200 |
| Cd | 0.06 | 0.01 | 600.00 | 100.00 | 60 000 |
| Ni | 0.02 | 0.02 | 100.00 | 0.001 | 0.100 |
| Cr | 0.01 | 0.01 | 100.00 | 0.100 | 10.000 |
| | | | | Σwi = 322.995 | Σwi qi =97880.511 |

$$WQI = \frac{97880.511}{322.995} = 303.04$$

Table 14: Water quality classification based on WQI value

| WQI value | Water quality | Water samples |
|---|---|---|
| <50 | Excellence | 21 |
| 50-100 | Good water | 30 |
| 100-200 | Poor water | 25 |
| 200-300 | Very poor water | 15 |
| <50 | Unsuitable for drinking | 09 |

**Chromium:** The concentrations of Cr in soil ranged from 74.31 to 90.14mg/kg, which was higher than that of the control (6.20mg/kg) as shown in table 6. Therefore most of the values obtained in this study conform to the acceptable limits. The values of Cr obtained in this study were lower than the 900–2000mg/kg reported by [10] in dumpsites within Ado-Ekiti town in South West Nigeria. The elevated concentrations were ascribed to deposited wastes which contained high concentrations of Cr. Although Cr toxicity in the environment is relatively rare, it still presents some risks to human health since chromium can be accumulated on skin, lungs, muscles, fat, in liver, dorsal spine, hair, nails and placenta where it is traceable to various heath conditions [41]. The Igeo showing moderately contaminated, ranging from 2.08 to 2.27. The C/P obtained for Cr ranged from 0.74 to 0.91, which falls under the class of very severe contamination and the EF obtained for Cr ranged from 4.17 to 5.33, which falls under the class of moderate enrichment. Therefore, the source of Cr appears to be anthropogenic from the existing mechanic workshop, where they dump chromium compounds. The normal range of chromium in soil is 100 mg/kg [42] and all the samples examined exceeded the normal value. In water, Cr was 0.01mg/kg lower than the drinking water standards stipulated by EPA and irrigation standards limit by FAO. In plants, the concentration of Cr in plants ranged from 0.62mg/kg in fruit of *Musa sapientum* to 4.35mg/kg in *Talinum triangulare* leaves. This fall within the natural occurrence in plant foodstuffs this is 0.01 to 14mg/kg [43].

**Nickel:** Nickel is used extensively in Nickel plating and alloy manufacture. In water, Ni concentration ranged from 0.01 to 0.02mg/kg. The values for Ni were within the acceptable limits of WHO (2006)/NAFDAC (2001). Similarly, Ni has been found in a variety of plants and ranges up to 340 mg/kg have been recorded non-edible wild plants. In benthic Algae of fresh water lakes, Ni

concentrations have ranged between 52 –74 mg/kg [42]. Small amounts of Ni may be beneficial to plants and its plant toxicity varies in magnitudes according to plant species. Cases of Ni poisoning in plants include dwarfing or repression of growth [45].The concentration of Ni in plants in the dumpsite ranged from ND to 3.00mg/kg in leaves of *Xanthosoma mafaffa*. This is below the category of Ni contents in plants as described by [40] which is between 10 – 50 mg/kg. The concentration of Ni in the soil samples at the dumpsites ranged from 57.32 to 65.20mg/kg (Table 6). For the control samples, Ni was 9.85mg/kg. The study by [10] found Ni to range between 18–335 mg/kg at the surface layer of soil for all the dumpsites. Nickel content in soil can be as low as 0.2mg/kg or as high as 450mg/kg although the average is about 20mg/kg [46]. The Igeo range for Nickel (1.36-1.48) obtained revealed that the samples examined fell into class 1-2, indicating moderately contaminated with Nickel as per Muller's six classes of geoaccumulation index. The contamination/ pollution index (C/P) was high and ranged from 1.64 to 1.86, showing slight pollution with Nickel (Table 8). The EF was low and ranged from 2.00 to 2.40, indicating moderate enrichment with nickel (Table 9).

