International Journal of Sciences

Research Article Volume 8 – June 2019 (06)

# Uptake of Heavy Metals by Plant Leaves around Industrial and Agricultural Areas of Enugu State, Southeastern, Nigeria

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**Abstract:** This research was carried out to determine the quantity of uptake of trace elements by the leaf of plants growing around industrial and agricultural areas of Enugu State. A total of twenty-two (22) plant leaf samples which consist of 12 different species such as *S. pyramidalis, Py. polystachyos, Se. sesban, C. odorata, P. foetida, H. suaveolens, T. platycarpa, C. mucunoids, C. digitalis, D. aegypticum, Sc. dulcis* and *L. oryza sativa* were collected from dumpsites, industrial sites, wetlands, mining sites and sewage site, across the study area. The samples were analyzed for heavy metals using standard laboratory methods. Results obtained in the study area revealed that the plant leaf samples obtained from the study area contained the following mean values: $Fe^{3+}$ (25.69 ± 21.04 mg/kg), Mn (11.03 ± 0.64 mg/kg), As (4.60 ± 1.56 mg/kg), Pb (3.38 ± 1.46 mg/kg), Zn (21.93 ± 11.02 mg/kg), Cd (0.79 ± 0.03 mg/kg), Cr (2.86 ± 4.84 mg/kg), Ni (0.53 ± 4.27 mg/kg) and Cu (12.74 ± 2.89 mg/kg). The mean concentrations of iron, arsenic, lead, cadmium and chromium were above the recommendable limits as stipulated by FAO/WHO for edible plants. Principal component analyses of the variables revealed strong relationship among the variables indicating same source of enrichment. This study is limited to plant leaves; hence, further research is recommended in the study area to evaluate the uptake of heavy metals by the roots and stems of the same plants.

**Keywords:** Heavy Metals, Plants, Uptake, Enugu State, Principal Component Analysis

## Introduction

Heavy metals are toxic to both plants and animals (Escarre et al., 2000). Traces amount of heavy metals can be found in our daily food intake, water we drink, air we breathe and soil we cultivate (Boularbah et al., 2006). Soils contaminated with toxic heavy metals from point sources have been considered as potential exposure routes for plant and animal populations (Carrizales et al., 2006). The uptake of heavy metals by plants can be from both natural and human activities (Smith and Bradshaw, 1979). The major induced heavy metals contamination by human activities are mining, industrial activities, agricultural activities, municipal solid waste disposal and sludge application (Kumar et al., 1995). Content of metals is a useful indicator for the assessment of plant pollution as excluders and as accumulators. Excluders are plants that possess low values of metals in their shoot or restrict the levels of heavy metal translocation within them over a wide range of soil concentrations (Baker 1981). Whereas, accumulators concentrate heavy metals in their shoots at both low and high soil metal concentrations and are utilized in extracting heavy metals from contaminated soils (Rotkittikhun et al., 2006). High accumulation of heavy metals in soil affects the quality of plants and crops. The enrichment of heavy metals in edible metal-tolerant plants and crops is creating hazard to animal and human health.

Research have showed that industrial and agricultural activities can lead to significant pollution of soils, water and plants. However, heavy metals like As, Cr, Cd, Pb, Mn, $Fe^{3+}$, Cu, Zn, and nickel (Ni) are toxic for plants and humans even at minimal amounts (Khan et al., 2008). Cadmium and lead play a key role in plant pollution especially when its value exceed certain level. Ni, Cu, and Zn are vital elements for plant growth. Nickel is an essential element of the enzyme urease, but when Ni absorptions in leaf tissue of plants exceed 50 mg/kg, the plants may suffer from excess Ni and reveal toxicity symptoms (Adriano 1986; McGrath and Smith, 1990). Once absorbed, Cu visibly cumulates in roots, even when the roots have been damaged by toxicity (Adriano 1986). Zinc phytotoxicity is accounted for acid and heavily sludge soils (Kabata-Pendias et al., 1993).

