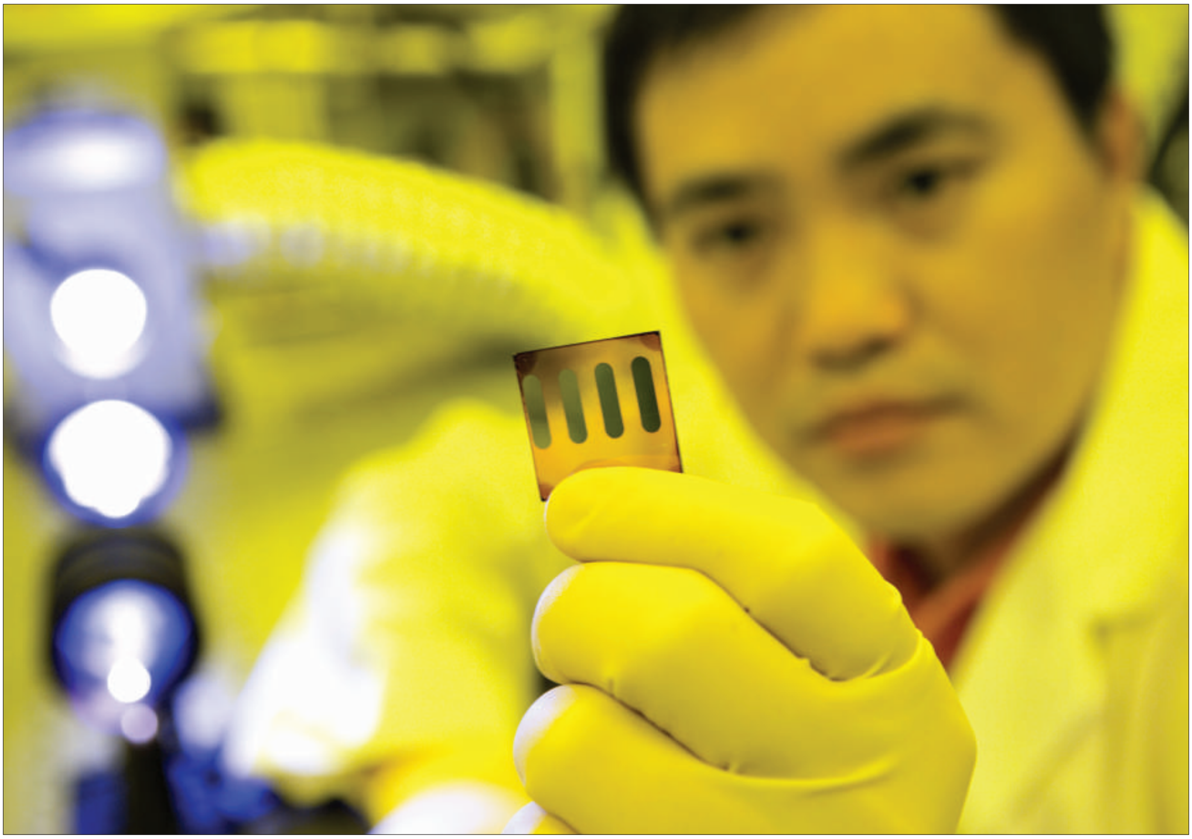

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# Research Article
# Multivariate Statistical Evaluation of Ecological Risks Associated with the Uncontrolled Tipping Method of Urban Wastes at Uyo Village Road, Akwa Ibom State, Nigeria

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## Abstract

**Background and Objective:** The activities of human beings have generated huge amounts of waste materials which are not properly managed by most countries of world thereby causing problems to the environment. **Materials and Methods:** This study used multivariate statistical approach to assess the accumulation and the actual source of Pb, Cd, Ni, Fe, Zn and Cu in the studied soil, stream and *Anarcardium occidentale* in Uyo Village Road where open dumping of wastes is currently practiced. **Results:** Results obtained revealed that the levels of all the metals in samples investigated were higher than their corresponding levels in the background samples (control). The mean values of all the metals determined in studied soils and stream were also higher than their recommended limits whereas; some were within their limits in *Anarcardium occidentale*. The study also indicated that Pb and Cd belong to the very high contamination class while the potential ecological risk index categorized the studied locations as the high risk class. **Conclusion:** The results obtained in the studied stream indicated a threshold of warning for the metals determined at all the locations. Multivariate analysis confirmed some fundamental factors responsible for the accumulation of these metals in the studied soil, water and fruits. Health risk assessment identified Cd as the metal with a very high risk potential and children were more vulnerable to the Cd toxicity through the consumption of *Anarcardium occidentale*.

Key words: Multivariate analysis, trace metals, ecological risk, uncontrolled tipping, dumpsite soil, Uyo village road, *Anarcardium occidentale*

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Human activities in the different areas of life have generated enormous waste materials into the environment however; these wastes are not properly managed by many countries of the world especially the developing and underdeveloped ones. Consequently, the environment has been heavily loaded with toxins which are circulated along the food chain. Reports have shown that the accumulation of contaminants, especially metals in the environments is a serious threat to life[1,2]. The improper management of urban waste has also elevated the level of toxic substances including metals in the environment[3,4]. The waste dumpsite in Uyo, Akwa Ibom State is located along Uyo village Road where fruits of *Anarcardium occidentale* (cashew) widely consumed in the area are harvested. Apart the fruits, the bark and leaves of cashew are widely used for its various medicinal potentials[5-8]. The leachates from the dumpsite are emptied into the adjourning stream where some aquatic foods are obtained. The downward part of the stream is also used as a fish pond and for irrigation of vegetables. Reports have shown that plants parts are effective bio-indicators of soil contamination by trace metals[9-11]. In this study, multivariate analysis was employed to evaluate the levels and the actual source of metals in the soil, water and fruits of *Anarcardium occidentale*. It has been reported that the use of multivariate analysis for the assessment of a polluted environment gives the accurate pollution status of the area under investigation[12,13]. According to Simeonov *et al.*[14] the contamination and subsequent pollution of the environment is a multivariate process in principle and it is only a multivariate approach that is suitable for the evaluation. Multivariate analysis technique identifies the impact from natural and anthropogenic sources on the environment[15]. Accordingly, Pearson correlation analysis, principal component analysis and Hierarchical cluster analysis were utilized for the effective pollution assessment of the study area. The multivariate analysis resulted in the identification of relationships among the trace metals and the factors responsible for their availability in the studied environment. This research was undertaken to assess the levels of toxic and essential elements in the waste-impacted soil, water and fruits of *Anarcardium occidentale* obtained from Uyo village Road, Uyo. Hence, the outcome of this study will reveal the negative impact of open dumping of wastes along Uyo village Road on the quality of soil, water and fruits of *Anarcardium occidentale*. It is also expected that the result will create awareness on the health problems associated with the consumption of *Anarcardium occidentale* harvested from the study area on the consumers. This study will assist the State waste management Agency on the proper waste management methods and reduce the menace of environmental contamination/pollution.

## MATERIALS AND METHODS

**Sample collection, treatment and analysis:** The soil, water and fruits used for this study were collected between November, 2018 and January, 2019 during the dry season using standard analytical procedures. Surface soil (0-15 cm) samples were obtained within Uyo Village Road dumpsite at 5 designated locations using soil Auger. Soil samples were also obtained from a location outside the waste dumpsite and used as the control. At each location, 3 sub samples were obtained and combined together to form a composite sample for the location. A total of 45 sub and 15 composite samples were collected for this study. These samples and control were sun dried for 3 days, homogenized and sieved through a 2 mm mesh. One gram of the sieved samples and control was digested using Aqua Regia on a hot plate and the filtrate preserved for metal analysis.