**Manganese:** Manganese (Mn) is an essential micronutrient throughout all stages of plant development. In humans, it has been implicated in with diseases such as diabetes, nervous instability, convulsions, bone disorders in babies and rheumatoid arthritis [44]. It is important for vital plant functions and act as a cofactor in various enzymes as well as in the structure of chlorophyll. The range of Mn in water was between 0.03 to 0.04mg/kg. This was within the stipulated drinking water standards. Manganese levels ranged from 220.42 to 239.10 mg/kg in soil of the study area (Table 6).A previous study [47] reported concentration in the range of 263.95 - 406.00 mg/kg at dumpsite and a range of 19.21 - 485.00 mg/kg at 100 m away from the dumpsite located within Akwa Ibom state. Manganese may be found in most soils since it is one of the elements in the Earth crust [48]. The Igeo indicated that the soils in the area fell under the class ranging from minimum of 0.69, practically uncontaminated; and maximum of 0.78 showing uncontaminated to slightly contaminated. The C/P indicated moderate contamination with content ranging from 0.46 to 0.50. The EF indicated depletion to minimal enrichment with a mean content of 1.11 ranging from 1.01 to 1.26. Normal threshold value for Manganese in soils is 100 mg/kg [49].

**Copper:** Copper enters water system through mineral dissolution and industrial effluents [50]. Among industrial sources include copper plating, pulp and paper mills, e-waste, sewage and other forms of waste waters. The Cu in water was ranged 0.04 – 0.59mg/kg. Cu was within drinking water standards stipulated by ICMR and EPA. The normal range of Copper in plants is 1 – 50 mg/kg although it is also reported that the normal range should be 4 – 15 mg/kg [44]. Cu in plants was largely within the normal range. It ranged from 0.66 mg/kg in *Musa sapientum* fruit to 14.72 in root of *Carica papaya.* In soil, the concentration of Cu ranged from 403.82 to 445.62 mg/kg. This was higher than the control and the value of 197.0mgkg [51]. The Igeo obtained for copper was pointing to moderate to highly contaminated and the values ranged from minimum of 2.07 to maximum of 2.16. The C/P for Cu ranged from 11.22 to 12.38 and the EF for Cu ranged from 4.15 to 4.91.

**Zinc:** Zinc belongs to a group of trace metals, which are essential for the growth of humans, animals and plants and are potentially dangerous for the biosphere when present in high concentrations. The main sources of pollution are industries and the use of liquid manure, composted materials and agrochemicals such as fertilizers and pesticides in agriculture [52]. The zinc concentration in the study area ranged from 198.47 to 218.10 mg/kg and is considered high (Table 6). The Igeo indicated that the soils in the study area fell under the class ranging from minimum of 0.74, practically uncontaminated and maximum of 0.84, showing slightly contaminated. The C/P indicated slightly polluted, ranging from 1.42 to 1.56 and the EF indicated moderate enrichment with a mean content of 1.18 and ranging from 1.11 to 1.30. Zinc in urban water is caused by a variety of industrial effluents including phosphates fertilizers, Metal Processing Units, landfill leachates, urban storm water, fly ashes of coal powered plants, poultry sewage and compost [44]. The Zn concentration in water ranged 0.89 – 1.22 mg/kg. This was higher than the stipulated drinking water standards by EPA and irrigation limits by FAO. The Zn range was 11.35 in root of *Musa Sapientum* to 89.94 in fruits of *Musa sapientum.* This range did not exceed the critical concentration range in plants of 100 – 400mg/kg reported by [35]. In Nigeria 47% of soils are depleted in zinc, however high concentrations of Zn were found in this dumpsite area, which clearly suggest that the source is anthropogenic instead of natural [53].