The toxicity of heavy metals in plants, particularly root and leafy plants, grown in heavy metal contaminated soils having higher concentrations of metals has led to considerable research to find out alternative strategies to minimize or remove the

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Published at: http://www.ijsciences.com/pub/issue/2019-06/
DOI: 10.18483/ijSci.2092; Online ISSN: 2305-3925; Print ISSN: 2410-4477

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heavy metals from the environment. However, several studies have been also carried out the accumulating capacity of plants that grew naturally on industrial and on agricultural contaminated soils. It has been discovered from such reviews that some of the plant species accumulate high levels of heavy metals more than the normal levels encountered generally in plants (Kidd and Monterroso, 2005; Yanqun et al., 2004; Walter et al., 2003; Bunzl et al., 2001) thereby suggesting that such plants can be used as decontaminants of heavy metal polluted soils. In the study area, there is scarcity of information about such heavy metals' tolerant plants locally. Therefore, the aim of this research is to determine the quantity of uptake of trace elements by plants around industrial and agricultural areas of Enugu State.

**Study Area**

The study area lies between latitudes 6°00ˈ and 7° 00ˈ N and longitudes 7° 00ˈ and 8° 00ˈ E with total areal extent of 7,161km$^2$ (2,764,9 sq.m) and population density of 5,590,513 according to National population commission data (2006). The topography of the area is mainly lowlands, escarpment, plateau and plains. The relief of the study area ranges from 50 – 450m above mean sea level. Two main rivers, Abonyi and Anambra, drain the entire area, along with their tributaries. Whereas, the Abonyi River drains the eastern portion, the Anambra River drains the western portion of the study area. The predominant drainage pattern is dendritic. The area under this study is part of the tropical rainforest vegetation of Nigeria. Enugu area is characterized by two distinct climatic seasons, namely; wet and dry seasons respectively. The wet season which commence from April ends in October with average annual rainfall of about 2,000 millimeters. While dry season starts from November to March with average temperature of about 27$^o$C.

**Geology and Hydrogeology**

The study area is located in the Anambra Basin and some parts of Southern Benue Trough and Niger Delta Basin. Several authors (Reyment, 1965; Murat, 1972; Nwachukwu, 1972; Benkhelil, 1982; Nwajide and Reijers, 1996; Obi, 2000) have studied the lithostratigraphic framework for the Early Cretaceous-Paleocene strata in southeastern Nigeria. The major geological formations found in study area are (from oldest to youngest) Asu River Group (Albian), Ezeaku Group (Touranian), Awgu Group (Coniacian), Nkporo Group (Campanian), Mamu Formation (Maastrichtian), Ajali Formation (Upper Maastrichtian), Nsukka Formation (Danian) and Imo Group (Paleocene) (Fig. 1). These formations consisst mainly of shale, shelly limestone, siltstone, claystone, and sandstone. The general strike direction of the beds is NW-SE with dip amount between 3$^o$ and 20$^o$NE/SW. Generally, aquifer distribution in the area is categorized by perched (semi -confine), shallow (unconfined) and deep (confined and unconfined) aquifer systems (Ezeigbo and Ozoko, 1989). The perched aquifers occurred in the Nsukka Formation while shallow unconfined aquifer systems occurred in the fractured and weathered horizon of the Abakaliki, Ezeaku, Awgu, Enugu, Mamu and Imo Formations. This aquifer is tapped by several hand dug wells and shallow boreholes at depth between 10 – 20m in several area of the study. The confined aquifer occurs at depths of between 50 – 350m.

