

Appraisal of Heavy Metal Concentration in the Plants and Soils at Onitsha, Anambra State, Southeastern, Nigeria

Ozoko Daniel Chukwuemeka* & Obibuzor Vitalis Chidozie
Department of Geology and Mining, Faculty of Applied Natural Sciences, Enugu State University of Science and Technology, Agbani, Enugu, Nigeria
chidozie@gmail.com

Abstract
Present investigation was ventured to examine the mobility, bioaccumulation and transfer of the heavy metals; Zn, Mn, Pb, Cd, As and Fe from analyzed plant roots tissues to shoots tissues using bioaccumulation factor (BAF), enrichment factor (EF) and translocation factor (TF) in the Onitsha, Southeastern, Nigeria. The analyzed plant species were sampled from dumpsites, mechanic workshop, abattoir, traffic, and mining sites. Current results indicated that concentrations of the examined metals in the root and shoot tissues of these plant species obtained from dumpsites exceeded those collected from mining sites and mechanic workshops. Bioaccumulation factor and enrichment factor values in *Brachiaria decumbens, Acacia modesta* and *Minuaria verna* species were above 1, indicating that these plants mighty be regarded as trace metals accumulators with potential for phytostabilization and phytoextraction. The ranking order of bioaccumulation factor for the analyzed heavy metals was Zn > Fe > Pb > Mn > As > Cd. Translocation factor values for Cr, Mn and Cu was higher than 1 by *Acacia modesta* and *xanthium strumarium*, indicating that the uptake and accumulation of these metals were higher in the shoot tissues rather than root tissues of the tested plant species.
Keywords: Onitsha; Bioaccumulation factor (BAF); Enrichment factor (EF); Translocation factor (TF); Heavy metals.
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Introduction

The massive increase in population, industrialization and manufacture of a wide range of chemical substances has resulted in a global worsening of environmental pollution (Onyia et al., 2020). According to the experts, environmental pollution with harmful metals has increased considerably as a result of increasing population and industrialization. Heavy metal pollution is a worldwide calamity caused by human-induced processes like mining, metals processing, electroplating, fossil fuel and energy manufacturing, transmission of electricity, agricultural intensives, waste disposal, and thawing activities (Lasta et al., 2000). The accumulation of heavy metals in plants from human-induced sources has heightened awareness of inorganic pollution and established species as inert biosensors (Padmavathiamma, and Li, 2007). Since then, a number of plant species have been used as bio monitors; these plants have a proclivity to ingest metals from their surroundings (Rafati et al., 2011).

The volume of waste generated through various activities has risen over the past few decades as a result of the fast development in living conditions (Sakakibara et al., 2011). Many mega cities in developed countries treat their waste appropriately, while others like Nigeria where Onitsha is located lack appropriate treatment infrastructure and discharge contaminated waste into the natural environment. Numerous studies across the globe are concerned with finding cost-effective solutions and the possibilities of using biosystems as "tools" in bioremediation efforts to clean up heavy metal-contaminated soil or aquatic environments (Greipsson, 2011). As a result, plants may be utilized to reduce heavy metal pollution in soil and wastewater.

The bioaccumulation factor is a critical measure in ecological toxicology and risk evaluation (Badr et al., 2012). Bioaccumulation factor (BAF), sometimes known as bioconcentration factor (BCF), is a metric that regulatory bodies have traditionally employed (Burhard et al., 2011), but BCFs are usually standardized, laboratory-based bioaccumulation indicators (Brisebois, 2013). The BAF is a percentage of plant metal concentration in root tissues to the soil or polluted environment [(Metal) root/(Metal) polluted environment or substrate].

According to the researches (Brisebois, 2013; Onyia et al., 2020; Lasta et al., 2000; Rafati et al., 2011), the efficacy of phytoremediation is often measured by a translocation factor (TF), which can be described as the ratio of the amount of metal in the shoot tissues to that in the root tissues [(Metal) shoot/ (Metal) root]. Plants having TF values greater than one are considered high-efficiency metal translocation plants (Ma et al., 2001). The discovery of metal hyperaccumulators, plants that has potential of accumulating abnormally high metal levels, reveals that plants have the natural ability to purify soil that is contaminated. As stated by Sutherland et al., (2000) developing an enrichment factor (EF) method is an alternate strategy utilized to determine the degree of pollution caused by humans. The enrichment factor is computed as the ratio of plant shoot content to polluted environmental medium (e.g., soil and wastewater) concentration [(Metal) shoot/(Metal) polluted substrate], (Branquinho et al., 2007). Therefore, the aim of this research is to determine the BAF, EF, and TF indices of the selected plant species obtained from Onitsha, to measure the buffer classifications formed by these plants and their capacity for phytoremediation.