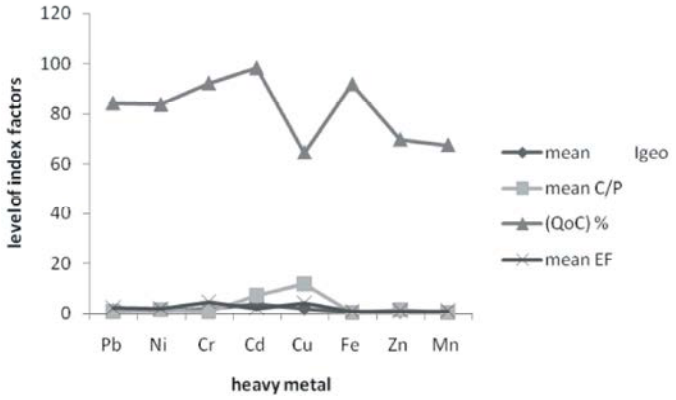


Fig. 2: Pattern of metal fluctuations in the dumpsite as shown by index factors

Table 15: Average Contamination factors (CF), geo- accumulation index (I-geo), Enrichment factor and quantification of contamination (QoC) heavy metals in soils of Anaye dumpsite

| Parameter | Mean Igeo | Mean C/P | (QoC) % | Mean EF |
|---|---|---|---|---|
| Pb | 1.45 | 0.85 | 84.33 | 2.33 |
| Ni | 1.41 | 1.74 | 83.81 | 2.17 |
| Cr | 2.16 | 0.81 | 92.35 | 4.78 |
| Cd | 3.70 | 7.11 | 98.42 | 2.00 |
| Cu | 2.11 | 11.78 | 64.62 | 4.42 |
| Fe | 0.63 | 0.57 | 91.95 | 1.00 |
| Zn | 0.79 | 1.50 | 69.89 | 1.18 |
| Mn | 0.73 | 0.47 | 67.73 | 1.11 |

**Quantification of Soil Contamination (QoC):** On the basis of the quantification of anthropogenic input of the heavy metals in the soils presented in Table 15, the order of contamination with individual metals is as follows: Anaye dumpsite: Cd > Cr > Fe > Pb > Ni> Zn > Mn > Cu . I-geo factor is not readily comparable with C/P and EF due to the nature of *I-geo* calculation which involves a logarithm function and a background multiplication factor 1.5 [54]. However, results from the different impact-assessing indices are consistent with each other as shown in Fig. 2. This could simply be an indication that the anthropogenic sources of the metals in the soils surrounding these waste dumpsite are of similar origin, with anthropogenic inputs in soils of the metals, generally, in a decreasing order of Cd (98.42%) > Cr (92.35%) > Fe (91.95%) > Pb(84.33%) > Ni (83.81%) > Zn (69.89%) > Mn (67.73%) > Cu (64.62%) as shown in Table 15.

**Pollution Load Index:** The PLI values calculated for the site was found to be polluted (PLI > 1), suggesting inputs from anthropogenic sources.

**Water Quality Index:** The water quality index (WQI) of the groundwater samples analyzed was calculated according to the procedure explained above and presented in Table 13 while Table 14 shows the five groups of WQI, ranging from excellent water to water unsuitable for drinking and the distribution of the thirty groundwater samples according to their respective quality group. The computed overall WQI was 303.04 belonging to the unsuitable for drinking quality category. The high value of the WQI obtained may be due to the impact of leachate from the dumpsite on the groundwater as well as infiltration arising from unlined soak-away within the vicinity.