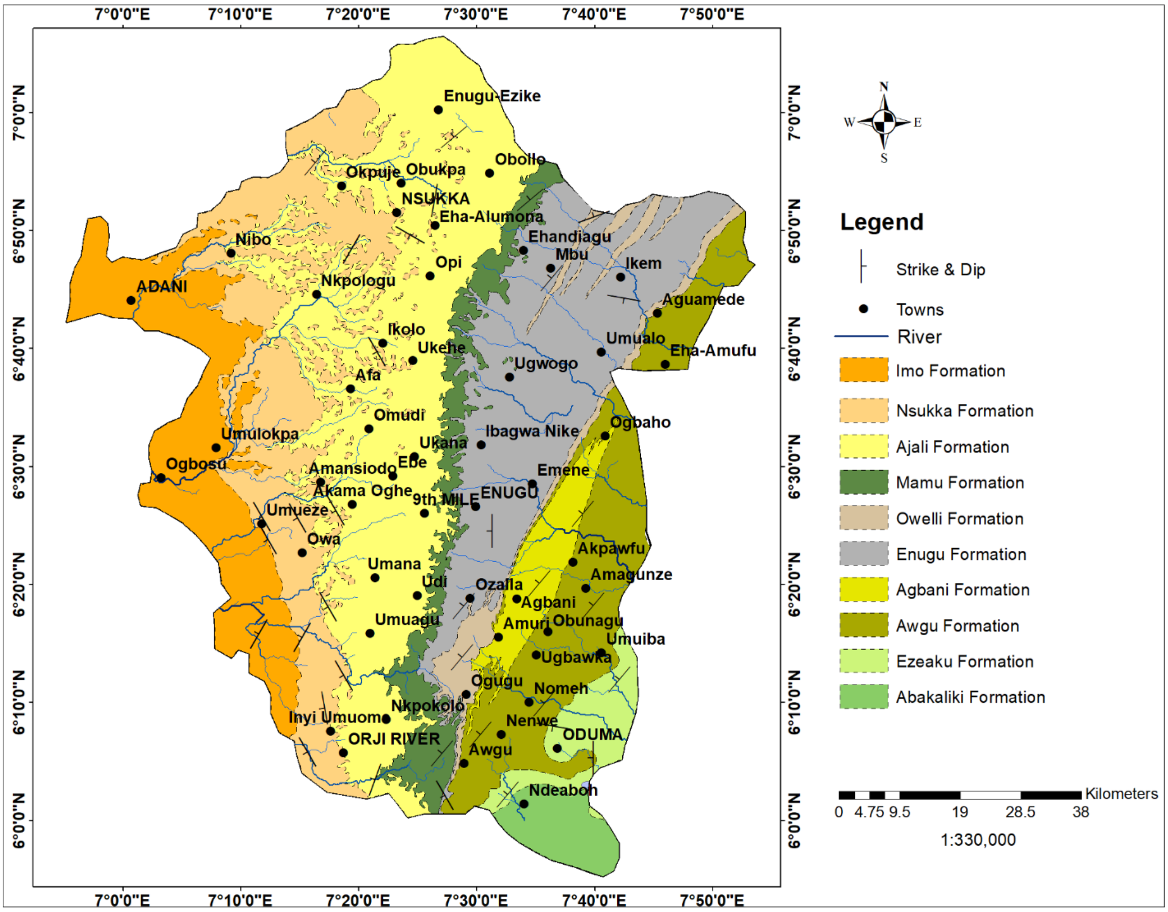


Figure 1. Geologic map of the study area

**Materials and Methods**

A total of twenty-two (22) plant leaf samples consisting 12 different species were collected from dumpsites (2), industrial sites (10), wetlands (3), mining sites (3) and sewage site (4), across the study area (Table 1). The choice of plant species collected was based on close distance to the source of contamination. Each of the plant samples were collected fresh from the field in required amounts, wrapped in polyethylene bags, labelled and transported to laboratory for analysis. All the collected plant samples were air dried and placed in oven for drying at 70°C and then ground to powder to pass through a 2 mm sieve for chemical analysis. 1 gm of finely ground plant sample was weighed into a 100 ml Kjeldahl flask and digested with 10 ml conc. HNO3 and 2 ml conc. The digested plant samples were analysed for heavy metals, e.g., Fe, Cd, As, Cr, Cu, Mn, Ni, Pb, and Zn by atomic absorption spectrophotometer (AAS) at the Department of Crop Science, University of Nigeria, Nsukka. Similarly, plant samples used for identification were also collected separately and kept in a brown envelope. The plants identification was done at Department of Botany, same University.

Table 1. Families, Species and Genus of the plants sampled prior to this work.

| **Family** | **Species** | **Genus** |
|---|---|---|
| Poaceae | *S. pyramidalis* | Sporobolus |
| Cyperaceae | *Py. polystachyos* | cyperus |
| Fabaceae | *Se. sesban* | Sesbania |
| Asteraceae | *C. odorata* | Chromolaena |
| Passifloraceae | *P. foetida* | Passiflora |
| Bankeraceae | *H. suaveolens* | Hydnellum |
| Boraginaceae | *T. platycarpa* | Pectocarya |
| Fabaceae | *C. mucunoids* | Calopogonium |
| Digitalis | *C. digitalis* | Plantaginaceae |
| Poaceae | *D. aegypticum* | Dactyloctenium |
| Scrophulariaceae | *Sc. dulcis* | Scoparia |
| Poaceae | *L. oryza sativa* | Liliopsid |

## RESULTS AND DISCUSSION

The results obtained during the undertaken study is presented in Tables 2. It was discovered that the heavy metals composition of the plant leaves was highly different in every areas of the undertaken study.