Water samples were collected from 5 different locations along Uyo Village Road stream according to APHA[16] methods. Water samples were also collected at the upper part of the stream outside the vicinity of the waste dumpsite and used as control. Water samples and control were collected in plastic containers pre-treated with 0.1 MHCl acid and sun-dried. The plastic containers were first rinsed with the water to be sampled before collection. Samples and control collected were treated with 1mL of concentrated $HNO_3$ to maintain the metals in one oxidation state. The samples were then preserved for the analysis of trace metals.

The fruits of *Anarcardium occidentale* (cashew) were obtained from plants at 5 different locations within the vicinity of Uyo Village Road wastes dumpsite. At each location, fruits were obtained from 4 different cashew plants and merged together to form a composite sample. Fruits were also collected from 4 different stands of cashew outside the waste dumpsite and used as the control. These samples and control were transferred to the laboratory in a cooler. In the laboratory these samples and control were washed carefully with deionized water, peeled and sliced into smaller pieces. The sliced samples and control was oven dried at 60°C for 24 h. The dried samples and control were later disaggregated using an agate mortar, homogenized, sieved and stored in clean bottles[17]. To 2 g of the sieved sample in a 100 mL beaker, 10 mL $HNO_3$ was added and heated for 15 min. The mixture was allowed to cool and then 5 mL conc. $HNO_3$ was added and heated again for 30 min till the volume of the mixture was reduced to 5 mL. Five milliliter of deionized water and 3 mL 30% $H_2O_2$ were added to the mixture. The beaker was covered and the solution heated until intense effervescence evolved. Then 1 mL 30% $H_2O_2$ was added and heated gently until the effervescence disappeared. Five milliliter conc. HCl was added to the mixture followed by 10 mL deionized water and the solution heated for 15 min and allowed to cool. The cooled mixture was then filtered and diluted to 60 mL with deionized water. The concentrations of Pb, Cd, Ni, Fe, Zn and Cu in the filtrates obtained were analyzed using 710 Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES).

**Determination of pollution indices**

**Contamination factor (CF):** The contamination factor of trace metals in the studied dumpsite soils was determined using Eq. 1:

$$CF = \frac{Ci}{Bi} \tag{1}$$

where, Ci is the metal level in studied dumpsite soil, Bi is the reference value which in this study is the background concentration of metals determined in Table 1.

**Ecological risk factor ($E^i_r$):** The Ecological risk factor of trace metals determined was determined using Eq. 2:

$$E^i_r = Tr \times CF \tag{2}$$

where, Tr is the toxic-response factor for a particular metal and CF is the contamination factor. Toxic response factors for metals determined as reported by Hakanson[18] are Pb (5.00), Cd (30.00), Ni (5.00), Fe (0.00), Zn (1.00) and Cu (5.00).

**Potential ecological risk index (RI):** The potential ecological risk index (RI) of the different locations where samples were collected within the dumpsite soil was determined using Eq. 3:

$$RI = \Sigma E^i_r \tag{3}$$

where, $\Sigma E^i_r$ indicates the summation of ecological risk factors of trace metals in the studied dumpsite soils[19]. According to Hakanson[18] $E^i_r$ and RI are classified as follows:

- Er<40 : Low ecological risk
- 40<Er≤80 : Moderate ecological risk
- 80<Er≤160 : Appreciable ecological risk
- 160<Er≤320 : High ecological risk
- >320 : Serious ecological risk
- RI<150 : Low ecological risk
- 150<RI<300 : Moderate ecological risk
- 300<RI<600 : High ecological risk
- RI≥600 : Significantly high ecological risk

**Metal pollution index (MPI):** Metal pollution index of trace metals in water was determined using Eq. 4:

$$MPI = \frac{\text{Concentration of metal in studied river}}{\text{Recommended limit for the metal in water}} \tag{4}$$

**Health risk assessment:** The health risk associated with the consumption of fruits of *Anarcardium occidentale* was assessed by calculating the daily intake rate (DI), non-carcinogenic risk (HQ) and total chronic hazard index (THI).

**Daily intake (DI):** The risk associated with human exposure to these trace metals via the consumption of the fruits of *Anarcardium occidentale* was assessed to appraise the non-cancer risk on human within the area investigated. Daily intake was calculated using USEPA[20] and HESP model[21]. Daily Intake (DI) of *Anarcardium occidentale* fruits ingested was validated using equation 5:

$$DI = C \times IngR \times EF \times EDBW \times AT \tag{5}$$

where, C is the mean metal concentration, IngR is the soil ingestion rate, EF is the exposure frequency/day/year, ED is the exposure period in a year, BW is the body weight in (g) and AT is the average time for non-carcinogens[20,22]. Numerical values for the parameters used for the computation of DI are indicated below.

**Non-carcinogenic risk (HQ):** A non-carcinogenic risk for individual metal expressed as hazard quotient was evaluated using Eq. 6:

$$HQ = \frac{DI}{Rfd} \tag{6}$$

where, HQ is the non-cancer hazard quotient and Rfd is the chronic reference dose for a metal. The Rfd mg $kg^{-1}$/day for trace metals are: Pb (0.00357), Cd (0.001), Ni (0.02), Fe (0.643), Zn (0.214) and Cu (0.14) by FAO/WHO[23].

**Total chronic hazard index (THI):** Total chronic hazard index (THI) which represents the sum of all the individual hazard quotients (HQ) was evaluated using Eq. 7:

$$THI = HQ = HQPb+HQCd+HQNi+HQFe+HQZn+HQCu \quad (7)$$

Risk assessment of parameters and values applied are ingestion rate (IR) (100 and 50 mg/day for children and adults, respectively[22,24]. Exposure frequency (day/year) (350 days/year)[25], Exposure duration (year) (6 years-child[22], 30 years-adult[22]), Average time for non carcinogens (day/year) (365 days/year)[26], Body weight (kg) (15 kg-child[20,26], 70 kg-adult)[26].

**Statistical analysis:** The analysis of mean, standard deviation, pearson correlation analysis, principal component analysis, cluster analysis of trace metals determined in soil, water and fruit were carried out using IBM SPSS Statistics 20.

## RESULTS AND DISCUSSION

Results for trace metals in soils, water and fruit samples from Uyo Village Road are shown in Table 1-3.

**Distribution of trace metals in the studied dumpsite soil, water and fruits of *Anarcardium occidentale*:** The results of trace metals in the studied dumpsite soil are shown in Table 1. Results in Table 1 indicate the following mean value: 247.569±7.989, 1.845±0.159, 41.804±3.314, 2735.484±29.746, 201.989±16.070 and 41.552±3.842 mg $kg^{-1}$ for Pb, Cd, Ni, Fe, Zn and Cu, respectively. These values are higher than the levels of these metals obtained in the control. This is an indication of anthropogenic addition of these metals to the soil environment by waste materials at the dumpsite. Consequently; the uncontrolled tipping method of waste management used by the government of Akwa Ibom State may have adverse effects on the environment if appropriate measures are not taken. These values are also higher than 85.00, 0.8, 35.00, 425.00, 50.00 and 36.00 mg $kg^{-1}$ recommended limits for Pb, Cd, Ni, Fe, Zn and Cu, respectively in soil by WHO[28]. Thus; these metals might have polluted the soil environment investigated and could pose a serious risks in the area.

