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# ASSESSMENT OF POLLUTION LEVELS AND RISK OF SOME HEAVY METALS IN SOIL AND *MANGIFERA INDICA* AROUND NIGERIA POLICE ACADEMY, WUDIL, KANO STATE, NIGERIA

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## ABSTRACT

Elevated concentrations of heavy metals in the environment are potential ecological and human health risk. This study investigated the levels of Co, Cr, Pb and Zn in soil and plant (mangifera indica) and the risk of theses metals to plants and animal life in the area. Atomic Absorption Spectrophotometer (AAS) was used to analyse the metal contents of the samples, and the data subjected to statistical analysis, geo-accumulation index (Igeo), ecological risk index ($E_r$) and health risk assessments. Except Co in site A and D, and Zn in site E, other soil metal concentrations are above the background values. All the soil samples fall within the uncontaminated to uncontaminated/moderately contaminated class (Igeo < 1), while the ecological risk results indicated that the studied sites contains metal with low risk to the environment ($E_r$ < 40) with the sites constituting low risk to the local ecosystem (RI < 110). The concentrations of Co and Zn in the plants are below the WHO permissible limit, while that of Cr and Pb exceeded the limit. There is no potential health risk from the metals, except from Pb in site C, which also accounted for 62.92 % of the total non-carcinogenic health risk. Only Cr indicated a life time probability of causing cancer. The current metal concentrations in soil and plants of the area does not pose serious threat to the population but should be properly monitored.

**Keywords:** Ecological Risk, Health Risk, Heavy Metals, *Mangifera indica*, Soil, Carcinogenic Risk

## INTRODUCTION

The recent surge in urbanization and industrialisation has come with a concomitant increasing concern for heavy metals exposure. Source of heavy metals pollution to soil includes agricultural activities, industrial activities, vehicular emission, including tear and wear of machine parts, nuclear waste etc. These sources, known as anthropogenic sources, continuously add to the natural geochemical level of the heavy metals as metals have the ability to accumulate in the environment, leading to a level that can pose ecological and health risk (Akande & Ajayi, 2017).

Many of these heavy metals are necessary for the normal function of plants and animals, while some (like As, Cd, Pb and Hg) have no known function in plants and animals (Mertz, 1981). However, they are generally non-biodegradable and even those that are considered as essential elements can accumulate to a toxic level (Nowrouzi & Pourkhabbaz, 2014). Heavy metals enter the food chain through several routes, including uptake by plant through the soil (Akande & Ajayi, 2017), aerial deposition onto leaf surfaces, and trapping of metals in hairs or rough cuticle surfaces (Marchner, 1995). While different plants vary in their potential to accumulate heavy metals (Latif *et al*., 2018), physic-chemical properties of the soil also influence availability of heavy metals for plant uptake (Mng'ong'o *et al*., 2021).

A number of serious health problems can develop as a result of excessive intake of heavy metals through consumption of vegetables and other plants grown in polluted area. Heavy metals in food plants accumulate in organs resulting in diverse health risks (Mahmood & Malik, 2014; Likuku & Obuseng, 2015; Emurotu & Onianwa, 2017), including cellular damage, carcinogenesis and neurotoxicity (Chen *et al*., 2016).

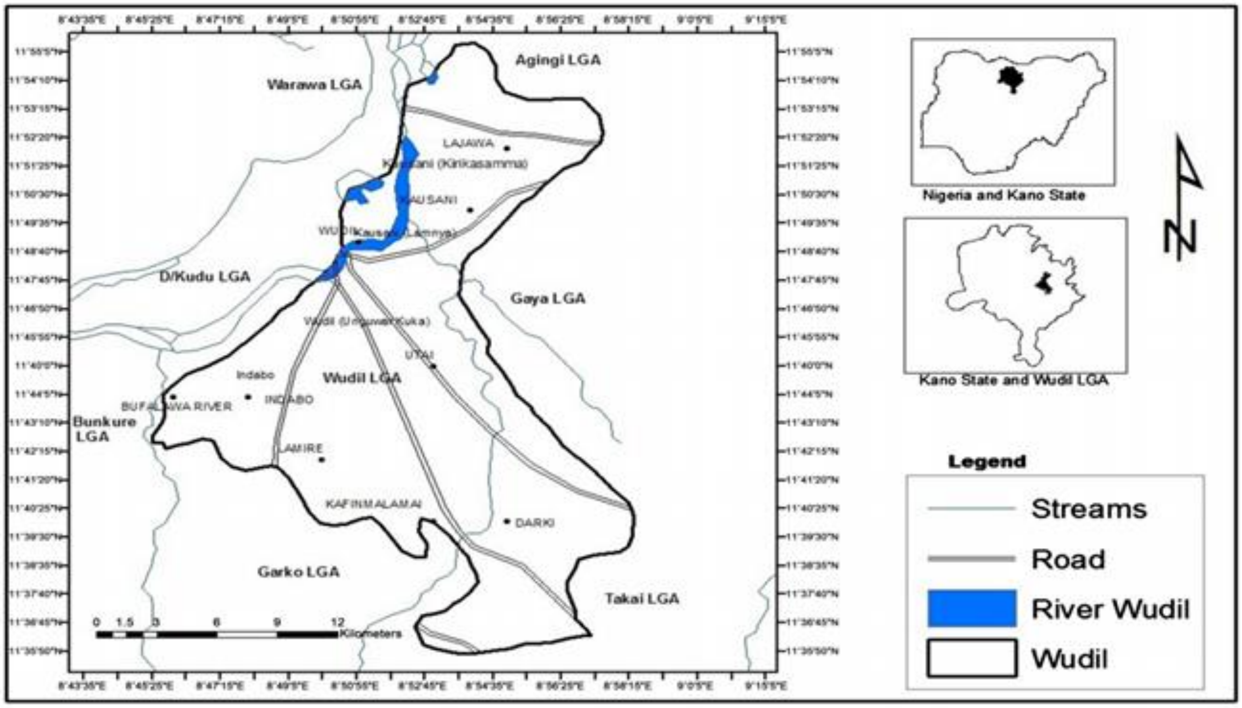
Accumulation of heavy metals in soil can also affect soil quality and yield of agricultural products (Emurotu & Onianwa, 2017). Terrestrial invertebrates are generally vulnerable to heavy metal pollutants leading to rapid decline of invertebrate biodiversity with dire consequences on ecosystem and food safety (Monchanin *et al*., 2021).