Materials and Methods

Location of the study area

Onitsha is a metropolitan city in Anambra State, south-eastern Nigeria. It is located on the eastern bank of the Niger River. The entire city make-up two Local Government Areas (LGA), namely, Onitsha North LGA and Onitsha South LGA and it is located between latitudes 6°06'0" and 6°12'0"N and longitudes 6°45'0" and 6°52'0"E (Figure 1). The city is estimated to cover a total area of 52 km^2 with a population of over 1 million and characterized with heavy inflow and outflow of human and vehicular traffic due to the presence of large markets, varying commercial activities and home to several industries. The study area is characterized by two types of landforms. It consists of undulating plains to the northeast (GRA phase II and Trans Nkisi) and ridges sometimes with flat rounded tops to the south (Nkpor). According to Nwajide (2013), the elevation varied from 60 to 150 m above sea level. Onitsha is drained by River Niger which runs from North to South of the city, and its tributaries Nkisi, Nakweze and Ndemilli Rivers. There are two distinct climatic seasons, both of which are warm. The wet season generally occurs from April to October while the dry season generally begins in November and ends in March. These seasonal climatic conditions are caused by the north-south fluctuations of a zone of discontinuity between the dry continental airmass and the humid maritime Atlantic airmass (Gamier, 1967).

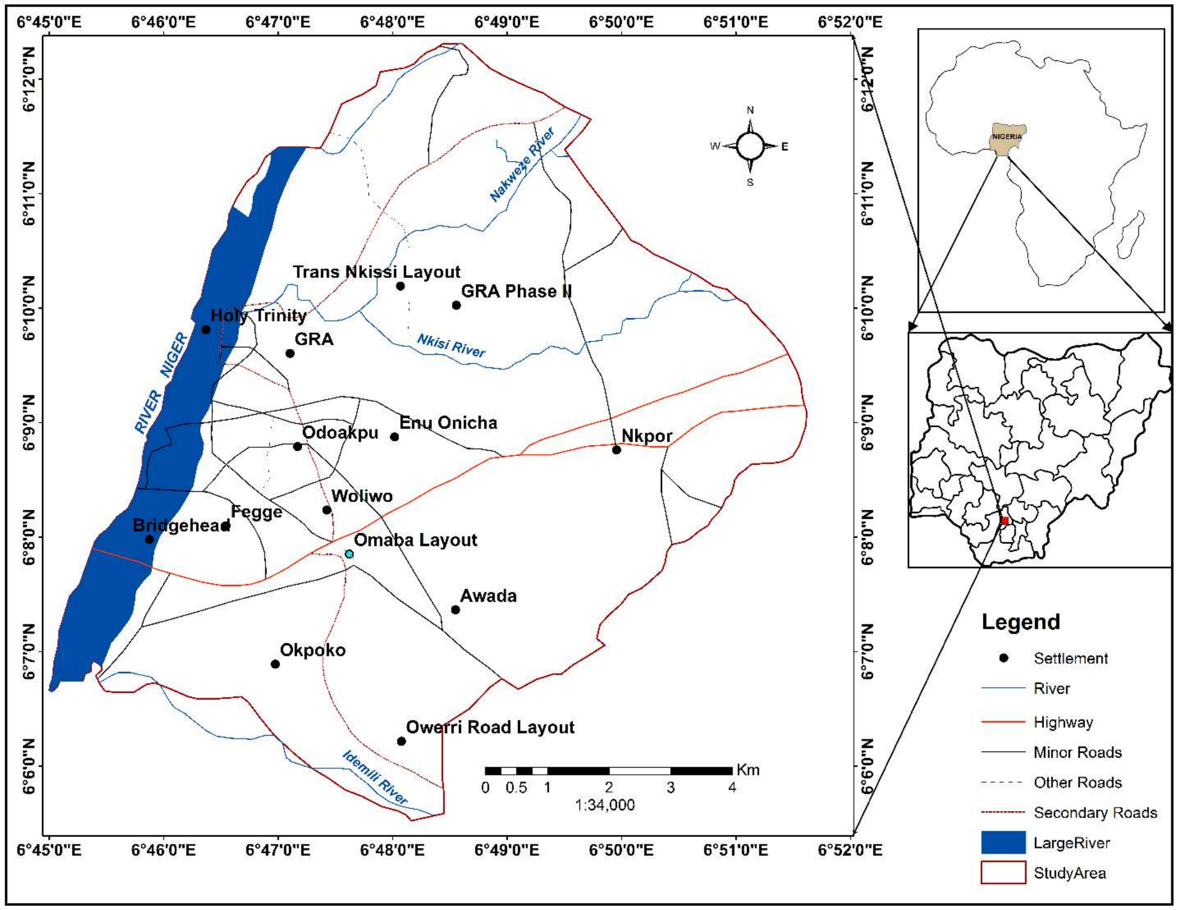

Figure 1: Location map of the study area

Geology of the study area