Results of trace metals in water samples from Uyo Village Road Stream are shown in Table 2. The results indicate the following values (mg $kg^{-1}$): 0.088±0.029, 0.052±0.017, 0.152±0.059, 0.587±0.136, 2.278±0.097 and 0.157±0.013 for Pb, Cd, Ni, Fe, Zn and Cu, respectively. These values are above 0.002, 0.001, 0.001, 0.102, 0.628 and 0.054 mg $kg^{-1}$ obtained in the control. Hence; a substantial quantity of these metals in the studied stream might have emanated from the waste dumpsite. This should be closely monitored to forestall the risk of metal toxicity and associated problems within the study area. These values are also higher than 0.05, 0.003, 0.02, 0.30, 5.00 and 2.00 mg $kg^{-1}$ recommended limits for Pb, Cd, Ni, Fe, Zn and Cu, respectively for potable water by WHO[29]. Consequently; the utilization of untreated water from the studied stream may result in serious health problems in the consumers.

Table 1: Levels (mg $kg^{-1}$) of trace metals in soil samples from Uyo Village Road dumpsite soil

| Location | Pb | Cd | Ni | Fe | Zn | Cu |
|---|---|---|---|---|---|---|
| SA | 247.142 | 1.854 | 37.582 | 2764.621 | 183.683 | 41.560 |
| SB | 253.263 | 2.036 | 39.327 | 2738.716 | 205.375 | 46.732 |
| SC | 237.520 | 1.945 | 45.803 | 2752.364 | 211.532 | 43.413 |
| SD | 257.385 | 1.627 | 43.565 | 2686.548 | 221.718 | 36.631 |
| SE | 242.534 | 1.762 | 42.741 | 2735.173 | 187.635 | 39.422 |
| Min | 237.520 | 1.627 | 37.582 | 2686.548 | 183.683 | 36.631 |
| Max | 257.385 | 2.036 | 45.803 | 2764.621 | 221.718 | 46.732 |
| Mean | 247.569 | 1.845 | 41.804 | 2735.484 | 201.989 | 41.552 |
| SD | 7.989 | 0.159 | 3.314 | 29.746 | 16.070 | 3.842 |
| Control | 5.143 | 0.614 | 3.410 | 272.872 | 11.422 | 8.626 |
| BGC | 20.00 | 0.30 | 68.00 | 46,000.00 | 95.00 | 45.00 |

SA-SE: Different locations where soil samples were collected, Min: Minimum, Max: Maximum, SD: Standard deviation, BGC: Background concentration of metals in average shale (ppm) is after Turekian and Wedepohl[27]

Table 2: Levels (mg $L^{-1}$) of trace metals in water from Uyo Village Road stream

| Location | Pb | Cd | Ni | Fe | Zn | Cu |
|---|---|---|---|---|---|---|
| WA | 0.127 | 0.074 | 0.252 | 0.762 | 2.162 | 0.173 |
| WB | 0.092 | 0.031 | 0.134 | 0.534 | 2.225 | 0.156 |
| WC | 0.101 | 0.040 | 0.152 | 0.682 | 2.312 | 0.142 |
| WD | 0.063 | 0.052 | 0.118 | 0.542 | 2.421 | 0.148 |
| WE | 0.056 | 0.064 | 0.102 | 0.415 | 2.270 | 0.165 |
| Min | 0.056 | 0.031 | 0.102 | 0.415 | 2.162 | 0.142 |
| Max | 0.127 | 0.074 | 0.252 | 0.762 | 2.421 | 0.173 |
| Mean | 0.088 | 0.052 | 0.152 | 0.587 | 2.278 | 0.157 |
| SD | 0.029 | 0.017 | 0.059 | 0.136 | 0.097 | 0.013 |
| Control | 0.002 | 0.001 | 0.001 | 0.102 | 0.628 | 0.054 |

WA-WE: Locations where water samples were collected along the studied stream, Min: Minimum, Max: Maximum, SD: Standard deviation

Table 3: Levels (mg $kg^{-1}$) of trace metals in *Anarcardium occidentale* from Uyo Village Road

| Location | Pb | Cd | Ni | Fe | Zn | Cu |
|---|---|---|---|---|---|---|
| FA | 0.090 | 0.033 | 0.028 | 16.231 | 0.083 | 0.051 |
| FB | 0.081 | 0.024 | 0.025 | 14.543 | 0.062 | 0.033 |
| FC | 0.064 | 0.022 | 0.021 | 11.820 | 0.065 | 0.031 |
| FD | 0.052 | 0.020 | 0.022 | 9.512 | 0.041 | 0.024 |
| FE | 0.046 | 0.017 | 0.024 | 7.624 | 0.038 | 0.019 |
| Min | 0.046 | 0.017 | 0.021 | 7.624 | 0.038 | 0.019 |
| Max | 0.090 | 0.033 | 0.028 | 16.231 | 0.083 | 0.051 |
| Mean | 0.067 | 0.023 | 0.024 | 11.946 | 0.058 | 0.032 |
| SD | 0.019 | 0.006 | 0.003 | 3.526 | 0.019 | 0.012 |
| Control | 0.026 | 0.001 | 0.002 | 1.264 | 0.026 | 0.013 |

FA-FE: Different locations where fruits of *Anarcardium occidentale* were collected in Uyo Village Road, Min: Minimum, Max: Maximum, SD: Standard deviation

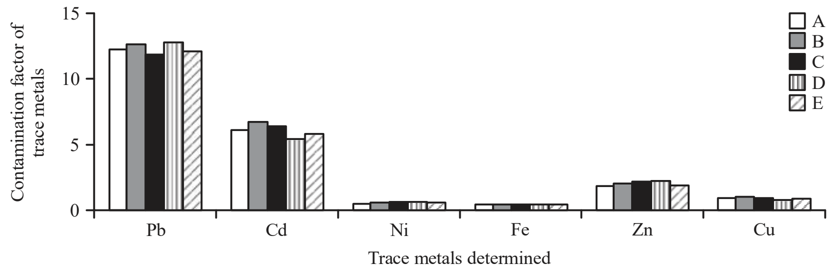


Fig. 1: Contamination factor of trace metals determined in soil

Table 4: Ecological risk factor and potential ecological risk index

| Location | Pb | Cd | Ni | Fe | Zn | Cu | RI | Risk grade |
|---|---|---|---|---|---|---|---|---|
| A | 61.80 | 185.40 | 2.75 | 0.00 | 1.93 | 4.60 | 256.48 | High |
| B | 63.30 | 203.70 | 2.90 | 0.00 | 2.16 | 5.20 | 277.26 | High |
| C | 59.40 | 194.40 | 3.35 | 0.00 | 2.23 | 4.85 | 264.23 | High |
| D | 64.35 | 162.60 | 3.20 | 0.00 | 2.33 | 4.05 | 236.53 | High |
| E | 60.65 | 176.10 | 3.15 | 0.00 | 1.98 | 4.40 | 246.28 | High |
| Mean | 61.90 | 184.44 | 3.07 | 0.00 | 2.13 | 4.62 | 256.16 | High |