Table 2. results of heavy metals analyzed in the plant leaf samples

| **Sample ID** | **Location** | **Plant Specie** | **$Fe^{3+}$** | **Mn** | **As** | **Pb** | **Zn** | **Cd** | **Cr** | **Ni** | **Cu** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PS1 | Dumpsites | *S. pyramidalis* | 17.01 | 10.03 | 3.01 | 4.75 | 26.73 | 0.10 | 0.01 | 0.02 | 15.41 |
| PS2 | | *Py. polystachyos* | 25.30 | 12.03 | 6.18 | 2.01 | 17.13 | 0.07 | 1.23 | 0.88 | 10.07 |
| PS3 | Industrial sites | *Se. sesban* | 0.03 | 0.31 | 0.03 | 0.10 | 4.67 | 0.04 | 0.02 | 0.05 | 1.22 |
| PS4 | | *I. cylindrical* | 0.37 | 15.01 | 0.01 | 0.13 | 10.10 | 0.09 | 0.31 | 1.00 | 7.31 |
| PS5 | | *C. odorata* | 10.87 | 0.10 | 2.09 | 2.27 | 21.99 | 0.09 | 6.82 | 0.02 | 5.18 |
| PS6 | | *P. foetida* | 32.00 | 9.43 | 4.00 | 0.02 | 18.72 | 0.05 | 2.20 | 0.05 | 0.20 |
| PS7 | | *A. tectonum* | 17.92 | 10.18 | 1.18 | 0.91 | 9.64 | 0.04 | 3.01 | 0.43 | 1.09 |
| PS8 | | *H. suaveolens* | 48.11 | 7.38 | 1.10 | 4.97 | 2.21 | 0.05 | 5.27 | 1.00 | 0.71 |
| PS9 | | *T. platycarpa* | 16.08 | 5.64 | 0.01 | 2.24 | 0.05 | 0.06 | 1.09 | 0.65 | 0.32 |
| PS10 | | *C. mucunoids* | 0.19 | 0.02 | 0.03 | 1.00 | 1.27 | 0.05 | 2.56 | 0.23 | 2.19 |
| PS11 | | *P. foetida* | 21.85 | 1.06 | 1.00 | 1.18 | 12.06 | 0.05 | 0.02 | 0.02 | 7.94 |
| PS12 | | *A. tectonum* | 11.09 | 0.08 | 0.32 | 3.03 | 0.97 | 0.06 | 5.69 | 0.11 | 5.48 |
| PS13 | wetlands | *C. mucunoids* | 12.03 | 5.07 | 1.10 | 0.01 | 10.01 | 0.02 | 0.15 | 0.01 | 5.01 |
| PS14 | | *C. digitalis* | 30.05 | 3.03 | 0.03 | 2.91 | 22.72 | 0.03 | 1.00 | 5.99 | 3.06 |
| PS15 | | *L. oryza sativa* | 24.18 | 6.92 | 3.09 | 0.62 | 13.28 | 0.02 | 0.43 | 0.06 | 6.98 |
| PS16 | Mining sites | *A. tectonum* | 20.01 | 4.06 | 0.01 | 5.00 | 8.18 | 0.03 | 1.18 | 1.22 | 3.74 |
| PS17 | | *Se. sesban* | 31.38 | 5.61 | 4.12 | 0.01 | 14.03 | 1.26 | 3.07 | 1.05 | 2.03 |
| PS18 | | *C. digitalis* | 20.67 | 6.00 | 0.03 | 5.03 | 14.03 | 1.08 | 6.61 | 5.59 | 3.74 |
| PS19 | Sewage site | *Se. sesban* | 27.10 | 0.08 | 0.80 | 1.00 | 20.20 | 0.21 | 1.38 | 6.35 | 4.03 |
| PS20 | | *T. platycarpa* | 10.12 | 1.09 | 3.01 | 3.56 | 21.09 | 0.01 | 5.46 | 1.92 | 4.12 |
| PS21 | | *Cal. mucunoides* | 38.07 | 1.02 | 1.15 | 2.28 | 10.21 | 1.56 | 3.12 | 0.86 | 6.40 |
| PS22 | | *I. cylindrical* | 24.17 | 0.08 | 3.01 | 3.24 | 26.63 | 0.79 | 1.38 | 7.68 | 5.21 |