The study area lies within the Niger Delta Basin whose rocks range from Upper Cretaceous to Recent in age. Tectonic evolution of the Niger Delta basin is closely related to that of the Nigerian Benue Trough (Reyment, 1965). The two major geological formations that outcropped in the area are Ameki Group and Ogwashi-Asaba Formation (Figure 2). The Ameki Group is made up of the Ameki, Nanka and Nsugbe Formations which are lateral equivalents. The formation consists of a series of highly fossiliferous greyish-green sandy clay with calcareous concretions and white clayey sandstones (Kogbe, 1986), and may attain a thickness of about 1400 meters in some parts, yielded a Mid Eocene age for the basal part. Overlying the Ameki group is the Ogwashi-Asaba Formation which represents the last sedimentary deposit within the Anambra and Afikpo Synclines. It lies unconformably on the Ameki Group. The Ogwashi-Asaba Formation comprises of alternating coarse-grained sandstone, lignite seams, and light-coloured clays of continental origin (Kogbe, 1976).

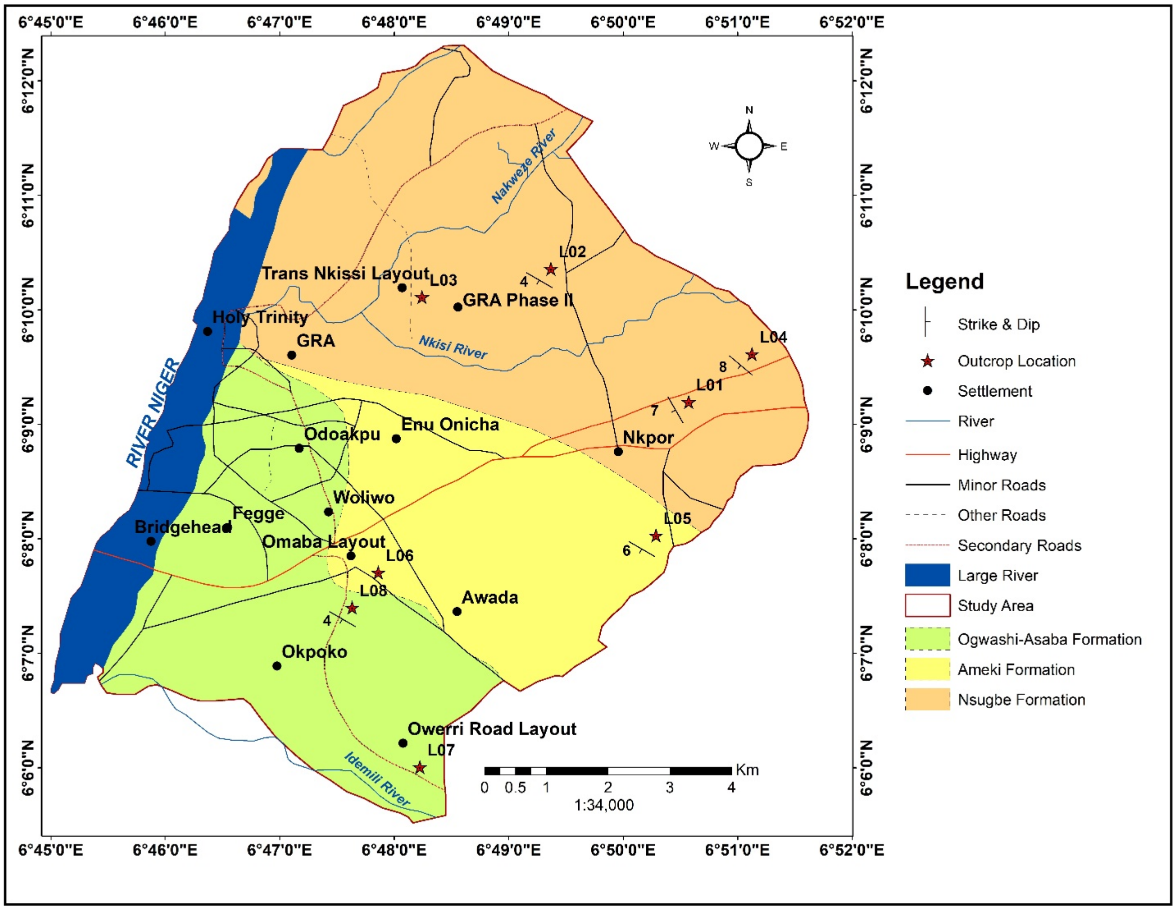

Figure 2: Geologic map of the study area

Soil and Plant Samples Collection and Analysis

A total of 47 top soil samples were randomly collected within a depth of 0-30cm using a round-pointed blade handheld scooping trowel from points within a sampling location and thoroughly mixed together to make up one representative sample from the sampling location. The samples were placed in a polyethylene bag, labelled appropriately and transported to the laboratory for treatment and analysis.