Results for the trace metals in the fruits of *Anarcardium occidentale* from Uyo Village Road are shown in Table 3. The results indicate the following mean values (mg kg$^{-1}$): 0.067$\pm$0.019, 0.023$\pm$0.006, 0.024$\pm$0.003, 11.946$\pm$3.526, 0.058$\pm$0.019 and 0.032$\pm$0.012, for Pb, Cd, Ni, Fe, Zn and Cu, respectively. These values are higher than their corresponding values in the control (Table 3). This shows anthropogenic inputs for the metals into the studied plants. The mean values for Pb, Ni and Fe are also higher than 0.050, 0.02 and 0.30 mg kg$^{-1}$ recommended limits for these metals in fruit by FAO/WHO[30]. However; the mean levels of Cd, Zn and Cu were within their stipulated limits of 0.050, 5.000 and 1.000 mg kg$^{-1}$ by FAO/WHO[30]. Consequently, the consumption of *Anarcardium occidentale* obtained from Uyo Village Road may results in health problems associated with the high levels of Pb, Ni and Fe in the consumers over a long time. This should be controlled to forestall a devastating condition in the area as the fruit is extensively consumed in the State.

**Pollution indices of trace metals in the studied soil:** The extent to which the soil at Uyo Village Road dumpsite has been contaminated by trace metals was also assessed using contamination factor (CF), ecological risk factor (Er) and potential ecological risk index (RI). Contamination factor signifies the relation between trace metals in the studied soil and the background concentration. In this study the average crustal values of the trace metals in Table 1 by Turekian and Wedepohl[27] were used as the background concentrations. Results obtained are illustrated in Fig. 1 and based on Hakanson[18] classifications; Pb and Cd belong to the very high contamination class. Ni, Fe and Cu belong to the no metal enrichment class while Zn belongs to the moderate contamination class.

**Ecological risk factor ($E^i_r$):** Results for the ecological risk factor of the trace metals determined are shown in Table 4. The results indicate that Pb and Cd belong to the appreciable and high ecological risk classes, respectively while Ni, Zn and Cu are in the low ecological risk class[31]. Due to the relative high toxic response factor of Cd, the metal indicated very high ecological risk factors that are devastating in the studied ecosystem. The ecological risk factors of the metals followed the order: Cd>Pb>Cu>Ni>Zn>Fe. Consequently, the ecological risk factors for the toxic metals were higher than for the essential ones and it calls for concern.

**Potential ecological risk index (RI):** The results for potential ecological risks of the different locations designated in the studied dumpsite soil are shown in Table 4. The results revealed that the studied locations have RI values between 150 and 300. Thus; all the locations belong to the moderate ecological risk class according to Yang *et al.*[31]. The major contributors to these high RI values at all the locations are Cd and Pb. These metals are known be very dangerous to human as they affect major organs in the body[32,33]. Exposure to this environment directly or indirectly by both children and adults should be minimized to forestall the attendants health problems. This problem could be exacerbated by the continuous dumping of metal containing waste materials at the dumpsite.

**Metal pollution index of trace metals in water:** The quality of Uyo Village Road stream was examined using metal pollution index (MPI) as described by Teodorovic *et al.*[34]. Metal pollution index is used to differentiate a polluted from an unpolluted aquatic environment. When the MPI is higher than 1 then the environment under investigation is

Table 5: Results of metal pollution index of trace metals in water from Uyo Village Road stream

| Location | Pb | Cd | Ni | Fe | Zn | Cu | Sum | Remark |
|---|---|---|---|---|---|---|---|---|
| WA | 2.54 | 24.67 | 12.60 | 2.54 | 0.43 | 0.09 | 42.87 | TOW |
| WB | 1.84 | 10.33 | 6.70 | 1.78 | 0.45 | 0.08 | 21.18 | TOW |
| WC | 2.02 | 13.33 | 7.60 | 2.27 | 0.46 | 0.07 | 25.75 | TOW |
| WD | 1.26 | 17.33 | 5.90 | 1.81 | 0.48 | 0.07 | 26.85 | TOW |
| WE | 1.12 | 21.33 | 5.10 | 1.38 | 0.45 | 0.08 | 29.46 | TOW |

WA-WE: Designated locations were collected, TOW: Threshold of warning

Table 6: Correlation matrix for trace metals in soil, water and fruits of *Anarcardium occidentale*

| Parameters | Pb | Cd | Ni | Fe | Zn | Cu |
|---|---|---|---|---|---|---|
| **Dumpsite soil** | | | | | | |
| Pb | 1.000 | | | | | |
| Cd | -0.324 | 1.000 | | | | |
| Ni | -0.377 | -0.272 | 1.000 | | | |
| Fe | -0.676 | 0.702 | -0.380 | 1.000 | | |
| Zn | 0.384 | -0.164 | 0.603 | -0.692 | 1.000 | |
| Cu | -0.218 | 0.993 | -0.316 | 0.634 | -0.127 | 1.000 |
| **Water** | | | | | | |
| Pb | 1.000 | | | | | |
| Cd | 0.116 | 1.000 | | | | |
| Ni | 0.917 | 0.480 | 1.000 | | | |
| Fe | 0.918 | 0.186 | 0.888 | 1.000 | | |
| Zn | -0.675 | -0.286 | -0.656 | -0.364 | 1.000 | |
| Cu | 0.272 | 0.745 | 0.515 | 0.067 | -0.751 | 1.000 |
| **Fruits of *Anarcardium occidentale*** | | | | | | |
| Pb | 1.000 | | | | | |
| Cd | 0.923 | 1.000 | | | | |
| Ni | 0.708 | 0.753 | 1.000 | | | |
| Fe | 0.995 | 0.922 | 0.647 | 1.000 | | |
| Zn | 0.925 | 0.930* | 0.575 | 0.934 | 1.000 | |
| Cu | 0.927 | 0.996 | 0.718 | 0.929 | 0.958 | 1.000 |

*Significant difference

considered polluted by metals determined. The results of MPI of trace metals determined in the studied river are shown in Table 5. The MPI values obtained for locations A, B, C, D and E are 42.87, 21.18, 25.75, 26.85 and 29.46, respectively. The highest MPI value (42.87) was obtained at the point source where metal contaminants are leached into the stream. This is reveals the negative impact of the studied dumpsite on the quality of the adjoining stream. Results in Table 5 indicate that all the locations studied were highly polluted with metals determined. Thus, untreated water from this source may not be suitable for drinking and other domestic use. The MPI values of metals determined at all the locations were higher than 1 signifying threshold of warning to those exposed to the water directly or indirectly[35].

**Multivariate analysis:** This research used Pearson correlation Analysis, Principal Component Analysis and Cluster Analysis for the determination of pollution status and relationships among of trace metals in the studied soil, water and fruits of *Anarcardium occidentale*.

**Pearson correlation analysis:** In this study, the strength of correlation was based on the following classifications of correlation coefficients by Evans[36]. The ranges of r-values used are as follows: 0.00-0.19 = very weak, 0.20-0.39 = weak, 0.40-0.59 = moderate, 0.60-0.79 = strong and 0.80-1.0 = very strong. Results in Table 6 indicate that Pb correlated negatively and weakly with Cd, Ni and Cu but positively and weakly with Zn. However; Pb exhibited a strong negative correlation with Fe. Cd showed a very weak negative relationship with Zn and a weak negative association with Ni. Cd exhibited a strong positive relationship with Fe and a very strong positive correlation with Cu. Ni exhibited a weak negative association with Fe and Cu but a strong positive relationship with Zn. Fe showed a strong negative association with Zn and a strong positive correlation with Cu. Zn showed a very weak negative association with Cu.

