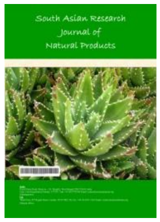

South Asian Research Journal of Natural Products

3(3): 26-36, 2020; Article no.SARJNP.60289

Assessment of Physicochemical Characteristics and Heavy Metal Concentration in Soils and Plants in Selected Refuse Dumpsites within Nkwerre L.G.A., of Imo State, Southeast Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Authors JEE, AJN and NOM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ISK and OJK managed the analyses of the study. Authors UKC and ADC managed the literature searches. All authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Elmarie Van Der Watt, University of the Free State, South Africa.
(2) Dr. Prasong Srihanam, Mahasarakham University, Thailand.
(3) Dr. Nargis Jamila, Shaheed Benazir Bhutto Women University, Pakistan.
Reviewers:
(1) Rohan Rajnikant Vakhariya, Shivaji University, India.
(2) Raj Narayan Roy, Dr. Bhupendra Nath Dutta Smriti Mahavidyalaya, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/60289

Original Research Article

Received 05 July 2020
Accepted 10 September 2020
Published 02 October 2020

ABSTRACT

Environmental contamination by heavy metals as a result of unregulated disposal of wastes is a serious challenge all over the world. Early detection and remediation of heavy metals in soil and plants will ameliorate serious potential threats posed to human health and other components of the ecosystem. This study was conducted to evaluate the physicochemical characteristics and selected heavy metal concentration in soils and edible plant at three different refuse dumpsites in Nkwerre Local Government Area of Imo State and compared with the permissible limits specified

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by WHO/FAO standards. Soil samples were collected from a depth of 0 – 20 cm using a soil auger while plant samples were collected from same source as the soil. Samples were collected from an area with no history of dumpsites which served as control. Standard analytical procedures were used for physicochemical parameters while Atomic Absorption Spectrophotometer (AAS) was used for the heavy metals analysis. Results showed significant ($p>0.05$) higher changes in the soil physicochemical properties relative to the control. Mean heavy metal concentration in soil from site A were: 239.158±26.57 (Fe); 0.080±0.008 (Cd); 0.012±0.001 (Ni); 1.040±0.12 (Mn); 0.899±0.10 (Pb); and 14.123±1.57 (Zn); site B were: 24.854±2.76 (Fe); 0.069±0.008 (Cd); 0.056±0.006 (Ni); 1.163±0.13 (Mn); 0.133±0.02 (Pb); and 16.004±1.78 (Zn) while that of site C were: 15.536±1.73 (Fe); 0.069±0.09 (Cd); 0.333±0.04 (Mn); 0.767±0.09 (Pb); 3.097±0.34 (Zn). The values of all the metals analyzed for samples from dumpsites were higher than those from the control but were below values recommended by the WHO/FAO except for Fe and Zn in some sites. *Talinum triangulare* showed bioaccumulation factor (BF) and transfer factor (TF) greater than 1 for Fe, Cd, Mn, Pb, and Zn indicating that the plant can be effectively used for phytoremediation. A strong positive correlation was observed for all the metals studied, Fe (r = 0.981), Cd (r = 0.720), Ni (r = 0.823), As (r =0.945), Mn (r = 0.830), Pb (r = 0.832) and Zn (r = 0.913) implying that the metal level in the refuse dumpsite soil is the major factor responsible for the heavy metal contents in the plant species studied. Regular monitoring of heavy metals in refuse dumpsite soil is recommended to forestall excessive accrual in the food chain.

Keywords: Physicochemical; heavy metal; soils; Talinum triangulare; dumpsites; Nkwerre.