Recently, there is a rising research interest on the human and ecological risk of heavy metals contamination of soil and plants (Okereke *et al*., 2016; Hu *et al*., 2017; Patrick-Iwuanyanwu & Chioma, 2017; Gebeyehu & Bayissa, 2020; Ohiagu *et al*., 2020). Health risk data can assist the government and regulatory bodies in decision making and environmental remediation to reduce or mitigate possible environmental hazards. The objectives of this study is to analyse the levels of Co, Cr, Pb and Zn in soil and *mangifera indica* in the study area and to assess the ecological risk to the ecosystem and health risk associated with the consumption of the plant by the population.

## MATERIALS AND METHODS

### Study area

The study area is the Nigeria Police Academy (POLAC) which is located in Wudil Local Government Area of Kano State, Nigeria, with geographic coordinates of 11°49 'N and 8°51 'E. It shares its western boundary with Warawa LGA to the northwest and Dawakin Kudu LGA to the southwest. Also, it is bounded to the south and southeast by Garko LGA and on the east by Albasu LGA (southeast); Gaya (east) and Ajingi, northeast and north (Figure 1). The climate is tropical with an annual mean temperature of 26°C, and an annual mean rainfall of 900 mm (Olofin, 2008).



POLAC is a regimented institution and it embodies a diversity of cadets from the 36 States and Capital of Nigeria
**Figure 1:** Map of the geographical area of Wudil LGA

**Sample collection and analysis**

Five individual trees belonging to the specie *Mangifera indica* was selected for leaf sampling within POLAC. The Leaves were collected from all sides of the tree canopy in the north, south, east and west directions, and from above and inside the tree canopy. Leaf samples for each tree were bulked and enclosed in perforated transparent plastic bag, and taken to the laboratory for pre-treatment; the leaf samples were washed with distilled water, air dried at room temperature for 5 weeks, then converted to powder by pounding with mortar and pestle, sieved through 0.2 mm sieve then stored in a polybag till digestion.

Five soil samples were also taken from each site, air dried and mixed thoroughly with the aid of agate mortars and pestles. The soil samples were then sieved through a 2 mm and 0.5 mm plastic sieve to obtain fine particles.

The samples were digested with a mixture of concentrated $HNO_3$ and $HClO_4$ (2:1 v/v), following the procedure recommended by the AOAC, (1990). The metals concentrations were determined using Flame Atomic Absorption Spectrophotometer.

**Table 1**: Sample code and description

| S/N | Sample Code | Description |
|---|---|---|
| 1 | A | Old Commandant market |
| 2 | D | Farmland close to cadet cafeteria |
| 3 | C | Farmland close to officer mess/gym |
| 4 | D | Construction site –post graduate hostel |
| 5 | E | Construction site close to hostel area |

**Multivariate statistical analysis**

Multivariate statistical analysis was performed with the aid of Microsoft excel and SPSS 20.0. Correlation analysis was performed on the data. Using Pearson correlation coefficient as a measure of similarity, cluster analysis was performed in order to classify the metal pollution. Hierarchical cluster analysis method was used in this study, and between groups linkage was chosen during the classifying procedure. Factor analysis, using principal component method was also carried out on the data.