Results for the correlation analysis of trace metals in water are shown in Table 6. Pb showed a very weak positive relationship with Cd and a weak positive association with Cu. Nevertheless; Pb exhibited a very strong positive association with Ni and Fe but a strong negative correlation with Zn. Cd showed a moderate positive correlation with Ni and a very weak positive association with Fe. Ni showed a weak negative association with Zn and a strong positive association with Cu. Ni correlated positively and significantly with Fe but moderately with Cu. Ni also showed a strong negative relationship with Zn. Fe exhibited a weak negative correlation with Zn and a very weak positive relationship with Cu. Results obtained also showed a strong negative correlation between Zn and Cu.

Results for the Pearson correlation analysis of trace metals in *Anarcardium occidentale* are shown in Table 6. Based on Evans[36] classifications of correlation coefficients, Pb exhibited a very strong positive relationship with Cd, Fe, Zn and Cu but a strong positive one with Ni. Cd showed a very strong positive correlation with Fe, Zn and Cu. Ni correlated positively and strongly with Fe and Cu but moderately with Zn. Fe indicated a very strong positive association with Zn and Cu. Zn showed a very strong positive correlation with Cu. The correlation analysis has shown the variable relationship that existed among the metals determined in the studied soil and water. Consequently, metals in the studied soil and water might have originated from various and diverse sources[37]. However, the relationship exhibited by metals determined in the studied fruits has shown that they might have emanated from a common source[38,39].

**Principal component analysis:** Principal component analysis (PCA) was used for the identification of the sources of

Table 7: Total variance explained for trace metals in dumpsite soil, water and fruit of *Anarcardium occidentale*

| Components | Initial eigenvalues Total | Variance (%) | Cumulative (%) | Extraction sums of squared loadings Total | Variance (%) | Cumulative (%) | Rotation sums of squared loadings Total | Variance (%) | Cumulative (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Soil samples** | | | | | | | | | |
| 1 | 3.199 | 53.314 | 53.314 | 3.199 | 53.314 | 53.314 | 2.353 | 39.217 | 39.217 |
| 2 | 1.444 | 24.073 | 77.387 | 1.444 | 24.073 | 77.387 | 1.900 | 31.672 | 70.889 |
| 3 | 1.280 | 21.340 | 98.726 | 1.280 | 21.340 | 98.726 | 1.670 | 27.837 | 98.726 |
| **Water samples** | | | | | | | | | |
| 1 | 3.704 | 61.727 | 61.727 | 3.704 | 61.727 | 61.727 | 2.994 | 49.897 | 49.897 |
| 2 | 1.555 | 25.918 | 87.645 | 1.555 | 25.918 | 87.645 | 2.265 | 37.748 | 87.645 |
| ***Anarcardium occidentale* (cashew)** | | | | | | | | | |
| 1 | 5.313 | 88.548 | 88.548 | 5.313 | 88.548 | 88.548 | - | - | - |

Extraction method: Principal component analysis

Table 8: Matrix of the major principal components

| | Component | | | | | |
|---|---|---|---|---|---|---|
| | Soil | | | Water | | Fruit |
| Metals | 1 | 2 | 3 | 1 | 2 | 1 |
| Pb | -0.529 | -0.708 | 0.468 | 0.885 | 0.454 | 0.975 |
| Cd | 0.855 | 0.147 | 0.496 | 0.532 | -0.658 | 0.982 |
| Ni | -0.470 | 0.880 | -0.006 | 0.972 | 0.162 | 0.767 |
| Fe | 0.950 | 0.089 | -0.235 | 0.781 | 0.564 | 0.968 |
| Zn | -0.631 | 0.367 | 0.663 | -0.803 | 0.209 | 0.951 |
| Cu | 0.817 | 0.073 | 0.566 | 0.663 | -0.726 | 0.984 |

trace metals in the studied samples[40]. The results for PCA of trace metals in the studied soil are shown in Table 7. The results revealed three principal factors with eigenvalues greater than one with 98.73% of total variance. Factor one (F1) contributed 53.31% of the total variance with very strong positive loadings on Fe, Cd and Cu. It also showed a strong negative loading on Zn and moderate negative loadings on Ni and Pb (Table 8). Factor one represents the negative impact of both the natural and anthropogenic inputs on the soil quality[41]. Factor two (F2) contributed 24.07% of the total variance with a very strong positive loading on Ni and a strong negative loading on Pb (Table 8). Factor two also showed weak positive loadings on Fe, Cd, Cu and Zn. Factor two represents the negative impact of wastes materials on the quality of the soil[42]. Factor three (F3) contributed 21.34% of the total variance with moderate positive loadings on Cd, Cu and Pb but a strong positive loading on Zn (Table 8). Factor 3 also indicated weak negative loadings on Fe and Ni. Factor 3 signifies a moderate negative impact of waste materials at the dumpsite on the quality of the soil[42,43].

Results of PCA of trace metals in water samples are shown in Table 7. Results obtained indicated 2 major factors with eigenvalues higher than one with 87.65% of total variance. Factor one (F1) contributed 61.73% of the total variance with strong positive loadings on Ni, Pb, Fe and Cu, a moderate positive loading on Cd but; a very strong negative loading on Zn (Table 8). This represents the negative impact of industrial and agricultural wastes at the dumpsite on the water quality of Uyo Village Road Stream[44,45]. Factor two (F2) contributed 25.92% of the total variance with strong negative loadings on Cu and Cd but moderate positive loadings on Pb and Fe. Factor 2 also showed weak positive loadings on Ni and Zn (Table 8). This represents the negative impact of anthropogenic and natural factors on the quality of water from the studied stream[46].

Results for the Principal components analysis of trace metals determined in the fruits of *Anarcardium occidentale* are also shown Table 7. The results revealed one major factor with eigenvalue greater than one and 88.55% of the total variance. The factor showed very strong positive loadings on all the metals namely: Cu, Cd, Pb, Fe, Zn and Ni (Table 8). This represents the negative impact of anthropogenic contaminants on the quality of the fruits. Consequently; the strong positive correlations exhibited by all the metals determined indicated that these metals might have originated from a common source[38]. The result of Principal component analysis has corroborated the outcome of correlation analysis of trace metals in the different samples.

**Cluster analysis:** The pair-wise associations that existed among trace metals in the studied soil are shown in Fig. 2a. The figure shows 2 major clusters namely: Cluster one linking Ni, Cu, Cd, Pb and Zn together and cluster 2 linking Fe only. Accordingly, majority of Ni, Cu, Cd, Pb and Zn might have emanated from the waste materials at the dumpsite. However, the figure shows that a greater proportion of Fe might have originated from the natural soil forming processes.

The relationships among trace metals determined in water samples from Uyo Village Road are illustrated in Fig. 2b. Results in Fig. 3 indicate 3 main clusters namely: Cluster one linking Pb, Cd, Ni and Cu together; Cluster 2 linking Fe alone and Cluster 3 linking Zn only. Consequently, the different clusters revealed that there might have been three major sources for the metals determined in water samples from the studied stream.