Consequently, eight (8) samples each of dominant plant species were collected from the study area. The plants samples collected were *Panicum maximum, Tamarix aphyda*, *Brachiaria decumbens, Vigna unguiculata, Minuaria verna, xanthium strumarium, Dodonea viscosa* and *Acacia modesta*. The soil in the root was carefully removed to retain the entire root and shoot of the plant for heavy metals analysis. The plant samples after uprooting were placed in a polyethylene bag. The plant samples were freeze-dried using the CHRIST Getriertrocknugsanlagen GmbH Freeze dryer at a temperature of 17°C with a vacuum mbar of 6.110, afterwards slowly ground with a stainless-steel grinder, filtered via a 40mesh stainless-steel sieve, and lastly kept in a clear container for the analysis of heavy metals. A duplicate 1.0g dry matter sample was digested sequentially at ambient temperature for 30 minutes utilizing a 20 ml solution containing concentrated H_2SO_4 and H_2O_2 of 37% in a 1:1 ratio, and finally processed at 350^{o}C utilizing a Kjeldahl digester. When the digest became apparent it was diluted using deionized water, then processed via an ashless Whatman 41 filter, and diluted to 100 ml using excessive distilled water before being stored in plastic containers at 4°C for heavy metals examination for Zn, Mn, Pb, Cd, As and Fe using an Skyray EDX3600B is a high-end energy dispersive XRF spectrometer (EDXRF).

Phytoremediation efficacy of the selected plant species in present research.

The bioaccumulation factor (BAF), enrichment factor (EF), and translocation factor (TF) were utilized for calculating the potential of the selected plant species for phytoremediation.

The Bioaccumulation Factor (BAF) was derived from the following equation:

$$BAF = \frac{Cr}{Cs} \quad (1)$$

Where, BAF is the bioaccumulation factor; Cr is the metal concentration in the root of the analyzed plant species and Cs is the metal concentration in the soil samples.

Using the equation below, the Enrichment factor (EF) is calculated as the metal's ratio of plant shoot concentration to polluted substrate or contaminated environmental medium concentration.

$$EF = \frac{Cps}{Cs} \quad (2)$$

Where, EF represent enrichment factor; Cps represent concentration of metal in plant shoot and Cs represent metal concentration in soil.

The translocation factor (TF) was calculated using the following relationship for heavy metals transfer from root to shoot in the examined plant species:

$$EF = \frac{Cps}{Cr} \quad (3)$$

Where, TF stand for Translocation Factor; Cs represents concentration of heavy metal in plant shoots, Cr is concentration of heavy metal in roots of the selected plant species.

Results and Discussion

Heavy metal concentrations in the water samples

The concentration of the heavy metals in the soil samples in Onitsha are presented in Tables (1). Generally, the results showed that the values of most of the heavy metals such (Zn, Mn, Pb, Cd, As and Fe) measured in the soil samples were all higher than the permissible limits as recommended by WHO/FAO (2001). It was found that the dumpsites, mechanic workshop and abattoir soils recorded highest concentration of metals than the industrial areas, markets, traffic, mining sites and motor park soils. Several studies have shown that high levels of toxic metals in soil has serious impact on the human health through food chain (Sakakibara et al., 2011). High level of these metals in the dumpsite soils may be attributed to the discharge of wastewater from domestic activities and hazardous waste of industrial activities into the dumpsites.

Table 1: Results of heavy metals analysis of the soil samples.

Sample ID	Zn (mg/kg)	Mn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	As (mg/kg)	Fe (mg/kg)
FG-AB-TS-1	20.2374	37.1125	20.0689	31.1125	33.2698	60.1996
FG-MW-TS-2	0.2814	0.4096	0.0693	0.4096	0.9984	13.4020
FG-TRF-TS-3	0.2640	0.1205	0.0342	0.1205	0.9356	11.4120