**Translocation Factor:** The translocation factor (TF), which is the ratio of the concentration of metal in the aerial portion of the plant to the total concentration in the part in the soil, is shown in Table 12. Pb, Cr, Cd and Zn had the higher TFs which are 1.73; 2.27; 1.89 and 7.92 respectively. The highest TF value obtained for *Carica papaya* were Cr (2.27) and Fe (2.27); for *T. triangulare* Cr (1.37) and Ni (1.67) while the highest TF for Cu (0.69) was recorded in *Carica papaya*. A study gave a generalized transfer coefficient in the soil-plant system as: As, Co, Cr, Cu and Pb (0.01 - 0.1), Cd and Zn (1 - 10), Ni (0.1-1) [55]. The TF of Cr, Ni and Pb are above the normal range in some plants species (Table 12). The main concern is Cr, Cd, Pb and Zn with high transfer factor since Cr, Cd and Pb are non-essential toxic elements for plants, animals and humans. This study showed a TF>1 for Cr in *T. triangulare,* TF>1 for Pb (1.51) in *Carica papaya* and in *Musa sapietum* (1.73) which agreed with earlier studies by [56]. The low TF value for Cu, despite its high contamination level in the landfill soil may be due to its

strong adsorption onto the organic matter, which renders it less bioavailable to plants. In the dumpsite, refuse was burned continuously, thus the higher concentration of certain metals such as Cr, Cd, Pb and Zn in some plant species may be due to foliar absorption since plants can absorb heavy metals through leaves.

**Plant/Soil Metal Concentration Ratio:** The plant/soil metal concentration ratio trend in Anaye dumpsite was as follows: Cr (6.69) > Mn (1.38) > Pb (1.36) > Ni (1.14) > Cd (0.92) > Zn (0.35) > Co (0.71) > Cu (0.07). This indicates that Cr, Mn, Pb and Ni were more available in the plant system of the dumpsite soil. It is interesting here to note that Cr had the highest plant/ soil metal concentration factor even though its bioavailability in plants (71.5 mg/kg) was lower compared to Manganese (192.3 mg/kg).

## CONCLUSION

Cadmium (Cd), Cobalt (Co), Chromium (Cr), Nickel (Ni) and Lead (Pb) all exceeded drinking water standards. Cobalt was compared to the tolerance limit reported by [45]. In case of crop plants Cadmium (Cd), Cobalt (Co) and Chromium (Cr) were above the maximum limit of the critical range [35]. Nickel (Ni) was considered above critical concentration range reported by [40]. Zinc (Zn) and Copper (Cu) were within normal concentration ranges. In the soil, Cadmium (Cd) and Nickel (Ni) exceeded the Probable Effect Level (PEL). The bioaccumulation between metals did not display much variation and the trend followed: Cr (6.69) > Mn (1.38) > Pb (1.36) > Ni (1.14) > Cd (0.92) > Zn (0.35) > Co (0.71) > Cu (0.07). Cr was more bio-available while Co was the least. Soil Geo-accumulation Index registered moderate soil contamination with Cr, Cu, Ni and Pb having more deposition compared to Fe, Zn and Mn. Cr had the highest plant/soil metal concentration factor even though its bioavailability in plants was higher compared to Manganese. Pollution Load Index for Anaye was greater than 1.