**Geo-accumulation index**

The Geo-accumulation Index (Igeo), was introduced by Muller, (1969) for determining the extent of metal accumulation in soil and sediments, and has been used by various workers for their studies. Igeo is mathematically expressed as:

$$\text{Igeo} = \log_2 \frac{C_n}{1.5B_n} \qquad (1)$$

Where $C_n$ is the concentration of the metal in the soil, $B_n$ is the geochemical background value. The factor 1.5 is incorporated in the relationship to account for possible variation in background data due to lithogenic effect. The geo-accumulation index (Igeo) scale consists of seven grades (0 –6) ranging from unpolluted to highly polluted (Table 2).

**Table 2**: Pollution grades of Geo-accumulation index of metals

| Igeo class | Igeo value | pollution status |
|---|---|---|
| 0 | Igeo<0 | unpolluted |
| 1 | 0 < Igeo < 1 | unpolluted to moderately polluted |
| 2 | 1 < Igeo < 2 | moderately polluted |
| 3 | 2 < Igeo < 3 | moderately to heavily polluted |
| 4 | 3 < Igeo < 4 | heavily polluted |
| 5 | 4 < Igeo < 5 | heavily to extremely polluted |
| 6 | Igeo < 5 | extremely polluted |

### Ecological risk index

The Potential Ecological Risk Index (RI) was originally introduced by Hakanson, (1980) to assess the degree of heavy metal pollution in soil, according to the toxicity of metals and the response of the environment. RI could evaluate ecological risk caused by toxic metals comprehensively. The calculating methods of RI are listed below:

$F_i = C^i_n / C^i_o$, (2)

$E^i_r = T^i_r x F_i$, (3)

$RI = \sum^n_{i=1} E$ (4)

Where $F_i$ is the single metal pollution index; $C^i_n$ is the concentration of metal in the samples; $C^i_o$ is the reference value for the metal; $E^i_r$ is the monomial potential ecological risk factor; $T^i_r$ is the metal toxic response factor according to Hakanson, (1980). The values for each element are in the order Zn = 1 < Cr = 2 < Co = Pb = 5. RI is the potential ecological risk caused by the overall contamination. There are four categories of RI and five categories of $E^i_r$ as shown in Table 3.

**Table 3:** Indices and Grades of Potential Ecological Risk of Metals

| $E^i_r$ value | Grades of ecological risk of metals | RI value | Grades of the environment |
|---|---|---|---|
| $E^i_r < 40$ | low risk | RI < 110 | low risk |
| $40 \leq E^i_r < 80$ | moderate risk | 110 ≤ RI < 200 | moderate risk |
| $80 \leq E^i_r < 160$ | considerable risk | 200 ≤ RI < 400 | considerable risk |
| $160 \leq E^i_r < 320$ | high risk | 400 ≤ RI | very high risk |
| $320 \leq E^i_r$ | very high risk | | |

### Transfer factor

The transfer factors (TF) of heavy metals from soils to crops, also called accumulation factor, uptake factor or concentration factor, is regarded as an index for evaluating the transfer potential of a metal from soil to plant (Zheng *et al*., 2007). It was calculated according to the method by Cui *et al*. (2005) as follows:

$TF = \frac{C_p}{C_s}$ (5)

Where $C_p$ and $C_s$ are the concentrations of the heavy metals in the plant and soil samples respectively

### Health risk assessment

#### *Daily intake of metals (DIM)*

The daily intake of metals (*DIM*) was assessed to estimate the average daily loading of metal into the body system of a specified body weight of a consumer. The daily intake of metal in this study was calculated based on the formula reported by Sajjad *et al*., (2009) as shown:

$DIM = \frac{C_m \, x \, CF \, x \, DFI}{BW}$ (6)

Where, $C_m$, CF, DFI and BW represent concentration of the heavy metals, conversion factor, daily food intake and body weight respectively. A conversion factor (CF) of 0.085 was used to convert the fresh sample weigh to dry weight, while The average adult daily vegetable intake rate of 0.345 kg/person/day and body weight of 60 kg was used as reported in literature (Wang *et al*., 2005; Likuku & Obuseng, 2015).

#### *Non-carcinogenic risk assessment*

The non-carcinogenic risk estimation of heavy metals consumption was determined using the Target Hazard Quotient (THQ) and Hazard Index (HI).

$THQ = \frac{DIM}{RfD}$ (7)

Where RfD is the oral reference dose (mg/kg/day), defined as the daily oral exposure to a substance that will not result in any deleterious effect in a life time for a given human population (FAO/WHO, 2013). The RfD values for the assessed metals are listed in Table 4.

THQ ≤ 1 means that the studied population is considered to be safe, while THQ > 1 means the population are exposed to toxic levels of the heavy metals.

**The hazard index (HI)** was calculated as the summation of the Target Hazard Quotient (THQ) arising from all the metals examined.

$HI = \Sigma THQ$ (8)

The value of the hazard index is proportional to the magnitude of the toxicity of the plant consumed.