GRA2-AB-TS-4	68.4822	46.8089	10.0192	26.8089	43.3061	75.7971
GRA2-DS-TS-5	80.3073	11.7658	17.0632	10.7658	15.5353	55.5300
GRA2-MKT-TS-6	1.0064	1.6231	0.0297	1.6231	3.4845	11.8104
GRA2-MS-TS-7	0.2048	0.1095	0.0000	0.1095	1.1999	29.1412
GRA2-TRF-TS-8	0.2221	0.1187	0.0046	0.1187	0.5143	6.5134
GRA-DS-TS-9	20.3171	10.8034	19.0683	10.8034	44.7248	66.4805
GRA-TRF-TS-10	0.2700	0.1647	0.0517	0.1647	0.6540	7.4057
HB-DS-TS-11	41.1485	34.5482	13.4015	43.5482	52.1791	18.2464
HB-HB-TS-12	0.2822	0.7230	0.0439	0.7230	0.4484	6.9231
HB-IA-TS-13	0.2373	0.4051	0.0319	0.4051	6.8197	6.1498
HB-MP-TS-14	0.2367	0.3795	0.0488	0.3795	6.8991	9.1519
HB-MS-TS-15	0.1146	0.0604	0.0250	0.0604	3.6629	1.9738
HB-MW-TS-16	0.2823	0.5481	0.1632	0.5481	4.0188	9.7232
HB-TRF-TS-17	0.1836	0.1795	0.0241	0.1795	3.2285	4.1810
HF-MS-TS-18	0.2260	0.2634	0.0104	0.2634	2.5511	18.2390
HT-DS-TS-19	50.2647	10.1915	20.0534	27.1915	40.2467	67.6233
HT-MKT-TS-20	0.1409	0.0599	0.0077	0.0599	8.4415	9.2746
HT-MW-TS-21	0.2438	0.3731	0.0209	0.3731	4.1849	9.9852
HT-TRF-TS-22	0.2661	0.1489	0.0146	0.1489	0.6090	7.2432
NKISI-TS-23	0.2720	0.2645	0.0208	0.2645	2.2395	22.3249
NKP-MS-TS-24	0.1366	0.1266	0.0016	0.1266	7.4838	10.4247
NKP-MW-TS-25	0.2476	0.2522	0.0231	0.2522	0.6789	14.3915
NKP-TRF-TS-26	0.1529	0.0865	0.0189	0.0865	4.4866	10.3042
NKP-MP-TS-27	0.1422	0.2608	0.0273	0.2608	4.2583	6.6657
OD-DS-TS-28	50.1503	22.3279	10.0150	19.3279	33.3369	52.0552
OD-MV-TS-29	0.9937	1.7401	0.1646	1.7401	0.5290	20.8650
OK-AB-TS-30	57.7264	27.4963	30.0263	57.4963	30.1063	82.1105
OK-DS-TS-31	60.2824	39.3641	40.0549	26.3641	51.3428	66.3492
OK-IA-TS-32	8.9485	8.2178	0.4646	8.2178	12.9558	10.4633
OK-MW-TS-33	0.2717	0.4109	0.0898	0.4109	5.4823	26.6195
OR-DS-TS-34	20.1852	22.2519	30.0027	10.2519	36.6234	51.8895
OR-MW-TS-35	0.2658	0.3553	0.0432	0.3553	1.1039	5.3425
OR-TRF-TS-36	0.1602	0.1309	0.0012	0.1309	3.7292	2.2499
TN-DS-TS-37	79.2704	20.2866	41.0433	48.2866	60.7487	73.7022
TN-MW-TS-38	0.2776	0.4452	0.0478	0.4452	0.4492	12.8144
TN-TRF-TS-39	0.2643	0.3551	0.1549	9.3551	5.1896	7.3015
UW-DS-TS-40	33.1847	20.1526	12.0237	10.1526	3.7053	41.2622
UW-MP-TS-41	0.1328	0.1791	0.0027	0.1791	3.1577	4.4597

UW-TRF-TS-42	0.2785	0.2841	0.0700	0.2841	0.7300	8.7425
UW-MW-TS-43	0.2731	0.2515	0.0385	0.2515	0.7348	8.4110
WO-AB-TS-44	31.3292	15.8063	10.2592	15.8063	10.7622	46.5543
WO-DS-TS-45	20.2713	30.1860	16.0413	10.1860	13.6147	13.5637
WO-MKT-TS-46	0.5898	1.0910	0.1041	1.0910	0.7157	7.4648
WO-MW-TS-47	0.2496	0.2711	0.0309	0.2711	7.6526	11.1924
Minimum	**0.1146**	**0.0599**	**0.0000**	**0.0599**	**0.1063**	**1.9738**
Maximum	**80.3073**	**46.8089**	**41.0433**	**57.4963**	**60.7487**	**82.1105**
Average	**13.8569**	**8.0269**	**6.3259**	**8.2008**	**12.4364**	**24.1899**
WHO/FAO (2001)	**300**	**-**	**50**	**3**	**2**	**-**

Heavy metal concentrations in the plant samples

Table (2) generalizes the concentrations of the examined heavy metals of Zn, Mn, Pb, Cd, As and Fe in milligram per kilogram (mg/kg) in shoots and roots tissues of the *Brachiaria decumbens*, *Tamarix aphyda, Vigna unguiculata, Minuaria verna, xanthium strumarium, Dodonea viscosa, Acacia modesta,* and *Panicum maximum*. The results indicated that the concentration of these plant species varied from 20.2737 to 63.2833, 8.0111 to 23.0848, 10.3144 to 22.4647, 3.0689 to 15.0642, 9.0066 to 27.1266 and 13.1452 to 87.3138 across the study area. The uptake of heavy metals by the plant roots was lower than those in shoots (Table 2).