## REFERENCES


1. Jhamnani, B. and S.K. Singh 2009. Groundwater contamination due to Bhalaswa landfill site in New Delhi, International Journal of Environmental Science and Engineering, 1: 121-5.
2. Long, Y.Y., D.S. Shen, H.T. Wang, W.J. Lu and Y. Zhao, 2011. Heavy metal source analysis in Municipal Solid Waste (MSW): Case study on Cu and Zn. J. Hazard. Mater., 186(2-3): 1082-1087.
3. Bronius, J. and L. Vaida, 2009. Investigation of influence of lapes landfill leachate on ground and surface water pollution with heavy metal. Environm. Engin. Landsc. Manage., 17(3): 131-139.
4. Prabpai, S., L. Charerntanyarak, B. Siri, M.R. Moore and B.N. Noller, 2009. Effects of residues from municipal solid waste landfill on corn yield and heavy metal content. Waste Manage., 29(8): 2316-2320.
5. Udosen, E.D., Benson, N.U., Essien, J.P. and Ebong, G.A. (2006): Concentration of heavy metals in waste dumpsites. International Journal of Soil Science, 23: 91-101.
6. Stollenwerk, K.G. and J.A. Colman, 2003. Natural remediation potential of arsenic-contaminated ground water, in Welch, A.H. and Stollenwerk, K.G., Eds., Arsenic in ground water- Geochemistry and occurrence, Boston, Kluwer, pp: 351-379.
7. Christensen, T.H., P. Kjeldsen, P.L. Bjerg, D.L. Jensen, J.B. Christensen, A. Baun, H.J. Albrechtsen and G. Heron, 2001. Biogeochemistry of landfill leachate plumes: Appl. Geochem., 16: 659-718.
8. Ogunyemi, S., R.O. Awodoyin and T. Opadeji, 2003. Urban Agricultural production: heavy metal contamination of AmaranthusCreienties. L. Grown in Domestic refuse land fill soil in Ibadan, Nigeria. Environ. Journal Agric. Sci., pp: 87-94.
9. Fatoki, O.S., 2000. Trace zinc and copper concentration in road side vegetation and surface soils: A measurement of local atmospheric pollution in Alice, South Africa. Int. J. Env. Stud., 57: 501-513.
10. Awokunmi, E.E., S.S. Asaolu and K.O. Ipinmoroti, 2010. Effect of leading on heavy metal concentration of soil in some dumpsites. African Journal of Environmental Science and Technology, 4(8): 495-499.
11. Woodbury, P.B., 2005. Municipal solid waste composting: potential effects of heavy metals in municipal solid waste composts on plants and the environment. Available at: http://www.css. cornell.edu/compost/mswfactsheets/msw.fs5.html.
12. Akintunde, I., 1986. Management and Disposal of Industrial Waste in Nigeria. Symposium on Plant Sanitation and Industrial Waste Disposal. University of Ibadan. Ibadan. 9th–13th September, 1986.