1. INTRODUCTION

Environmental pollution occasioned by anthropogenic activities is a serious issue all over the world [1]. For many people, the way to dispose of waste is to simply drop it someplace. Indiscriminate disposal of waste materials is a common practice among the low-income and upper middle-income earners in many developing countries such as Nigeria [2]. The root cause of these environmental issues have been attributed to be rapid pace of urbanization, land use changes, and industrialization [3,4,5]. In most cities in Nigeria, it is common to find flagrant citation of huge refuse dumpsite within market places, cities and residential areas [6]. Conventionally, dumpsites are known to be rich in soil nutrients for plant growth and development because it is believed that the decayed and composted wastes enhance soil fertility [7]. This justifies the reason why most resource poor farmers use the soils to fill poly-bags and nursery pots to grow seedlings [8]. This practice is scientifically unacceptable in this era and as such, there is need for proper assessment of dumpsite waste soils to ensure environmental safety and sustainability. These wastes often contain heavy metals in various forms and at different contamination levels some of which are particularly hazardous to plants, animals and humans [9]. One of the major challenges associated with indiscriminate disposal and burning or decay of certain wastes is that they produce substances that contain toxic metals known as heavy metals [10]. Heavy metals are classified as metals which occur naturally in the earth crust and exhibit specific gravity more than 5 gcm^{-1} [11]. Such metals include lead (Pb), mercury (Hg), arsenic (As), cadmium (Cd), chromium (Cr), and higher levels of micronutrient (e.g. iron (Fe), copper (Cu), nickel (Ni) and zinc (Zn)). Their high presence in the environment arises from anthropogenic activities including mining, painting, batteries, municipal waste, metal scraps, motor oil and the application of pesticides, herbicides and fertilizers [12]. The presence of such metals in the ecosystem is of major concern due to its high relative toxicity at certain levels and non-degradability in the environment [13]. Waste dumpsite is considered as one of the major sources of heavy metals pollution in the environment [14].

Plants grown in some dumpsites of Nigeria have been reported to contain higher levels of metals [15,16]. Plants grown on a land polluted with municipal, domestic or a land polluted with municipal, domestic or industrial wastes can absorb heavy metals in form of mobile ions present in the soil through their roots or through foliar absorption [17]. These absorbed metals eventually gets bioacumulated in the roots, stems, fruits, grains and leaves of plants [18] which could cause various ailments including deaths in humans and animals through consumption [19].

It has been reported that heavy metals and anions in dumpsites leachates can cause chromosomal disorder and inhabitants in the vicinity of landfill sites are prone to mutagenic effects [20]. The level of contamination arising from percolation of leachates is determined by a number of factors that include the physico-chemical properties of the leachates and soil and the hydrological condition of the surrounding site. The presence of heavy metals in the environment is of great ecological significance due to their toxicity at certain concentrations, translocation through food chains and non-biodegradability which is responsible for their accumulation in the biosphere [21]. Heavy metal toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. Exposure to heavy metals may cause blood, bone disorders, kidney damage, decreased mental capacity and neurological damage [22,23]. Toxicity sets in when the heavy metal content in the soil exceeds natural background level [24]. This may cause ecological destruction and deterioration of environmental quality, influence yield, quality of crops as well as atmosphere, and health of animal through food chains.

Therefore, knowledge of the level of heavy metals would educate the general public about the potential environmental risks associated with the use of refuse dumpsite soil for arable farming and consumption of plants growing around solid waste dumpsites with respect to heavy metal toxicity. Thus, the present study was aimed at evaluating the physicochemical characteristics and Heavy metal contents of soil and edible plants from selected dumpsites in Nkwerre L.G.A., Imo State Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Nkwerre Local Government Area of Imo State located within Imo Sedimentary basin of South-eastern Nigeria. It lies within latitudes $5°15^1$ and $7°15^1$ North and longitudes $6°50^1$ and $7°25^1$ East [25] and covers an area of about 38 Km^2 [26] with a population figure of about 2, 35273 as at 2006 National Population census figure. Rainfall distribution is bimodal, with peaks in July and September and a two-week break in August. There are two main climate regimes: A dry season and a wet season. The rainy season begins in April and lasts till October or early November. Annual rainfall ranges from 1500 to 2200 mm per year. However, variations occur in rainfall amount from year to year. Temperatures are high and similar all over the state. The hottest months are January to March, with the mean annual temperatures above 20°c. The mean daily maximum air temperatures range from 28°C to 35°C, while the mean daily minimum air temperature ranges from 19°C to 24°C. There are three major markets that has existed for decades viz., Eke Eziachi, Nkwoji and Nkwommiri markets respectively. Activities in these markets generate wastes of various kinds.

2.2 Method of Sample Collection

At each of the dumpsite and control, a study site of 10 × 20 m was measured with a measuring tape, demarcated with wooden pegs and rope. A systematic sampling approach comprising three line-transects of 5 m intervals was used. Within each of the line transects, three samples of the top soil were taken along each of the transect lines following the method of Tanee and Eshalomi-Mario, [27]. The soil samples were collected at each plot using improvised soil auger at a depth of 0-20 cm. Plants were sampled at the same locations as the soil samples at 20 cm depth rooting zone and mixed to form composite samples at each location after which they were transported to the laboratory for analysis. The choice of plant species collected was based on species dominance and availability at the point of sample collection.