The results of present investigation showed that the extent of heavy metal concentrations varied in between the analyzed plant species, (root and shoot) and kinds of heavy metal, due to plant communities respond differently to heavy metal that present in dumpsite depending on their potentiality to absorb and detoxify different heavy metals (Ma et al., 2001). The results indicate that these plant species contained high Fe concentrations in both root and shoot. The high concentrations of Fe in the roots of plant formulate two hypotheses: (i) it may be due to higher absorption capacity of plant's roots, or (ii) it may be due to the presence of higher amounts of iron in the respective soil.

Table 2: Heavy metals concentration in roots and shoots of the plant species

Sample ID	Name of Plant	Factors	Zn (mg/kg)	Mn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	As (mg/kg)	Fe (mg/kg)
TN-DS-V1	*Brachiaria decumbens*	Shoot	60.1380	10.0103	20.1256	8.0613	27.1266	81.5906
		Root	43.4805	8.0111	15.8731	10.0445	20.0243	84.9617
TN-TRF-V2	*Tamarix aphyda*	Shoot	49.5472	19.1513	11.0555	5.0608	19.0765	33.8077
		Root	45.2675	19.0946	10.3144	3.0689	12.0809	31.7289
UKP-AB-V3	*Vigna unguiculata*	Shoot	40.5945	21.1479	14.1845	9.0706	26.0380	42.0420
		Root	40.6487	23.0848	14.0518	9.0613	26.0362	44.1753
UW-DS-V4	*Minuaria verna*	Shoot	51.7416	10.0656	15.3224	10.0656	10.0542	87.3138
		Root	39.2740	10.0057	20.5941	14.0371	9.0655	80.7610
GRA2-MS-V5	*xanthium strumarium*	Shoot	23.8697	13.0310	17.4214	13.0650	10.0121	29.1021
		Root	20.2737	9.0700	20.5149	7.0628	18.0989	29.1431
FG-TRF-V6	*Dodonea viscosa*	Shoot	50.3829	8.0485	10.7930	10.0810	15.0551	41.8561
		Root	61.1198	18.0108	12.0306	10.0787	17.0354	38.2433
FG-MW-V7	*Acacia modesta*	Shoot	63.2833	11.0242	18.7364	11.0651	10.0211	32.9557
		Root	60.2683	10.0849	20.4486	15.0642	9.0066	13.1452
OK-MW-V8	*Panicum maximum*	Shoot	47.2720	13.0019	22.4647	9.0464	10.0508	27.4733
		Root	45.2767	10.0237	20.3882	5.0511	10.0519	31.6846

Bioaccumulation Factor (BAF), Enrichment Factor (EF) and Translocation Factor (TF) in the examined plant species.

As revealed in Table (3), the BAF values for *Brachiaria decumbens*, *Tamarix aphyda, Vigna unguiculata, Minuaria verna, xanthium strumarium, Dodonea viscosa, Acacia modesta,* and *Panicum maximum* of the determined heavy metals of Zn, Mn, Pb, Cd, As and Fe were found to be in the ranges of 1.4630 to 4.4107, 0.9980 to 2.8759, 1.6305 to 3.2555, 0.3742 to 1.8369, 0.7242 to 2.0935 and 0.5434 to 3.5123 across the study area. The trend in the average values of BAF by these plant species were in the ascending order of Zn > Fe > Pb > Mn > As > Cd. Among the heavy metals, BAF value was found to be the highest for Zn by *Brachiaria decumbens* while the lowest BAF value was found for Cd in *Tamarix aphyda*.

Table (3) also showed that the enrichment factor (EF) values for the analyzed heavy metals by *Brachiaria decumbens*, *Tamarix aphyda, Vigna unguiculata, Minuaria verna, xanthium strumarium, Dodonea viscosa, Acacia modesta,* and *Panicum maximum* were observed to be in the ranges of Zn (1.7226 to 4.5669), Mn (1.0027 to 2.6346), Pb (1.7061 to 3.5512), Cd (0.6171 to 1.5931), As (0.8051 to 2.1812) and Fe (1.1357 to 3.6095) across the study area and in the ranking order of Zn > Fe > Pb > Mn > As > Cd. Moreover, the maximum values of EF was observed at (FG-MW-V7) *Acacia modesta*.

Onyia et al., (2020) reported that EF values greater than 1 indicate higher availability and distribution of metals in the contaminated environment, subsequently increasing the metal accumulation in plants species.