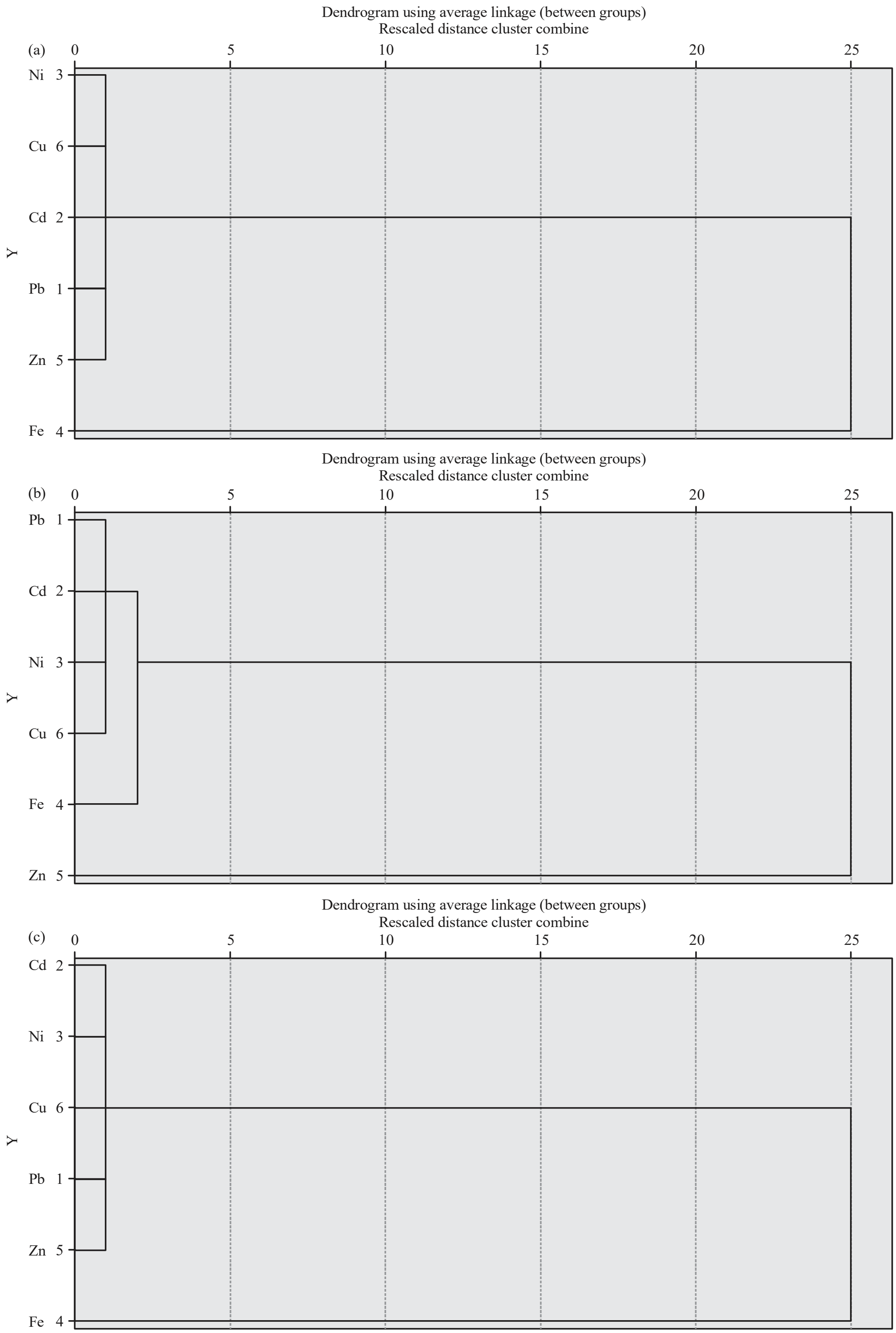


Fig. 2(a-c): Hierarchical dendrogram for classification of trace metals in (a) Dumpsite soils studied, (b) water samples studied and (c) *Anarcardium occidentale*

Table 9: Result for non-carcinogenic risk for each trace metal and exposure pathway

| | DI ($\times 10^{-4}$) | | HQ ($\times 10^{-3}$) | |
|---|---|---|---|---|
| Metals | Child | Adult | Child | Adult |
| Pb | 0.052 | 0.028 | 1.40 | 0.80 |
| Cd | 0.018 | 0.09 | 1.80 | 0.90 |
| Ni | 0.019 | 0.01 | 0.095 | 0.05 |
| Fe | 9.2 | 4.9 | 1.40 | 0.80 |
| Zn | 0.092 | 0.024 | 0.021 | 0.011 |
| Cu | 0.025 | 0.013 | 0.017 | 0.0093 |
| THI | | | 4.8 E-03 | 2.5 E-03 |

DI: Daily intake, HQ: Hazard quotient, THI: Total chronic hazard index

Cluster analysis for trace metals determined in the fruits of *Anarcardium occidentale* revealed 2 major clusters as shown in Fig. 2c. The clusters are (1) one linking all the trace metals determined except Fe together and (2) the one linking Fe alone. Thus; all the metals determined in *Anarcardium occidentale* except Fe might have originated from a common source (wastes at the dumpsite) while most of the Fe content in *Anarcardium occidentale* might have emanated from a different source probably natural. Generally, the study has shown that the improper management of urban wastes might have contributed immensely to the accumulation of these metals in the soil, adjoining stream and cashew plants. Thus, the current method of managing waste in the State should be reviewed and an appropriate method adopted to forestall the impending calamity.

**Results of health risk assessment:** The daily intake rate (DI), non-carcinogenic risk (HQ) and a total chronic hazard index (THI) were the parameters determined to assess the health risk associated with the consumption of the fruits of *Anarcardium occidentale* fruits.

**Daily intake rate:** Results for the daily intake (DI), hazard quotient (HQ) and total chronic hazard index (THI) are shown in Table 9. The consequence of metal toxicity on human beings through the consumption of cashew could be explained by evaluating the daily intake (DI) rate. The daily intake rate of all the metals for both the children and adults was lower than their recommended oral reference dose (RfDs) stipulated by USEPA[47]. The results indicated Fe as the metal with the highest daily intake rate for children and adults. Generally, the daily intake rate for the metals followed the order Fe>Zn>Pb>Cu>Ni>Cd for children and Fe>Cd>Pb>Zn >Cu>Ni for the adults. The high daily intake of Fe obtained is in agreement with the report by Ebong *et al.*[48]. Conversely; the high Fe intake via the consumption of cashew fruit may not have a serious health implication on the consumers as an essential element but should be controlled to avoid problems associated with bioaccumulation over time[49]. Nevertheless; the low intake rate of toxic metals determined (Pb, Cd and Ni) should not be overlooked because these metals could be highly toxic even at a very low concentration. These toxic metals can also bio-accumulate in human body over time thereby resulting in serious health problems.