Note that all the parameters are measured in mg/kg; PLS represents plant leaf samples

Table 3. Descriptive statistics of heavy metals anlayzed in the plant leaf samples

| **Source** | **Statistics** | **$Fe^{3+}$** | **Mn** | **As** | **Pb** | **Zn** | **Cd** | **Cr** | **Ni** | **Cu** |
|---|---|---|---|---|---|---|---|---|---|---|
| Dumpsite | Min. | 17.01 | 10.03 | 3.01 | 2.01 | 17.13 | 0.07 | 0.01 | 0.02 | 10.07 |
| | Max. | 25.30 | 12.03 | 6.18 | 4.75 | 26.73 | 0.10 | 1.23 | 0.88 | 15.41 |
| | Mean | **21.16** | **11.03** | **4.60** | **3.38** | **21.93** | **0.09** | **0.62** | **0.45** | **12.74** |
| Industrial sites | Min. | 0.03 | 0.02 | 0.01 | 0.02 | 0.05 | 0.04 | 0.02 | 0.05 | 0.20 |
| | Max. | 48.11 | 15.01 | 4.00 | 4.97 | 21.99 | 0.09 | 5.69 | 1.00 | 7.94 |
| | Mean | **24.07** | **7.52** | **2.01** | **2.49** | **11.02** | **0.07** | **2.86** | **0.53** | **4.07** |
| Wetlands | Min. | 12.03 | 3.03 | 0.03 | 0.01 | 10.01 | 0.02 | 0.15 | 0.01 | 3.06 |
| | Max. | 30.05 | 6.92 | 3.09 | 2.91 | 22.72 | 0.03 | 1.00 | 5.99 | 6.98 |
| | Mean | **21.04** | **4.98** | **1.56** | **1.46** | **16.37** | **0.03** | **0.58** | **3.00** | **5.02** |
| Mining sites | Min. | 20.01 | 4.06 | 0.01 | 0.01 | 8.18 | 0.03 | 3.07 | 1.05 | 2.03 |
| | Max. | 31.38 | 6.00 | 4.12 | 5.03 | 14.03 | 1.26 | 6.61 | 5.59 | 3.74 |
| | Mean | **25.69** | **5.03** | **2.07** | **2.52** | **11.11** | **0.63** | **4.84** | **3.32** | **2.89** |
| Sewage site | Min. | 10.12 | 0.08 | 1.15 | 1.00 | 10.21 | 0.01 | 1.38 | 0.86 | 4.12 |
| | Max. | 38.07 | 1.09 | 3.01 | 3.56 | 26.63 | 1.56 | 5.46 | 7.68 | 6.40 |
| | Mean | **24.09** | **0.64** | **2.08** | **2.28** | **18.42** | **0.79** | **3.42** | **4.27** | **5.26** |
| **WHO (1998)** | | 20 | 8 | 2 | 2 | 50 | 0.02 | 1.30 | 10 | 10 |