2.3 Sample Pretreatment

The collected dried soil samples were thoroughly mixed in clean plastic bucket to obtain a composite sample, crushed and sieved with 2 mm mesh before stored in labeled polythene bags prior to analysis. Plant samples collected from the field were washed under running tap water to remove adhered soils, and were then sorted into parts including roots and shoots. The samples were dried in an oven for 48 h at 80°C. The dried samples were ground using agate mortar and pestle, sieved to < 2 mm and transferred to polyethylene bags for storage until later analysis.

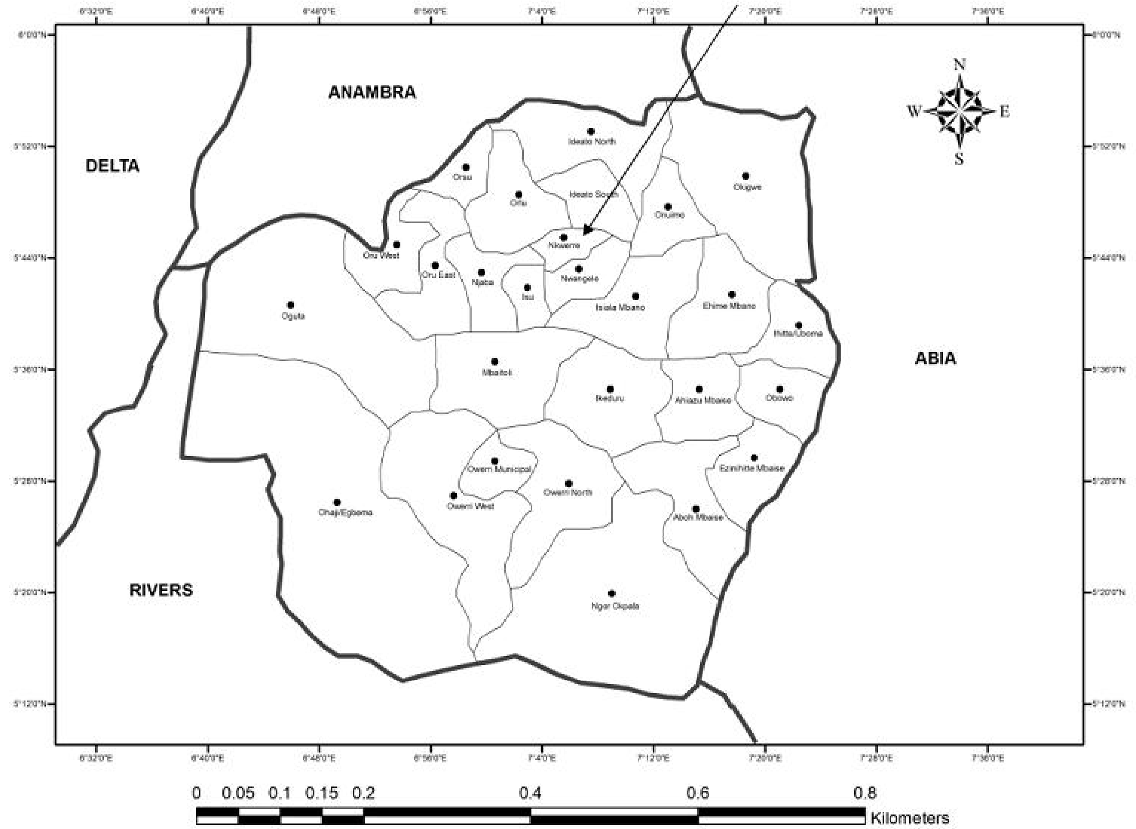

Fig. 1. Map of Imo State showing Nkwerre L.G.A., Imo State

2.4 Method of Soil Analysis

One gram of soil sample previously air dried, cleaned, gently crushed using an agate mortar and pestle and sieved through a standard sieve of 2 mm mesh size was weighed and digested with aqua-regia. The mixture was heated slowly in a fume-hood at a temperature between 50-60°C for 30 minutes. The resulting mixture was filtered into a cleaned plastic container using Whatman filter paper and make up to 50 mL with double-distilled water and stored for instrumental analysis. The physicochemical characteristics of the soil samples were determined according to the Association of Official Analytical Chemist's standard methods AOAC, [28].