Table 3: Bioaccumulation Factor (BAF) and Enrichment Factor (EF) levels for the analyzed heavy metals in plant species

Sample ID	Name of Plant	FACTORS	BAF and EF values for the examined heavy metals					
			Zn (mg/kg)	Mn (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	As (mg/kg)	Fe (mg/kg)
TN-DS-V1	*Brachiaria decumbens*	BAF	3.1378	0.9980	2.5092	1.2248	1.6101	3.5123
		EF	4.3399	1.2471	3.1815	0.9829	2.1812	3.3729
TN-TRF-V2	*Tamarix aphyda*	BAF	3.2668	2.3788	1.6305	0.3742	0.9714	1.3117
		EF	3.5756	2.3859	1.7477	0.6171	1.5339	1.3976
UKP-AB-V3	*Vigna unguiculata*	BAF	2.9335	2.8759	2.2213	1.1049	2.0935	1.8262
		EF	2.9296	2.6346	2.2423	1.1061	2.0937	1.7379
UW-DS-V4	*Minuaria verna*	BAF	2.8343	1.2465	3.2555	1.7116	0.7289	3.3386
		EF	3.7339	1.2539	2.4222	1.2274	0.8084	3.6095
GRA2-MS-V5	*xanthium strumarium*	BAF	1.4630	1.1299	3.2430	0.8612	1.4553	1.2048
		EF	1.7226	1.6234	2.7539	1.5931	0.8051	1.2031
FG-TRF-V6	*Dodonea viscosa*	BAF	4.4107	2.2438	1.9018	1.2289	1.3698	1.5809
		EF	3.6359	1.0027	1.7061	1.2293	1.2106	1.7303
FG-MW-V7	*Acacia modesta*	BAF	4.3493	1.2564	3.2325	1.8369	0.7242	0.5434
		EF	4.5669	1.3734	2.9619	1.3493	0.8058	1.3623
OK-MW-V8	*Panicum maximum*	BAF	3.2674	1.2487	3.2229	0.6159	0.8083	1.3098
		EF	3.0506	1.6198	3.5512	1.1031	0.8082	1.1357

Present study showed that the values of translocation factor (TF) of *Brachiaria decumbens*, *Tamarix aphyda, Vigna unguiculata, Minuaria verna, xanthium strumarium, Dodonea viscosa, Acacia modesta,* and *Panicum maximum* for the examined heavy metals; Zn, Mn, Pb, Cd, As and Fe were ranged between 0.8243 to 1.3831, 0.4469 to 1.4367, 0.7440 to 1.2679, 0.7171 to 1.8498, 0.5532 to 1.5791 and 0.8671 to 2.5071 within the study area. Results indicated that TF was less than 1 by *Vigna unguiculata, Dodonea viscosa, Minuaria verna* and *Panicum maximum* for the entire metals analyzed at TN-DS-V, TN-TRF-V and OK-MW-V except Cd, As, Mn and Pb. This means the quantities of heavy metals absorbed in the roots tissues higher than those in the shoots tissues, meanwhile the subsequent rising order of the TF values for heavy metals was as follows; Fe > Mn > As > Pb > Zn > Cd.

Table 4: Translocation Factor (TF) values of the determined heavy metals in plant species

Sample ID	Name of Plant	Translocation Factor Values					
		Zn (mg/l)	Mn (mg/l)	Pb (mg/l)	Cd (mg/l)	As (mg/l)	Fe (mg/l)
TN-DS-V1	*Brachiaria decumbens*	1.3831	1.2496	1.2679	0.8026	1.3547	0.9603
TN-TRF-V2	*Tamarix aphyda*	1.0945	1.0029	1.0719	1.6491	1.5791	1.0655
UKP-AB-V3	*Vigna unguiculata*	0.9987	0.9161	1.0094	1.0010	1.0000	0.9517
UW-DS-V4	*Minuaria verna*	1.3175	1.0059	0.7440	0.7171	1.1091	1.0811
GRA2-MS-V5	*xanthium strumarium*	1.1774	1.4367	0.8492	1.8498	0.5532	0.9986
FG-TRF-V6	*Dodonea viscosa*	0.8243	0.4469	0.8971	1.0002	0.8838	1.0945
FG-MW-V7	*Acacia modesta*	1.0500	1.0931	0.9163	0.7345	1.1126	2.5071
OK-MW-V8	*Panicum maximum*	1.0441	1.2971	1.1018	1.7909	0.9999	0.8671

CONCLUSION

The present study showed that plants grown in dumpsite, mechanic workshops and abattoir environments have a high risk of having heavy metal concentrations beyond the permissible limit as compared to the industrial areas, markets, traffic, mining sites and motor park soils. In addition to that, this study indicated that among all the plant species analyzed, *Acacia modesta* and *Minuaria verna* tend to absorb, translocate and accumulate heavy metals in their root and shoot tissues more than *Brachiaria decumbens*, *Tamarix aphyda, Vigna unguiculata, xanthium strumarium, Dodonea viscosa,* and *Panicum maximum*.