Note that all the parameters are measured in mg/kg

FAO/WHO (1996), established a provisional guideline value of 20 mg/kg for $Fe^{3+}$ in plants. In the study area, the average concentrations of $Fe^{3+}$ ranged between 18.78 to 25.69 mg/kg with the highest mean value of 25.69 mg/kg observed at *Sc. dulcis* leaf within the mining sites. Consequently, the least mean value of 24.07 mg/kg at *D. aegypticum* leaf around industrial sites (Fig. 2a). The high uptake of iron by *Sc. dulcis* indicates its ability to absorb the metals from the soil. Generally, the results show that $Fe^{3+}$ values in the various sites exceeded FAO/WHO threshold values, therefore, it is a potential risk for plants. Mn concentration in plant leaf samples at different locations varied between the mean range of 7.52 to 0.07 mg/kg (Fig. 2b). The FAO/WHO standard is 8 mg/kg for edible plants. Our observed values were within this limit except at dumpsite samples. The *S. pyramidalis* leaf growing in industrial sites had the highest amount (11.03 mg/kg) of Mn, which support the idea that this plant has high absorption rate of trace heavy metals from the soil where it grows while the *Se. sesban* and *Ca. Cajan* leaves growing in wetlands contained the least contents (0.07 mg/kg) of Mn. The concentration of arsenic in plant leaf samples was found exceptional higher in some locations at the study area. The maximum and minimum concentrations of arsenic were 3.09 and 1.56 mg/kg (Fig. 2c). Concentration of arsenic in some of the locations exceeded the permissible level of arsenic in plant leaf samples which is set at 2 mg/kg (FAO/WHO, 1996). The *C. odorata*, *H. suaveolens*, *Py. polystachyos* and *S. pyramidalis* leaf growing in sewage, industrial, mining and dumpsites showed mean value higher than the acceptable limit for arsenic, while *I. Cylindrical*, *L. oryza sativa*, *Cal. mucunoides* and *D. aegypticum* leaves growing in wetlands contained the least mean values below the recommendable limit. The mean concentration of Pb in plant leaf samples varied from 2.52 to 1.46 mg/kg (Fig. 2d). The mean values *Cal. mucunoides*, *Sc. dulcis and P. foetida* recorded at all the locations except are above the standard limit of 2 mg/kg as recommended by FAO/WHO (1996) for edible plants. The higher concentration of Pb in the abandoned mining sites and other locations suggests that the absorption may be affected by other factors. Zn mean values ranged from 21.93 to 11.02 mg/kg with the highest concentration of 26.73 and 26.63 mg/kg observed in the leaves of *S. pyramidalis* and *I. cylindrical* plants from dumpsits and sewage sites respectively. The high concentration of Zn in the leafs of the *S. pyramidalis* and *I. cylindrical* plants growing in the dumpsites and sewage sites may be due to the absorption of the metals from the soils. However, all the sites recorded mean values of zinc that were below the FAO/WHO (1996) permissible limit of 50 mg/kg. Mean concentrations of Cd in plant leaf samples were 0.79 and 0.03 mg/kg (Fig. 3b). Cd concentration at all the sampling locations were above the WHO/FAO (1996) permissible limit of 0.02 mg/kg.

Chromium concentration in plant samples was high at the study area. The average concentration of chromium fluctuates between from 4.84 to 0.58 mg/kg (Fig. 3c). *C. odorata*, *P. foetida*, *A. tectonum*, *H. suaveolens*, *C. mucunoids*, *A. tectonum*, *Se. sesban*, *C. digitalis*, *T. platycarpa*, *Cal. mucunoides* plant leaves accumulated significantly higher concentration of Ni above the permissible limit of 1.30 mg/kg as recommended by FAO/WHO (1996) at Industrial, mining and sewage sites. The high concentrations of the Cr in these plant species could be due to the absorption of Cr contents from the polluted soil. The guideline value of Ni is 10 mg/kg by FAO/WHO (1996). Nickel concentration in the study area has not exceeded the guideline value; hence, it is not a potential health risk to plants (Fig 3d). Average values for Cu ranged from 12.74 – 2.89 mg/kg. However, S. *pyramidalis* and *Py. polystachyos* within dumpsites (Table 2) show higher values above standard limit of 10 mg/kg as regulated by FAO/WHO (1996).