2.5 Metal Analysis of Plant Samples

The harvested plant (*Talinium triangulare*) were separated into roots and shoots and analyzed separately for heavy metal content. 1 g of < 2 mm fraction plant samples was weighed into porcelain crucibles and was ignited in a muffle furnace for 6 h at a temperature between 450 - 500°C. Grey white ash was obtained at the completion of the ashing. The ash samples were allowed to cool and then 10 mL of 2 M HNO_3 was added to each sample. The solution was evaporated to near dryness on a hot plate and the cooled residues were re-dissolved in 10 mL 2 M HNO_3. The solutions were then filtered into 25 mL volumetric flasks. Both the crucible and the filter paper were washed into the flasks, made up with deionized water and then stored in polyethylene tubes for instrumental analysis. Atomic Absorption spectrophotometer (Perkin-Elmer Analyst 2000) was used to analyze soil and plant digests for As, Mn, Co, Pb, Zn and Ni. The instrument setting and operational conditions were done in accordance with the manufacturers' specifications.

The bioaccumulation factor (BF) and the transfer factor (TF) were calculated to determine the degree of metal bioaccumulation and translocation in the sampled plant species growing at the refuse dumpsite using the following formula:

$$BF = \frac{\text{Concentration of metal in plant}}{\text{Concentration of metal in soil}} \quad (1)$$

$$TF = \frac{\text{Concentration of metal in plant shoot}}{\text{Concentration of metal in plant root}} \quad (2)$$

2.6 Data Analysis

All data obtained were presented as mean and standard deviation and compared with the national guideline limits set by the World Health Organization (WHO. Pearson' correlation coefficient (r) was calculated between metal levels in soil and plant samples for individual metals.

3. RESULTS AND DISCUSSION

The result from the physicochemical analysis of the dumpsite composite samples is presented in Table 1. The mean pH across the sampled sites ranged between 7.20 to 7.26 with the control having 7.43. This shows that the pH of the sampled sites was slightly alkaline in nature. Similar pH range values had been reported by [29] and [30]. The higher pH level in the dump sites than their controls has been reported to be as a result of liming materials and also the activities of some microorganism on the solid wastes [30].

The significance of this pH imbalance is that it can inhibit or completely wipe out all biological processes that may be necessary for the natural treatment of the abandoned site thereby resulting in incomplete natural treatment and consequent pollution of the surrounding environment. Also, from the pH value it could be inferred that complex varieties of inorganic soluble substances are still components of the dumpsite and are still active these components are easily leached resulting in the alkaline condition of the leachates [31].

The electrical conductivity of the refuse waste soils ranged from 200 – 600 mS cm^{-1}. The relatively high conductivity value of the waste soil may be associated with the presence of metal scraps which is one of the constituents of refuse dumpsite and this implicates that there are more soluble salts in the soil [32,33]. The values of percentage organic carbon (O.C) ranged between 18.561 to 24.200. The values of organic carbon within the waste dump may be as a result of burning of solid wastes at the dumpsites [34].

The total nitrogen in the refuse waste soils ranged from 1.127 to 2.070 while the least was observed in control (0.680). The percentage nitrogen of dumpsite B, C and E with that of the control were significantly different at $p \leq 0.05$.The high concentration of these parameters may be attributed to have contributed to the good growth of plants observed in these sites which implicates that the soils would support plant species diversity and growth [35,36].

There was no significant difference in the concentration of phosphorous from all the dumpsites except the control with mean value of 24.769. The total phosphorous concentration at dumpsites B, C and D are 7.350, 7.301 and 7.274 respectively. According to [37], phosphorus-rich soils are washed into lakes, where some of the phosphorus dissolves and stimulates growth of phytoplankton and aquatic plants.

There was no significant difference in Ca^{2+} concentration of site B and D. The highest value of Ca^{2+} was from dumpsite C (14.420 ± cmol kg-1) while the least value was from dumpsite C 12.311±0.01 cmol kg^{-1} and the control was 1.780±0.03 cmol kg^{-1}. This is in line with [38] who reported higher Ca^{2+} concentration 10.27-11.77 cmol kg^{-1} for soils at a landfill in Nigeria. The concentration of potassium (K) was highest at dumpsite B (1.829 ± 0.092 cmol kg^{-1}) and least at dumpsite C (1.011 ± 0.045 cmol kg^{-1}) while the control was (0.691 ± 0.01 cmol kg^{-1}). There was no significant difference in the potassium concentration across the dumpsites A, B, and C except the control. The obtained values for K were lower than 0.92-1.21 cmol kg^{-1} reported by [38].