#### *Carcinogenic risk assessment*

Carcinogenic risk (CR) assessment estimates the probability of an individual developing cancer over a lifetime due to exposure to the potential carcinogen. CR was calculated using the following equation:

$CR = CSF \, x \, DIM$ (9)

Where DIM and CSF are the daily intake of metals (mg/kg/day) and cancer slope factors $(mg/kg/day)^{-1}$ respectively. The CSF for the studied heavy metals are listed in Table 4.

According to US EPA, (2011) CR between $1 \times 10^{-6}$ to $1 \times 10^{-4}$ represent a range of permissible predicted lifetime risks for carcinogens. Chemical for which the risk factor falls below $1 \times 10^{-6}$ may be eliminated from further consideration as a chemical of concern.

**Table 4**: Reference dose and cancer slope factors for the investigated metals

| metal | Oral reference dose (RfD) (mg/kg/day) | Cancer slope factor (CSF) $(mg/kg/day)^{-1}$ |
|---|---|---|
| Co | 0.02 | 0 |
| Cr | 0.003 | 0.5 |
| Pb | 0.004 | 0.0085 |
| Zn | 0.3 | 0 |

## RESULTS AND DISCUSSION

### Levels of heavy metals in soils and plant samples

#### *Levels of heavy metals in soil*

The results of heavy metals in the soil of Nigeria Police Academy has been analysed and the mean result presented in Fig. 2. The results show that, metal concentrations (mk/kg dry weight) in the studied area were in the following range: Co (1.8±0.93 – 27.6±0.35), Cr (150.90±0.86 - 261±2.52), Pb (26.80±0.96 – 62.40±2.70), Zn (34.90±0.05 – 99.00±0.47). The mean concentrations of the metals can be arranged in the following decreasing order: Cr > Zn > Pb > Co. Except Co in site A and D and Zn in site E, other metal concentrations are above the background values (the horizontal lines in the figures).

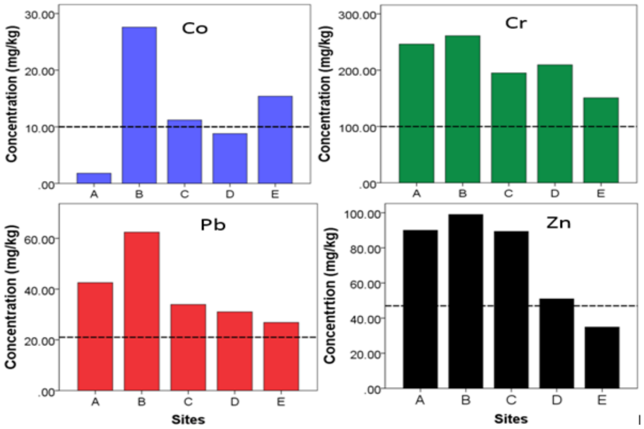


**Figure 2:** Mean concentrations of heavy metals in soil

To evaluate the degree of anthropogenic input of metal pollutant, Geo-accumulation index was calculated for the different metals, and the result summarized in Figure3. From the results, site A and C are uncontaminated with respect to Co (Igeo < 0), while other metals are in the uncontaminated – moderately contaminated class (0 > Igeo < 1). All the metals are in the uncontaminated – moderately contaminated class in site B, while only Cr was found to be in the uncontaminated – moderately contaminated class in site D and other metals in the uncontaminated class. In site E, Pb and Zn are in the uncontaminated class while Co and Cr are in the uncontaminated – moderately contaminated class. The average Igeo for the observed metals were in the decreasing order of Cr (0.48) > Pb (0.26) > Zn (-0.061) > Co (-0,67) In general, none of the Igeo value is greater than 1 showing that the studied area can be classified as not seriously polluted with the selected heavy metals.

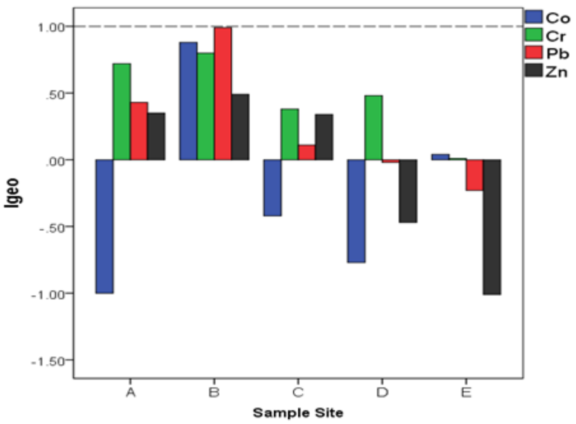


**Figure 3:** Values of Geo-accumulation index of metals at different sampling sites

***Levels of heavy metals in plants***

The mean concentrations of the studied heavy metals in the plant (*Mangifera indica*) are show in Table T. Cobalt (Co) has a minimum value of 4.00±0.07 mg/kg (in site D) and a maximum value of 5.20±0.20 mg/kg (site B). The results of this study are comparable to that reported by Adejoh, (2016), but higher than that of Lawal & Audu, (2011). However, all the values are lower than the upper permissible limit set by FAO/WHO.