13. Nounamo, L., M. Yemefack, M. Tchienkoua and R. Njomgang, 2000. Impact of natural fallow duration on topsoils characteristics of a Ferralsol in southern Cameroon. Nig. J. Soil Res., 3: 52-57.
14. Amusan, A.A., D.V. Ige and R. Olawale, 2005. Characteristics of soil and crop uptake of metals in municipal waste dumpsites in Nigeria Journal of Hum. Ecol., 1(2): 167-171.
15. Awofolu, O.R., 2005. Environmental Monitoring and Assessment in Nigeria, 105: 431-447.
16. Muller, G., 1969. Index of geoaccumulation in sediments of the Rhine River, J. Geol., 2: 108-118.
17. Abrahim, G.M.S. and R.J. Parker, 2008. Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. Environ. Monit. Assess., 136: 227-238.
18. Lu, X., L. Li, L. Wang, K. Lei, J. Huang and Y. Zhai, 2009. Contamination assessment of mercury and arsenic in roadway dust from Baoji. China Atmos. Environ., 43: 2489-2496.
19. Shi, G., Z. Chen, C. Bi, Y. Li, J. Teng, L. Wang and S. Xu, 2010. Comprehensive assessment of toxic metals in urban and suburban street deposited sediments (SDSs) in the biggest metropolitan area of China. Environ. Pollut., 158: 694-703.
20. Lacatusu, R., 2000. Appraising levels of soil contamination and pollution with heavy metals. In: H. J. Heineke W, Eckelmann AJ, Thomasson RJ, Jones A, Montanarella L, Buckley B (Eds.). European Soil Bureau- Research Report No. 4.Section 5(7):393 403. The European Soil Bureau, Joint Research Centre I-201020 ISPRA – Italy.
21. Aiyesanmi, A.F., 2008. Baseline heavy metal concentrations in river sediments within Okitipupa southeast belt of the Nigerian bituminous sand field. Journal of Chemical Society of Nigeria, 33(2): 29-41.
22. Simex, S.A. and G.R. Helz, 1981. Regional geochemistry of trace elements in Chesapeake Bay. Environ. Geo., 3: 315-323.
23. Loska, K., D. Wiechula, B. Barska, E. Cebula and A. Chojnecka, 2003. Assessment of arsenic enrichment of cultivated soils in Southern Poland. Pol. J. Environ. Stud., 12(2): 187-192.
24. Kothai, P., P. Prathibha, I.V. Saradhi, G.G. Pandit and V.D. Puranik, 2009. Characterization of atmospheric particulate matter using pixe technique. Int. J. Environ. Sci. Eng., 1(1): 27-30.
25. Chakravarty, M. and A.D. Patgiri, 2009. Metal pollution assessment in sediments of the Dikrong River, NE India. J. Hum. Ecol., 27(1): 63-67.
26. Seshan, B.R.R., U. Natesan and K., Deepthi, 2010. Geochemical and statistical approach for evaluation of heavy metal pollution in core sediments in southeast coast of India. Int. J. Environ. Sci. Tech., 7(2): 291-306.
27. Nyangababo, J.T., E. Henry and E. Omutange, 2005a. Lead, cadmium, copper, manganese and zinc in wetland waters of Victoria Lake Basin, East Africa. Bull. Environ. Contam. Toxicol., 74(5): 1003-1010
28. Kamaruzzaman, M.C.., M.S. Ong, A. Noor, S. Shahbudin and K.C.A. Jalal, 2008. Geochemistry of sediment in the major estuarine mangrove forest of Terengganu Region, Malaysia. Am. J. Appl. Sci., 5(12): 1707-1712.
29. Ong, M.C. and B.Y. Kamaruzzaman, 2009. An assessment of metal (Pb and Cu) contamination in bottom sediments from South China Sea coastal waters, Malaysia. Am. J. Appl. Sci., 6(7): 1418-1423.
30. Sutherland, R.A., 2000. Bed sediment associated trace metals in an urban stream Oahu. Hawaii. Environ. Geo., 39(6): 611-627.
31. Tomilson, D.C., D.J. Wilson, C.R. Harris and D.W. Jeffrey, 1980. Problem in assessment of heavy metals in estuaries and the formation of pollution index. Helgol. Wiss. Meeresunlter, 33(1-4): 566-575.
32. Victor, A.A., F.A. Akinlolu and E.S. Cheo, 2006. Heavy metal concentrations and distribution in surface soils of Bassa industrial zone1, Douala, Cameroon. The Arab. J. Sci. Eng., 31(2A): 147-158.
33. Ramakrishnaiah, C.R., C. Sadashivaiah and G. Ranganna, 2009. Assessment of Water Quality Index for Groundwater in Tumkur Taluk, Karnataka State, India. E-Journal of Chemistry, 6(2): 523-530.
34. Benavides, Maria P., Susanna M. Gallego, Maria L. Tomaro, 2005. Cadmium Toxicity in Plants; Brazilian Journal of Plant Physiology, 17(1): 21-34.
35. Maiti, S.K., 2003. Handbook of Methods in Environmental Studies – Vol. 2: Air, Noise, Soil and Overburden Analysis, ABD Publishers.
36. Abenchi, E.S., O.J. Okunola, S.M.J. Zubairu, A.A. Usman and E. Apene, 2010. Evaluation of Heavy metals in roadside soils of major streets in Jos Metropolis, Nig. J. Environ. Chem. Ecotoxicol., 2(6): 98-102.