Magnesium concentration differs significantly at all the dumpsites at $p < 0.05$. The dumpsite with the highest Mg^{2+} concentration was dumpsite B (0.910±0.05 cmol kg^{-1}) and the least was from dumpsite C (0.121±0.01 cmol kg^{-1}) while the control was 0.289±0.03 cmol kg^{-1}. There was higher Mg^{2+} concentration in dumpsites than the control. However, the magnesium concentration in this study was lower across the dumpsites than 4.97-6.23 cmol kg^{-1} reported by [38] for landfill soils in Nigeria. Magnesium is the central core of the chlorophyll molecule in plant tissues.

Table 1. Mean and standard deviation values of chemical and physical properties constituent of soils at control and three market dumpsites

Samples		pH	E.C	Organic carbon	Total nitrogen	Aval. phosphorous	Ca	K	Mg	Na	Total hardness	Chloride	Sulphate
A	Mean	7.43^{a}	600.00^{a}	7.561^{d}	0.680^{c}	24.769^{a}	1.780^{c}	0.691^{b}	0.289^{c}	0.320^{a}	0.596^{c}	576000.00^{a}	0.476^{c}
	Std. Deviation	0.115	36.354	0.140	0.142	2.076	0.071	0.063	0.041	0.052	0.059	36642.34	0.055
B	Mean	7.20^{a}	200.00^{b}	24.200^{a}	2.070^{a}	7.350^{b}	14.420^{a}	1.829^{a}	0.910^{a}	0.410^{a}	4.856^{a}	450000.00^{c}	4.511^{a}
	Std. Deviation	0.112	18.961	2.035	0.091	0.114	1.521	0.092	0.084	0.067	0.101	1236.12	0.100
C	Mean	7.26^{a}	200.00^{b}	18.516^{c}	1.127^{b}	7.301^{b}	12.311^{b}	1.011^{a}	0.121^{b}	0.401^{a}	2.578^{b}	523000.00^{b}	1.126^{b}
	Std. Deviation	0.102	18.961	2.014	0.016	0.114	1.254	0.045	0.0261	0.063	0.069	33456.220	0.097
D	Mean	7.23^{a}	200.00^{b}	22.116^{b}	2.021^{a}	7.274^{b}	14.312^{a}	1.761^{a}	0.879^{a}	0.408^{a}	4.842^{a}	45000.00^{c}	4.511^{a}
	Std. Deviation	0.113	18.961	2.027	0.052	0.113	1.500	0.074	0.067	0.036	0.101	1236.124	0.100

Values are mean and standard deviation of triplicates. Means along the column having the same superscript of letter are not significant (≤ 0.05).
A = Control, B = Eke Eziachi market dumpsite, C = Nkwoji market dumpsite, D = Nkwommiri market dumpsite

Thus, if Mg is deficient in soil, the shortage of chlorophyll results in poor and stunted growth of plants. Magnesium also helps to activate specific enzyme systems. Magnesium is abundant in the earth's crust and is found in many forms [38].

There was no significant difference in the sodium concentration for all the dumpsites and the control at 0.05 probability level. The highest value of sodium concentration was in dumpsite B (0.410 ± 0.067 cmol kg^{-1}) while the lowest value was from dumpsite the control (0.320±0.052 cmol kg^{-1}). The sodium ion concentration of the dumpsite C was 0.401 ±0.063 cmol kg^{-1} while that of dumpsite D was 0.408±0.036.

There was a significant difference among total hardness, chlorides and sulphate at 0.05 probability level. The presence of high value of pH, chloride and iron concentration in the soil samples suggest that the soil samples might have been contaminated by leachate migration from open dumping site. Chloride in reasonable concentration is not harmful, but it causes corrosion in concentrations above 250 mg/L, while at about 400 mg/L, it causes a salty taste in water. An excess of chloride in water is usually taken as an index of pollution and considered as tracer for groundwater contamination [39].