The concentrations of Cr ranged from 1.65±0.47 mg/kg (site E) to 3.10±0.56 mg/kg (site B), which are all above the maximum permissible limit set by FAO/WHO, but low compared to the one of Pateh *et al.,* (2015) and that of Chima & Akah,(2017) which were 9.3 mg/kg and 4.06 mg/kg respectively. The toxicity of Chromium is attributable to the Cr (VI) form. The lethal or sub lethal doses of Cr (VI) compounds cause haematological effects in humans and reproductive and developmental effects (Bonde & Olsen, 1992).

The mean values for Pb are between 5.74±0.05 mg/kg to 9.45±0.72 mg/kg. Like Cr, the levels of Pb are all above the maximum permissible limit set by FAO/WHO. This values are high when compared to the 2.47 mg/kg of Chima & Akah,(2017) and 3.3 mg/kg of Pateh *et al.,* (2015), but within the range reported by Mng'ong'o *et al*., (2021) (0.10 – 28.50 mg/kg). Lead is a non-essential element as it is toxic even at a trace level**.** Exposure to a high level of it over a short period of time may cause weakness, anaemia, memory loss, brain damage and even death. It can also damage a developing baby's nervous system, can cause miscarriage, stillbirths, and infertility (NIOSH, 1995).

The Zn levels are all below the maximum allowable limit. The values are also lower than that reported by Kpee & Edori (2017) (3.84-6.32 mg/kg)**;** Adelasoye & Oyeyiola, (2014) (5.04 mg/kg); and Ang & Ng, (2000) (5.20 - 12.22 mg/kg), but within the range reported by Onyedikachi et *al.,* (2018), (3.23 – 29.71 mk/kg). Although Zn is an essential element in both plant and animals, elevated concentrations of the metal can supress Cu and iron absorption and can result to other side effects like diminished growth, histological and functional change in the kidney (FAO/WHO, 2011; Adejoh, 2016).

**Table 5:** Mean concentrations of heavy metals in *Mangifera indica* in the study area (mg.kg)

| Sites | Co | Cr | Pb | Zn |
|---|---|---|---|---|
| A | 4.73±0.14 | 2.43±0.10 | 6.43±0.47 | 15.10±0.07 |
| B | 5.20±0.20 | 3.10±0.56 | 7.50±0.36 | 13.40±0.03 |
| C | 4.58±0.15 | 2.43±0.18 | 9.45±0.72 | 16.55±0.18 |
| D | 4.00±0.07 | 2.50±0.39 | 5.74±0.05 | 16.43±0.03 |
| E | 5.05±0.08 | 1.65±0.47 | 6.55±0.34 | 13.18±0.03 |
| WHO/FAO | 50.00 | 1.30 | 0.30 | 99.40 |

**Transfer factor**

Transfer factor is used to show the proportion of the metal that are available to the plant from the soil (Smith *et al.,* 1996). It is significant because soil to plant transfer factor is one of the pathways of human exposure through the food chain. It is dimensionless as it is a ratio of two concentrations. The transfer factors of the studied metals into the *Mangifera indica* in the studied area are shown in Table 6. The range of values for the observed metals are as follows: Co (0.19 – 2.63), Cr (0.01 – 0.01), Pb (0.12 – 0.28), Zn (0.14 – 0.38). There is no significant difference between the average transfer factors of Co, Pb and Zn, although the transfer factors varied slightly between sampling sites. However, the transfer factor of the three mentioned metals (Co, Pb and Zn) varied significantly between that of Co. There is no variation of the transfer factor of Co between sites. Uptake of metals from soil to plant is a function of physical and chemical properties of the soil (such as pH, soil organic matter, CEC, etc.) and the physiological make-up of the plant species (US EPA, 2007)**.**

**Table 6:** Transfer factor for the selected metals at different sites

| site | Co | Cr | Pb | Zn |
|---|---|---|---|---|
| A | 2.63 | 0.01 | 0.15 | 0.17 |
| B | 0.19 | 0.01 | 0.12 | 0.14 |
| C | 0.41 | 0.01 | 0.28 | 0.19 |
| D | 0.45 | 0.01 | 0.19 | 0.32 |
| E | 0.35 | 0.01 | 0.24 | 0.38 |

**Multivariate statistical analysis**

***Correlation analysis***

The Pearson's correlation coefficient measures the strength of a linear relationship between any two variables on a scale of -1 (perfect inverse relation) through 0 (no relation) to +1 (perfect sympathetic relation). The matrix of linear correlation coefficient for metals in soil and plant were shown in Table 7. Significant positive correlations (0.05 level, 2 tailed) were found between lead in plant (pPb) and the following: pCo (r = 0.585), sCo (r = 0,519), pCr (r = 0.860), sCr (r = 0.847) and pZn (r = 0.770). pZn also correlated positively with pCr (r = 0.807), sCr (r = 0.785) and sPb (r = 0.546), while significant positive correlation was also found between sCo and pCo. (r = 0.612).