37. Nwachukwu, M.A., H. Feng and J. Alinnor, 2011. Trace metal Deposition in soil from Auto-mechanic village to urban residential areas in Owerri, Nigeria. Proc. Environ. Sci., 4: 310-322.
38. Udousoro, I.I., I.U. Umoren and E.O. Asuquo , 2010. Survey of some heavy metal concentrations in selected soils in South Eastern parts of Nigeria. World J. Appl. Sci. Technol., 2(2): 139-14.
39. Pam, A.A., R. Sha'Ato and J.O Offem, 2013. Contributions of Automobile Mechanic Sites to Heavy Metals in Soil: A Case Study of North Bank Mechanic Village Makurdi, Benue State, Central Nigeria. J. Chem. Biol. Physical Sci., 3(3): 2337-2347.
40. Nirmal Kumar, J.I. Hiren Soni and Rita N. Kumar, 2006. Biomonitoring of selected freshwater macrophytes to assess lake trace element contamination: a case study of Nal Sarovar Bird Sanctuary, Gujarat, India, J. Limnol., 65(1): 9-16.
41. Reyes-Gutiérrez, L.R., E.T. Romero-Guzmán, A. Cabral- Prieto and R. Rodríguez-Castillo, 2007. Characterization of Chromium in Contaminated Soil Studied by SEM, EDS, XRD and Mössbauer Spectroscopy. Journal of Minerals & Materials Characterization & Engineering, 7(1): 59-70.
42. Wedepohl, K.H., 1995. The composition of the continental crust, Geochim. Cosmochim. Acta, 59(7): 1217-1232.
43. Fifield, F.W. and P.J. Halnes, 2000. Environmental chemistry. Second Ed. Blackwell Science Ltd., Oxford pp: 364-375.
44. Abbasi, S.A., Naseema Abbasi and Soni, Rajendra, 1998. Heavy metals in the environment, Mittal Publications.
45. Sharma, B.K., 2001. Environmental Chemistry – 6th Revised Edition; GOEL Publishing House.
46. Lenntech Water Treatment, 2009. Chemical Properties, Health and Environmental Effects of Cobalt. Lenntech Water Treatment and Purification Holding B.V. www.lenntech.com/periodic/ elements/co.htm.
47. Udeme, A.E., 2001. Solid waste analysis and characterization and Department of Chemistry. University of Uyo.
48. Dara, S.S., 1993. A textbook of environmental chemistry and pollution control. S. Chard & Company Ltd. Ram Nagar, New Delhi 110055.
49. Larocque A.C.L. and P.E. Rasmussen, 1998. An overview of trace metals in the environment: mobilization to remediation, Environ. Geol., 33: 85-91.
50. Adepelumi, A., B. Ako and I.T. Ajayi, 2001. Groundwater contamination in basement –complex area of Ile-Ife, south western Nigeria: A case study using the electrical-resistivity of geographical method. Hydrogeology Journal, 9(6): 611-622.
51. Pascual-Barrera, A., G. Gold-Bouchot, V. Ceja-Moreno and M. Del Rı´o-Garcı´a, 2004. Heavy metals and hydrocarbons in sediments from three Lakes from San Miguel, Chiapas, Mexico Bull. Environ. Contam. Toxicology, 73: 762-769.
52. Romic, M. and D. Romic, 2003. Heavy metal distribution in agricultural top soils in urban area, Environ. Geol., 43: 795-805.
53. Aswathanarayana, U., 1995. Geo-environment: An Introduction, A.A. Balkema, Rotterdam, The Netherlands.
54. Fagbote, E.O. and E.O. Olanipekun, 2010. Evaluation of the status of Heavy Metal pollution of soil and plant *(Chromolaena Odorata)* of Agbadu Bitumen Deport Area, Nigeria. American - Eurasian J. Sci. Res., 5(4): 241-248.
55. Kloke, A., D.R. Sauerbeck and H. Vetter, 1984. Changing metal cycles and human health, (ed .J.O. Nriagu). Spinger-Verlag, Berlin, pp: 113-141.
56. Oyedele, D.J., I.B. Obioh, J.A. Adejumo, A.F. Oluwole, P.O. Aina and O.I. Asubiojo, 1995. Lead contamination of soils and vegetation in the vicinity of a lead smelter in Nigeria. The Sci. of the Total Environ., 1732: 189-195.