**Hazard quotient representing the non-carcinogenic risk:** Table 9 shows the results of hazard quotient (HQ) for the metals determined in the studied fruits. Results in Table 9 indicate that the HQ for the metals determined is <1 consequently; these metals may not pose a serious health risk in both the children and adults. The results also identified Cd as the metal with the highest HQ values for both the children and adults. The HQ values for both children and adults followed the order Cd>Pb = Fe>Ni>Zn>Cu (Table 9). The potential health risk of Cd through the consumption of cashew fruit is much higher in children than in adults. This should be closely monitored since Cd is a highly toxic even metal in a very minute quantity[50,51]. Even though the THI value of each of the metals is less than one, there is a tendency that the consumers of the fruits are being exposed to non-carcinogenic health problems which according to Man *et al.*[52] are directly related to the THI value.

**Total chronic hazard index (THI):** Results for the total chronic hazard index (THI) of oral exposure to Pb, Cd, Ni, Fe, Zn and Cu via the consumption of cashew are indicated in Table 9. The average THI values for both the children and adults are 4.8E-03 and 2.5E-03, respectively. The THI results revealed that hazard quotient of Cd in the children and adults contributed 38 and 35%, respectively to the total hazard index. Pb, Ni, Fe, Zn and Cu contributed 30, 2, 30, 0 and 0%, respectively to the total hazard index for children. For the adults, Pb, Ni, Fe, Zn and Cu contributed 31, 2, 31, 1 and 0%, respectively to the overall hazard index. The THI values for the children and adults followed the order Cd>Pb = Fe>Ni>Zn>Cu.

**Consequence of the study:** This study has shown the negative impact of open dumping of waste materials at Uyo Village Road dumpsite on the quality of the environment. The ecological risk assessment has indicated the negative impact of waste materials at the dumpsite on the soil environment. The principal factor responsible for the accumulation of metals in the area has been attributed to the waste materials. The poor quality of the adjoining stream is a consequence of leachate from the waste dumpsite. Consequently, the quality of both the fish from the pond and edible plants in farms irrigated with water from the studied stream might be seriously affected. The study has also revealed that the major route of toxic metals into the fruits of *Anarcardium occidentale* is the waste materials at the open dumpsite. Hence, the consumption of these fruits from Uyo Village Road over time may exposed the consumers especially children to metal toxicity and its attendants' effects. The use of multivariate analysis in this work has proven to be an effective tool for the identification of the source and pathway of toxic metals in the environment as reported by Hou *et al.*[53].

## CONCLUSION

This study has shown that the uncontrolled tipping method of waste management currently practiced in the study has a significant negative impact on the ecosystem. These waste materials have impacted negatively on the quality of soil, water, air and edible plants within the environment. Consequently, the uncontrolled tipping method of waste management should be discouraged to forestall the impending disaster that may occur in the area. Water obtained from the stream investigated should be properly treated before consumption to avoid metal toxicity and associated problems on the consumers. Cultivation of edible plants within the vicinity of this waste dumpsite should be discouraged to avoid problems along the food chain. The consumption and the use of cashew parts from the study area for the treatment of ailments should be discouraged to avoid metal toxicity. The consequences associated with the open dumping of wastes at Uyo Village Road highlighted in this study should be widely publicized.

## SIGNIFICANCE STATEMENT

This study discovers the negative impact of open dumping of wastes at Uyo Village road, Akwa Ibom State on the quality of the soil, stream and cashew in the area. This study will assist the researchers to discover the influence of these wastes on the metal loads in the study area. It will also help the researchers to identify the possible health risks associated with the long term consumption of the cashew fruits harvested from the area which previous works might have overlooked. Consequently, the outcome of this study will help the Agency responsible for the disposal of wastes to arrive at adopting a better method of waste management in the State.

## REFERENCES


1. Zhou, Q.X. and Y.F. Song, 2004. Remediation of Contaminated Soils: Principles and Methods. Science Press, Beijing, China, pp: 367-377.
2. Okoronkwo, N.E., S.A. Odemelam and O.A. Ano, 2006. Levels of toxic elements in soils of abandoned waste dumpsite. Afr. J. Biotechnol., 5: 1241-1244.
3. Ebong, G.A., M.M. Akpan and V.N. Mkpenie, 2008. Heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by *Carica Papaya* and *Talinum triangulare* in Uyo, Nigeria. E-J. Chem., 5: 281-290.
4. Odai, S.N., E. Mensah, D. Sipitey, S. Ryo and E. Awuah, 2008. Heavy metals uptake by vegetables cultivated on urban waste dumpsites: Case study of Kumasi, Ghana. Res. J. Environ. Toxicol., 2: 92-99.
5. Agedah, C.E., D.D.S. Bawo and B.L. Nyananyo, 2010. Identification of antimicrobial properties of cashew, *Anacardium occidentale* L. (Family Anacardiaceae). J. Applied Sci. Environ. Manage., 14: 25-27.
6. Ifesan, B.O.T., J.F. Fashakin, F. Ebosele and A.S. Oyerinde, 2013. Antioxidant and antimicrobial properties of selected plant leaves. Eur. J. Med. Plants, 3: 465-473.
7. Aderiye, B.I., O.M. David and V.A. Atere, 2015. Administration of cashew extracts in the treatment of some infections and diseases. Adv. Med. Plant Res., 3: 75-86.
8. Olaniyan, M.F., 2016. Cholesterol lowering effect of cashew leaf (*Anacardium occidentale*) extract on egg yolk induced hypercholesterolaemic rabbits. Scholars Acad. J. Biosci., 4: 886-891.
9. Zurayk, R., B. Sukkariyah and R. Baalbaki, 2001. Common hydrophytes as bioindicators of nickel, chromium and cadmium pollution. Water Air Soil Pollut., 127: 373-388.
10. Malizia, D., A. Giuliano, G. Ortaggi and A. Masotti, 2012. Common plants as alternative analytical tools to monitor heavy metals in soil. Chem. Cent. J., Vol. 6. 10.1186/1752-153X-6-S2-S6.
11. Ojekunle, Z.O., M. Adeboje, A.G. Taiwo, R.O. Sangowusi, A.M. Taiwo and V.O. Ojekunle, 2014. Tree leaves as bioindicator of heavy metal pollution in mechanic village, Ogun State. J. Applied Sci. Environ. Manage., 18: 639-644.
12. Hani, H., 1996. Soil analysis as a tool to predict effects on the environment. Commun. Soil Sci. Plant Anal., 27: 289-306.
13. Zupan, M., J.W. Einax, J. Kraft, F. Lobnik and V. Hudnik, 2000. Chemometric characterization of soil and plant pollution: Part 1: Multivariate data analysis and geostatistical determination of relationship and spatial structure of inorganic contaminants in soil. Environ. Sci. Pollut. Res., 7: 89-96.
14. Simeonov, V., J. Einax, S. Tsakovski and J. Kraft, 2005. Multivariate statistical assessment of polluted soils. Open Chem., 3: 1-9.