There was generally poor correlation between any particular metal in soil and its plant counterpart. This indicates that metal concentrations in plants is not a linear function of the soil concentration. Plants can also be exposed to metals through aerial deposition on leaf surfaces, trapping metals in hairs or rough cuticular surfaces (Marchner, 1995). Weak correlation between concentration of heavy metals in soil and vegetables has also been reported by Chanda *et al*., (2011) and Agbenin *et al*., (2019). However, positive correlation was found between soil Co and plant Co. This is due to high transfer factor found for this metal.

On the other hand, significant negative correlations also existed between sZn and pCo (r = -0.610), sCo (r = -0.870). Factors which increase soil zinc concentrations tend to have reverse effect on soil cobalt concentrations and vice versa. Because of the high dependent of plant cobalt concentrations on soil cobalt concentration, there will be proportionate effect on plant cobalt concentrations.

**Table 7**: Pearson correlation coefficients of metals in plant and soil

| | pCo | sCo | pCr | sCr | pPb | sPb | pZn | sZn |
|---|---|---|---|---|---|---|---|---|
| **pCo** | 1 | | | | | | | |
| **sCo** | **0.612*** | 1 | | | | | | |
| **pCr** | 0.137 | 0.097 | 1 | | | | | |
| **sCr** | 0.387 | 0.014 | 0.395 | 1 | | | | |
| **pPb** | **0.585*** | **0.519*** | **0.860*** | **0.847*** | 1 | | | |
| **sPb** | 0.246 | 0.243 | -0.025 | 0.203 | 0.155 | 1 | | |
| **pZn** | 0.149 | 0.258 | **0.807*** | **0.785*** | **0.770*** | **0.546*** | 1 | |
| **sZn** | **-0.610*** | **-0.870*** | 0.023 | 0.135 | -0.38 | 0.217 | 0.129 | 1 |

*correlation is significant at 0.05 level (two tailed)
pCo = plant Cobalt, sCo = soil Cobalt, pCr = plant Chromium, sCr = soil Chromium, pPb = plant Lead, sPb = soil Lead, pZn = plant Zinc, sZn = soil Zinc

***Cluster Analysis***

Cluster analysis assigns a set of observations into subsets (called cluster) so that observations in the same cluster are similar in some sense. Connections and relations for Hierarchical cluster analysis creates a hierarchy of clusters which may be represented in a tree structure called dendogram. The dendogram of the hierarchical cluster analysis of metal contents in the soil and plant is illustrated in Fig. 4. Four clusters were identified: Cluster 1 contains pCr, sCr, pPb, and pZn; Cluster 2 contains pCo and sCo, while sPb and sZn were isolated as Cluster 3 and Cluster 4 respectively.

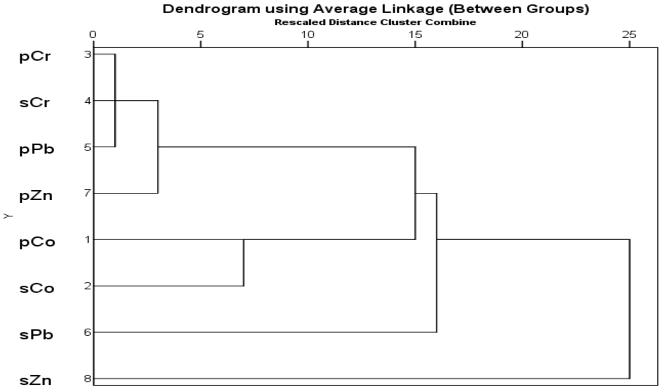


**Figure 4:** Dendogram of the hierarchical cluster analysis of metal contents in plant and soil using Average Linkage (Between Group)

***Principal Component Analysis***

Table 8 shows the result of the principal component loadings for metal contents in soil and plant of the study area, while Figure 5 represent the component plot. Based on correlation matrix, three components were extracted, which explained 92.87% of the total variance. Component 1 accounted for 48.98 % of the total variance and has strong positive loadings for pCo, sCo, pCr, sCr, pPb and pZn. This component is a combination of cluster 1 and 2 in the cluster analysis, and may reflect elements with similar controlling factors. Component 2 accounted for 28.72% of the total variance and has strong negative loadings for pCo and sCo and also strong positive loading for sZn. This component reflects the source of Zn pollution to the area, which has negative influence on Co concentrations in soil and plant. Component 3 accounted for 15.18% of the total variance and has strong positive loading for sPb. Lead in soil (pPb) has low correlation with most of the variables, was isolated in the cluster analysis and exist alone in component 3, showing that source or controlling factor of lead soil pollution is different from other metals pollution in the area. Further studies are needed to identify the real sources of these metals pollution.