Although no control plant from the examined species has been found for comparison test, the present study concluded that the analyzed plants can be regarded as accumulators or hyperaccumulators for phytoremediation, since a suitable plant species is one of the most important factors which can be used to uptake the heavy metals from the environment. Finally, it is recommended that additional research should be conducted in the study area to determine the biotic potential of the analyzed plant species for phytoremediation of other heavy metals.

References

Badr, N., Fawzy M., and Al-Qahtani, K. M. (2012). Phytoremediation: An Ecological Solution to Heavy-Metal-Polluted Soil and Evaluation of Plant Removal Ability. World Applied Sciences Journal 16 (9): 1292-1301.

Burkhard, L. P., Arnot, J. A., Embry, M. R., Farley, K. J., Hoke, R. A., Kitano, M., Leslie, H. A., Lotufo, G. R., Parkerton, T. F., Sappington, K. G., Tomy, G. T. and Woodburn, K. B. (2011). Comparing Laboratory and Field Measured Bioaccumulation Endpoints. SETAC. Integrated Environmental Assessment and Management. V. 8(1), pp 17-31.

Branquinho, C., Serrano, H. C., Pinto, M. J. and Martins-Loucao, M. A. (2007). Revisiting the plant hyperaccumulation criteria to rare plants and earth abundant elements. Environmental Pollution, V. 146, Issue 2, pp 437–443.

Brisebois, A. R. (2013). Relationship between the Bioconcentration Factor (BCF), the Bioaccumulation Factor (BAF), and the Trophic Magnification Factor (TMF). Project Submitted in Partial Fulfillment of the

Requirements for the Degree of Master of Resource and Environmental Management Report No. 576 in the School of Resource and Environmental Management Faculty of the Environment. Simon Fraser University. Canada.

Garnier, B.J., (1967). Weather condition in Nigeria. Climatological Research Series, No. 2 McGill University, Montreal, Canada. 66p.

Greipsson, S. (2011). Phytoremediation. *Nature Education Knowledge*, *2*, 7.

Kogbe, C.A., (1976). Paleogeographic history of Nigeria from Albian times. In Kogbe, C.A. (ed). Geology of Nigeria. Elizabethan Publishers, Lagos, pp. 237-252.

Kogbe, C.A., (1986). The cretaceous and Paleogene sediments of southern Nigeria. In Kogbe, C.A. (ed). Geology of Nigeria. 2nd Edition. *Rockview Nigeria Limited, Jos,* 286p.

Lasta, M. M., Pence, N. S., Garvin, D. F., Ebbs, S. D., & Kochina, L. V. (2000). Molecular physiology of zinc transport in the Zn hyperaccumulator Thlaspi caerulescens. *Journal of Experimental Botany*, *51*(342).

Onyia, P.C., Ozoko, D.C., & Ifediegwu, S.I. (2020): Phytoremediation of arsenic-contaminated soils by arsenic hyperaccumulating plants in selected areas of Enugu State, Southeastern, Nigeria, *Geology, Ecology, and Landscapes,* DOI: 10.1080/24749508.2020.1809058

Ma, L. Q., Komar, K. M., Tu, C., Zhang, W., Cai, Y. and Kennelley, E. D. (2001). A fern that hyperaccumulates arsenic. *Nature, 409:* 579-579.

Padmavathiamma, P. K., & Li, L. Y. (2007). Phytoremediation technology: Hyperaccumulation metals in plants. *Water, Air, and Soil Pollution*, *184*(1–4), 105–126. https://doi.org/10.1007/s11270-007-9401-5

Rafati, M., Khorasani, N., Moattar, F., Shirvany, A., Moraghebi, F., & Hosseinzadeh, S. (2011). Phytoremediation potential of Populus alba and Morus alba for cadmium, chromuim and nickel absorption from polluted soil. *International Journal of Environmental Research*, *5*, 961–970.

Reyment, R. A. (1965). *Aspects of the geology of Nigeria*. University of Ibadan.

Sakakibara, M., Ohmori, Y., Ha, N.T.H., Sano, S., Sera, K. (2011). Phytoremediation of heavy metal contaminated water and sediment by Eleocharis acicularis. Clean: Soil, Air, Water 39, 735–741

Sutherland, R.A., Tolosa,C. A., Tack, F. M. G. and Verloo, M. G. (2000). Characterization of selected element concentration and enrichment ratios in background and anthropogenically impacted roadside areas, Archives of Environmental Contamination and Toxicology, 38, 428–438.

WHO/FAO. (2001). *Codex alimentarius commission. Food additives and contaminants. Joint FAO/WHO Food Standards Programme, ALINORM 10/12A*. Retrieved from www.transpaktrading.com/static/pdf/research/achemistry/introTofertilizers.pdf