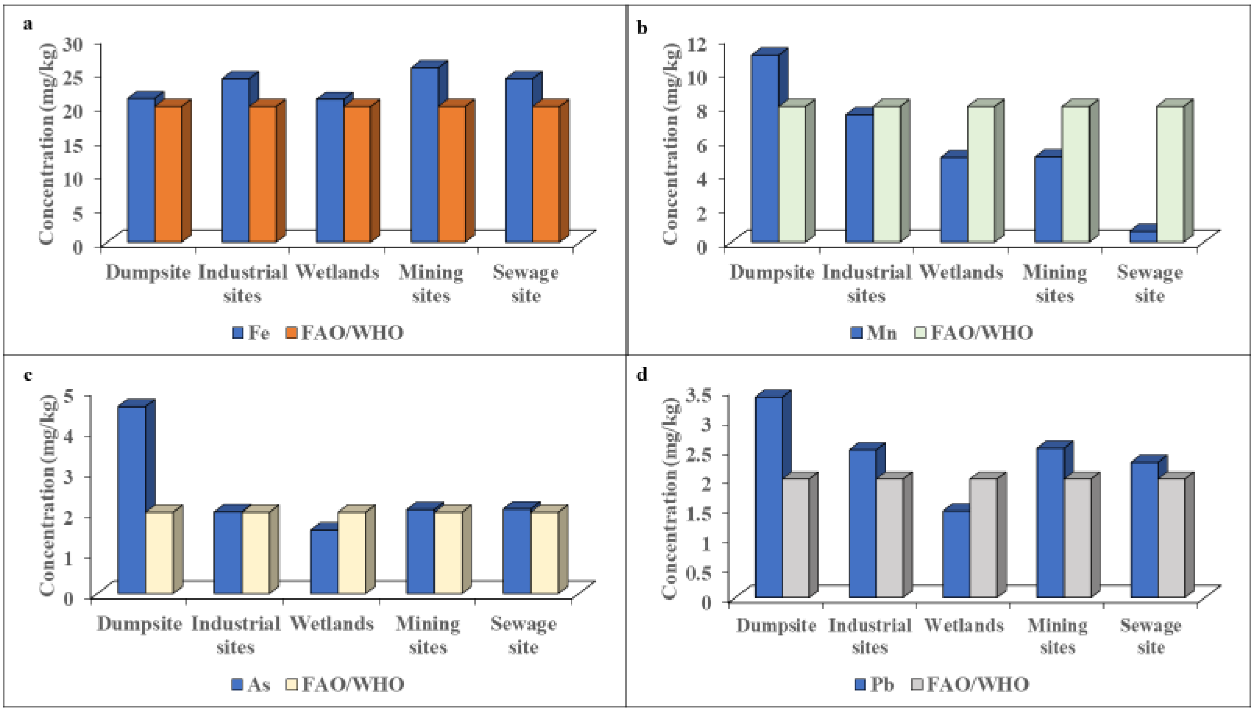

Figure 2: Bar chart showing the various heavy metal distributions in the study area