**Table 8:** Principal component loadings for metals in soil and plant

| | Components | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| pCo | **0.593** | **-0.584** | 0.118 |
| sCo | **0.522** | **-0.773** | 0.176 |
| pCr | **0.825** | 0.403 | -0.371 |
| sCr | **0.856** | 0.421 | -0.145 |
| pPb | **0.983** | -0.046 | -0.18 |
| pZn | **0.844** | 0.399 | -0.235 |
| sZn | -0.299 | **0.918** | -0.220 |
| sPb | 0.334 | 0.119 | **0.935** |
| % of variance | 48.98 | 28.72 | 15.18 |
| Cumulative % | 48.98 | 77.7 | 92.87 |

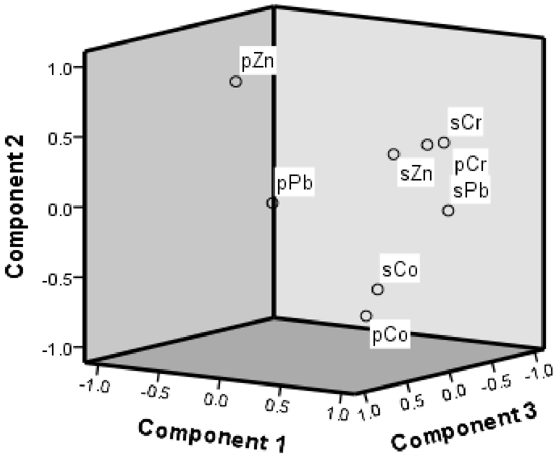


**Figure 5**: Principal component plot

**Ecological Risk Assessment**

The ecological risk assessment results for heavy metals in soil were summarized in Fig. 6. It was found that the average monomial risk factors ($E_i^r$) were ranked in the following order: Pb > Co > Cr > Zn. The average monomial ecological risk for all the metals are all below 40 ($E_i^r < 40$), indicating that these metals posed low risk to the environment. The results also showed that all the samples in the studied sites contains metal with low risk to the environment (monomial ecological risk below 40).

In order to quantify the overall potential risk of the observed metals, RI was calculated as the sum of all the four risk factors (Fig. 6). RI could characterize the sensitivity of local ecosystem to the toxic metals and represent ecological risk resulted to the overall contamination. The RI values for the studied sites are in the following order: B (35.99) > C (19.47) > A (17.85) > E (17.84) > D (17.06). This results indicate that all the studied sites constituted low risk to the local ecosystem (RI < 110). While geo-accumulation index (Igeo) focuses on the accumulation levels of individual metals without regard to toxicity of the metal, potential ecological risk index describes both ecological risk caused by individual metal and overall risk from varied pollutants (Yisa et al., 2012).

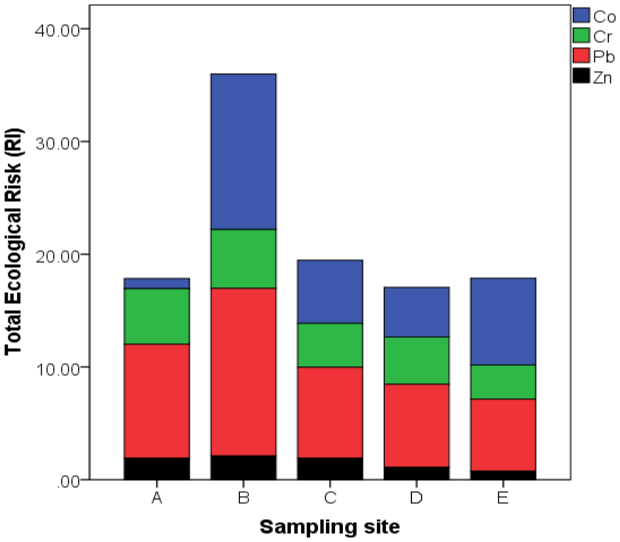


**Figure 6**: Contributions of each metal to total ecological risk

**Health Risk Assessment of heavy metals in plants**

***Non-carcinogenic risk assessment***

The non-carcinogenic human health risk from the consumption of *mangifera indica* contaminated with the studied heavy metals was estimated through calculation of daily intake of metals (DIM) (by adults), target hazard quotient (THQ) and hazard index (HI) and the results obtained presented in Table 9. The DIM results for Co, Cr, Pb and Zn ranged from 0.0020 – 0.0025, 0.00081 – 0.0015, 0.0028 – 0.0046 and 0.0064 – 0.0081 respectively. It was observed that all the DIM values are below the tolerable limit set by FAO/WHO, **(**2011)**.**

THQ estimates the risk of exposure, taking into consideration the measured concentration and the oral reference dose, weighted by the length and frequency of exposure, amount ingested and body weight (Tsafe *et al*., 2012). The average THQ values for the observed metals are in the order Pb > Cr > Co > Zn. Except Pb in site C, other THQ values were found to be <1. THQ < 1 means that the exposed population is safe from the health risk arising from the selected metals, while THQ > 1 means that there might be potential health risk arising from consumption of the contaminated plant.