15. Samara, C., T. Kouimtzis and G.A. Katsoulos, 1994. Characterization of airborne particulate matter in Thessaloniki, Greece: Part II: A multivariate modeling approach for the source apportionment of heavy metal concentrations within total suspended particles. Toxicol. Environ. Chem., 41: 221-232.
16. APHA., 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edn., American Public Health Association, Washington, DC., USA., ISBN-13: 9780875532356, Pages: 1220.
17. Keane, B., M.H. Collier, J.R. Shann and S.H. Rogstad, 2001. Metal content of dandelion (*Taraxacum officinale*) leaves in relation to soil contamination and airborne particulate matter. Sci. Total Environ., 281: 63-78.
18. Hakanson, L., 1980. An ecological risk index for aquatic pollution control. A sedimentological approach. Water Res., 14: 975-1001.
19. Cao, H.C., Z.Q. Luan, J.D. Wang and X.L. Zhang, 2009. Potential ecological risk of cadmium, lead and arsenic in agricultural black soil in Jilin province, China. Stochastic Environ. Res. Risk Assess., 23: 57-64.
20. USEPA., 1989. Risk assessment guidance for superfund, Volume I: Human health evaluation manual (part A). EPA/540/1-89/002, United States Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC., USA., December 1989.
21. Veerkamp, W. and W. ten Berge, 1999. Human exposure to soil pollutants (HESP). Shell Internationale Petroleum, Maatschappij B.V., The Hague, Netherlands.
22. Grzetic, I. and R.H.A. Ghariani, 2008. Potential health risk assessment for soil heavy metal contamination in the central zone of Belgrade (Serbia). J. Serb. Chem. Soc., 73: 923-934.
23. FAO/WHO., 2006. Food safety risk analysis: A guide for national food safety authorities. FAO Food and Nutrition Paper 87, World Health Organization/Food and Agriculture Organization, Rome, Italy.
24. USEPA., 2011. USEPA Regional Screening Level (RSL) summary table. U.S. Environmental Protection Agency, November 2011.
25. Wang, X., F. Wang, B. Chen, F. Sun and W. He *et al*., 2012. Comparing the health risk of toxic metals through vegetable consumption between industrial polluted and non-polluted fields in Shaoguan, South China. J. Food Agric. Environ., 10: 943-948.
26. USEPA., 2000. Risk-based concentration table. United States Environmental Protection Agency, Washington, DC., USA.
27. Turekian, K.K. and K.H. Wedepohl, 1961. Distribution of the elements in some major units of the earth's crust. Geol. Soc. Am. Bull., 72: 175-192.
28. WHO., 1996. Permissible limits of heavy metals in soil and plants. World Health Organization, Geneva, Switzerland.
29. WHO., 2008. Guidelines for Drinking Water Quality. 3rd Edn., Vol. 1, World Health Organization, Geneva, Switzerland, ISBN-13: 9789241547611, Pages: 668.
30. FAO/WHO., 2011. Joint FAO/WHO food standards programme codex committee on contaminants in foods, fifth session, The Hague, The Netherlands, 21-25 March 2011. CF/5 INF/1, March 2011, World Health Organization/Food and Agriculture Organization, Rome, Italy, pp: 64-89.
31. Yang, Z., Y. Wang, Z. Shen, J. Niu and Z. Tang, 2009. Distribution and speciation of heavy metals in sediments from the mainstream, tributaries and lakes of the Yangtze River catchment of Wuhan, China. J. Hazard. Mater., 166: 1186-1194.
32. Granero, S. and J.L. Domingo, 2002. Levels of metals in soils of Alcala de Henares, Spain: Human health risks. Environ. Int., 28: 159-164.
33. Barbier, O., G.T. Jacquille, M. Tauc, M. Cougnan and P. Poujeol, 2005. Effect of heavy metals on and handling by, the kidney. Nephron Physiol., 99: 105-110.
34. Teodorovic, I., N. Djukic, S. Maletin, B. Miljanovic and N. Jugovac, 2000. Metal pollution index: Proposal for freshwater monitoring based on trace metal accumulation in fish. Tiscia, 32: 55-60.
35. Bakan, G., H.B. Ozkoc, S. Tulek and H. Cuce, 2010. Integrated environmental quality assessment of Kizilirmak River and its coastal environment. Turk. J. Fish. Aquat. Sci., 10: 453-462.
36. Evans, J.D., 1996. Straightforward Statistics for the Behavioral Sciences. Brooks/Cole Publishing, Pacific Grove, CA., USA., ISBN-13: 9780534231002, Pages: 600.
37. Al-Khashman, O.A. and R.A. Shawabkeh, 2006. Metals distribution in soils around the cement factory in Southern Jordan. Environ. Pollut., 140: 387-394.
38. Romic, M. and D. Romic, 2003. Heavy metals distribution in agricultural topsoils in urban area. Environ. Geol., 43: 795-805.
39. Yang, Z., W. Lu, Y. Long, X. Bao and Q. Yang, 2011. Assessment of heavy metals contamination in urban topsoil from Changchun City, China. J. Geochem. Explor., 108: 27-38.
40. Wu, E.M.Y. and S.L. Kuo, 2012. Applying a multivariate statistical analysis model to evaluate the water quality of a watershed. Water Environ. Res., 84: 2075-2085.
41. Lu, Y., W. Yin., F. Zhu and G. Zhang, 2010. The spatial distribution and sources of metals in urban soils of Guangzhou, China. Proceedings of the 19th World Congress of Soil Science, Soil Solutions for a Changing World, August 1-6, 2010, Brisbane, Australia, pp: 77-80.
42. Olabanji, I.O., E.A. Oluyemi and E.I. Obianjuwa, 2015. Nondestructive analysis of dumpsite soil and vegetable for elemental composition. J. Environ. Chem. Ecotoxicol., 7: 1-10.
43. Azeez, J.O., O.A. Hassan and P.O. Egunjobi, 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 Sediment Contam.: Int. J., 20: 370-386.
44. Nriagu, J.O., 1989. A global assessment of natural sources of atmospheric trace metals. Nature, 338: 47-49.

45. Wu, Y.F., C.Q. Liu and C.L. Tu, 2008. Atmospheric deposition of metals in TSP of Guiyang, PR China. Bull. Environ. Contam. Toxicol., 80: 465-468.
46. Sun, X., D. Fan, M. Liu, Y. Tian, Y. Pang and H. Liao, 2018. Source identification, geochemical normalization and influence factors of heavy metals in Yangtze River Estuary sediment. Environ. Pollut., 241: 938-949.
47. USEPA., 2010. Integrated risk information system (IRIS). United States Environmental Protection Agency, Washington, DC., USA. https://www.epa.gov/iris
48. Ebong, G.A., E.U. Dan, E. Inam and N.O. Offiong, 2018. Total concentration, speciation, source identification and associated health implications of trace metals in Lemna dumpsite soil, Calabar, Nigeria. J. King Saud Univ.-Sci., (In Press). 10.1016/j.jksus.2018.01.005.
49. Goyer, R.A., 1995. Nutrition and metal toxicity. Am. J. Clin. Nutr., 61: 646S-650S.
50. IARC., 1993. Cadmium and cadmium compounds. IARC Monogr. Eval. Carcinog. Risks Hum., 58: 119-237.
51. ATSDR., 2012. Toxicological profile for cadmium. CAS No. 7440-43-9, Agency for Toxic Substances and Disease Registry, Public Health Statement, Atlanta, GA., USA., September 2012.
52. Man, Y.B., X.L. Sun, Y.G. Zhao, B.N. Lopez and S.S. Chung *et al*., 2010. Health risk assessment of abandoned agricultural soils based on heavy metal contents in Hong Kong, the world's most populated city. Environ. Int., 36: 570-576.
53. Hou, D., J. He, C. Lu, L. Ren, Q. Fan, J. Wang and Z. Xie, 2013. Distribution characteristics and potential ecological risk assessment of heavy metals (Cu, Pb, Zn, Cd) in water and sediments from Lake Dalinouer, China. Ecotoxicol. Environ. Saf., 93: 135-144.