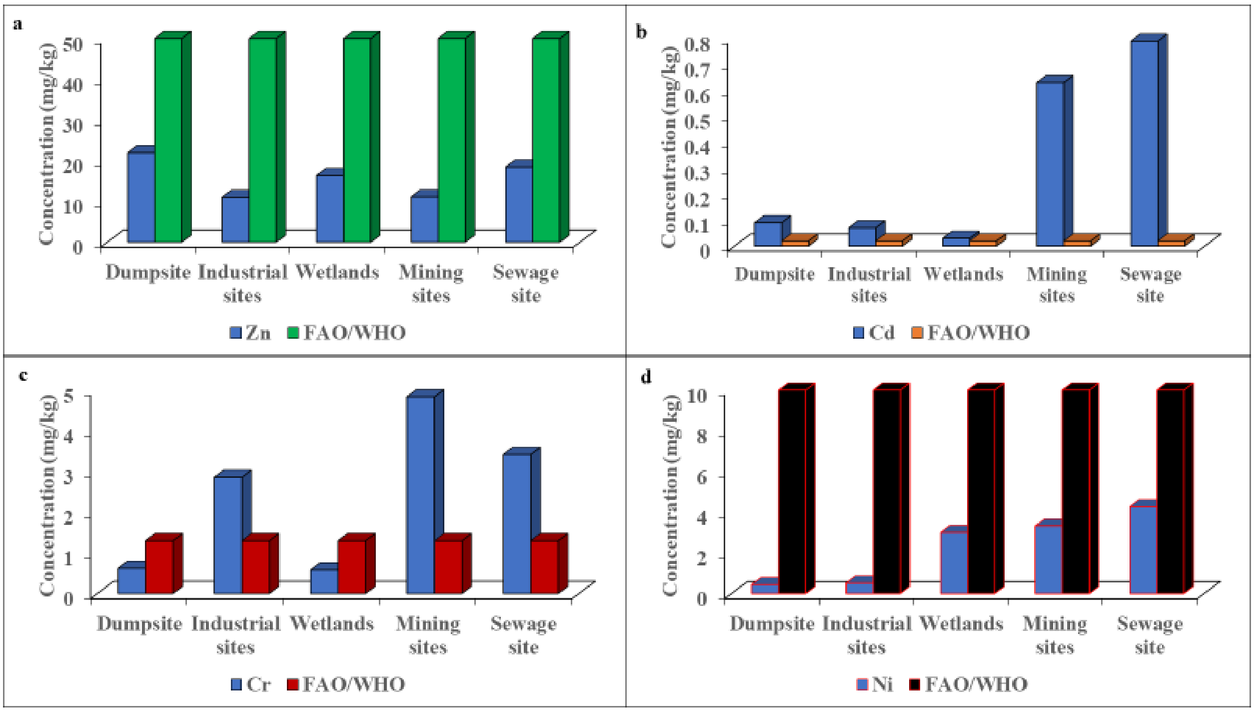


Figure 3: Bar chart showing the various heavy metal distributions in the study area

**Principal Component Analysis**

Principal component analysis, conducted using centroid approach, aid to observe various interesting relationships among the analyzed variables (Table 4).

Table 4. Show the principal component weights of heavy metals of the plant samples.

| Parameters | Component 1 | Component 2 | Component 3 | Component 4 |
|---|---|---|---|---|
| As | 0.3845 | 0.3155 | 0.0852 | 0.4164 |
| Cd | 0.0964 | 0.5837 | 0.0972 | 0.3596 |
| Cr | -0.4045 | 0.3202 | -0.1483 | -0.4566 |
| Cu | 0.2630 | 0.1480 | 0.4717 | -0.4265 |
| Fe | -0.3826 | -0.1075 | 0.3794 | 0.1937 |
| Mn | 0.4012 | 0.2452 | -0.3505 | -0.1237 |
| Ni | -0.4596 | 0.1251 | -0.0093 | 0.4437 |
| Pb | 0.2471 | -0.3494 | 0.5305 | 0.0885 |
| Zn | -0.1738 | 0.4751 | 0.4363 | -0.2217 |
| Eigenvalue | 4.377 | 2.344 | 1.829 | 2.923 |
| % Variance explained | 43.8 | 23.4 | 18.3 | 29.2 |
| % Cumulative variance | 43.8 | 67.2 | 85.5 | 76.4 |

Component 1 accounts for 43.8% of the variance and is depicted by high degrees of Mn and As. The presence of those elements, especially manganese and arsenic, to the contamination of the plant leaves is considerable. Component 2 accounted for 23.4% of the total variance. A high, positive loading appeared for Cd, Zn, Cr and As. The high loading for Cd, corresponding closely to the concentration of iron in the plant leaves, indicates the importance of the iron to the binding of metal ions in the plant samples. Component 3 accounted for 18.3% of the total variance and is characterised by high lead, copper, zinc and iron concentrations described by the high positive dependence. Their co-occurrence with Cd, Cr and Ni, metals characteristic of component 1, was inversely proportional. Also, copper and manganese, though to a lesser extent, were present in the plant leaf samples in elevated amounts. Component 4 accounted for 29.2% of the total variance. It is characterized by high contribution of nickel, arsenic and cadmium present in the largest concentrations.

**Conclusion**

The study was carried out to evaluate the uptake of heavy metals by plant leaves at different locations of Enugu State industrial and agricultural sites. The aim of the research is to determine toxicity of heavy metals in different species of plant leaves in different locations. The results revealed that all plants absorb water and mineral from soil through the ascent of sap; as a result, the heavy metals uptake by these species of plants also occurs in the same way. The mean concentrations of iron, arsenic, lead, cadmium and chromium were above the recommendable limits as stipulated by FAO/WHO for edible plants. Principal component analyses of the variables revealed strong relationship among the variables indicating same source of enrichment.

**Acknowledgements*:***
The authors are highly indebted to Mr. Okafor Joel Ekene for his assistance during the sample collection.

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