HI is the cumulative effect of all the studied toxic metals. The results show the HI values of 1.13, 1.58, 1.69, 1.23 and 1.10 for sites A, B, C, D and E respectively. The results also show that Pb contributed 62.91% of the total HI in the studied area, while Cr, Co and Zn contributed 28.43 %, 8.51 %, and 1.76 % respectively. Hence, the non-carcinogenic risk contribution of the metals can be arranged in the following order Pb > Cr > Co > Zn. The additive effect of contaminants to the population to non-carcinogenic risk is necessary on humans**.** However, it is worthy of note that the result of this study took into account the risk of only four heavy metals while ignoring other contaminants. Hence, the non-carcinogenic risk to the population arising from the consumption of the studied plant might have been under estimated.

**Table 9:** Daily intake of metals (DIM), Target Hazard Quotient (THQ) and Health Index (HI) of heavy metals in the plant

| Site | Co | | Cr | | Pb | | Zn | | |
|---|---|---|---|---|---|---|---|---|---|
| | DIM | THQ | DIM | THQ | DIM | THQ | DIM | THQ | HI |
| A | 0.0023 | 0.12 | 0.0012 | 0.40 | 0.0031 | 0.78 | 0.0074 | 0.025 | 1.13 |
| B | 0.0025 | 0.13 | 0.0015 | 0.50 | 0.0037 | 0.93 | 0.0065 | 0.022 | 1.58 |
| C | 0.0022 | 0.11 | 0.0012 | 0.40 | 0.0046 | 1.15 | 0.0081 | 0.027 | 1.69 |
| D | 0.0020 | 0.10 | 0.0012 | 0.40 | 0.0028 | 0.70 | 0.0080 | 0.027 | 1.23 |
| E | 0.0025 | 0.13 | 0.00081 | 0.27 | 0.0032 | 0.80 | 0.0064 | 0.021 | 1.10 |
| WHO/FAO | 0.05 | 1 | 0.20 | 1 | 0.214 | 1 | 60 | 1 | |

### *Carcinogenic Risk Assessment*

The cancer slope factors (Table 4) were used to estimate the carcinogenic risk (using equation 9), and the result presented in Table 10. Carcinogenic Risk is the incremental risk or the probability of an individual developing cancer over life time (Gebeyehu & Bayissa, 2020). The normal range set by USEPA is from 1.0 x $10^{-6}$ to 1.0 x $10^{-4}$ (USEPA, 2011). The results of this study show that the cancer risk due to Cr ranged from 4.10 x $10^{-4}$ to 7.5 x $10^{-4}$. These values are a little above the upper limit of 1.0 x $10^{-4}$. These values indicated a life time probability of contracting cancer due to ingesting plant contaminated with Cr in the study area. This shows that Cr should be placed for further consideration as chemicals of concern with regard to the studied population. On the other hand, the CR risk values for Pb were found to be less than the maximum threshold value and hence indicating no cancer risk from Pb to the adult population in the area.

CR was not calculated for Co and Zn because there was no carcinogenic or mutagenic data for these metals.

**Table 10:** Carcinogenic Risk (CR) of heavy metals in plant

| Site | Co | Cr | Pb | Zn |
|---|---|---|---|---|
| A | 0 | 6.00 x $10^{-4}$ | 2.60 x $10^{-5}$ | 0 |
| B | 0 | 7.50 x $10^{-4}$ | 3.10 x $10^{-5}$ | 0 |
| C | 0 | 6.00 x $10^{-4}$ | 3.90 x $10^{-5}$ | 0 |
| D | 0 | 6.00 x $10^{-4}$ | 2.40 x $10^{-5}$ | 0 |
| E | 0 | 4.10 x $10^{-4}$ | 2.72 x $10^{-5}$ | 0 |

## Conclusion

Although the mean heavy metal concentrations in the soil of the studied area exceeded the background values, the area can still be classified as generally unpolluted to moderately polluted. The metal pollutants did not pose significant ecological risk to the ecosystem. The concentrations of the metals in *mangifera indica* show that only Pb may pose non-carcinogenic risk to the area, while Cr indicated a life time probability of causing cancer. The study indicated that soil to plant transfer may not be the only route of accumulation of these heavy metals from the environment. There is need to continue to monitor these metals to avoid the ecological risk, non-carcinogenic and carcinogenic health risk that may arise from elevated levels of the metals in soil and *Mangifera indica*.

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