Though chloride does not react chemically with species in water and harmless at relatively low concentration, the higher level observed for the dumpsite leachates is an indication of excess salinity and mineral pollution being active in the dumpsite. The mean values for sulphate for site A is 0.476±0.055, site B 4.511±0.100 and site C 1.126±0.097, when compared to the control with 0.476±0.055 mg/L in the dumpsite leachates these values are lower than the control values and also below the value reported by [39].

Table 2a shows the mean values of heavy metal in dumpsite leachate in Soil and *Talinum triangulare* (in mg/kg).

The heavy metal concentration in soil and plant parts is presented in Table 2a. The mean concentrations (mg/kg) of heavy metals in soil from the three dumpsites are Fe (239.158±26.57; 24.854±2.76; 15.536±1.73), Cd (0.080±0.008; 0.069±0.008; 0.069±0.09), Co (0.012±0.001; 0.056±0.006; exceeding control values. The table also shows that there is an appreciable level of metal bioaccumulation in the test roots and shoot system. Iron and Zinc are the most absorbed metals with 27.342±3.04, 24.854±2.76, 15.536±1.73 for Iron in the shoot and 4.190±0.47, 1.158±0.13, 2.036±0.23 for Zinc in the shoot. Similar trend also followed in root with Fe 26.921±2.99 22.474±2.50, 11.658±1.30 and Zn 4.495±0.50, 1.480±0.76, 2.203±0.24 all exceeding the control values respectively. Similar result had been reported by [30] in Port Harcourt area of Nigeria (Table 2b). It was observed that the values obtained for concentrations for heavy metals (except for Fe, Cr and Cd in certain instances) in plant parts (shoot and roots) for sample and control site are well within the permissible limits specified by WHO standards as shown in Table 2b indicating that the site did not show a considerable pollution with respect to the metals analyzed.

Heavy metals may have harmful effects on soil, crops and human health [12]. The results showed that the concentration of heavy metals in the soil increased at the dumpsites than the control sites for all the metals implying that the solid waste deposited at the site had a high amount of substances containing heavy metals. This is in agreement with [10]) who reported that the levels of Pb at dumpsites were higher than the levels at the control samples. High level of Pb can cause inhibition of enzyme activities, water imbalance, alterations in membrane permeability and disturbs mineral nutrition [29].

The bioaccumulation factor (BF) and the Transfer factor (TF) for the heavy metal up-take in the plant tissues is presented in Table 3. The results showed that the BF and TF for Fe (4.18, 1.85), Mn (2.52, 1.51), Pb (1.83, 1.33), Cd (1.77, 1.56) and Zn (2.53, 1.92) were observed to be greater than 1. This indicates that the plant roots are able to solubilize and take up the metals from very low levels in the soil, even from nearly insoluble precipitates [29]. The TF is an essential indicator that allows the assessment of mobility of heavy metals in plants [15]. This finding suggests that *Talinum triangulare* plant can be used as a bioaccumulator of Fe, Zn, Cd, Mn and Pb and indicates that it can function as hyperaccumulator for the metals [33].These findings agreed with study carried out by [33,23] and [39]. When transfer factor is less than one, it may be a probability that soil is the main source of metal bioaccumulation in plants. However, it is more revealing that, when the value is higher than one, the total concentrations of metals in soil do not necessary correspond to the metal bioavailability in plants [29].

Table 2a. Heavy metal contents in soil of the various dumpsites sampled

	Dumpsites			
Properties	**Control**	**Eke Eziachi market**	**Nkwoji market**	**Nkwommiri market**
Fe	13.7762^{aC}±1.38	239.158^{aA}±26.57	24.854^{aB}±2.76	15.536^{aC}±1.73
Cd	ND	0.080^{hA}±0.008	0.069^{gB}±0.008	0.069^{fB}±0.09
Cu	ND	0.012^{hB}±0.001	0.056^{gA}±0.006	ND
As	ND	ND	ND	ND
Mn	0.157^{gC}±0.02	1.040^{eB}±0.12	1.163^{eA}±0.13	0.333^{eC}±0.04
Pb	ND	0.899^{fA}±0.10	0.133^{fB}±0.02	0.767^{eA}±0.09
Zn	2.968^{dB}±0.29	14.123^{cA}±1.57	16.004^{cA}±1.78	3.097^{dB}±0.34

Mean having the same small letters along the column are not significantly different, and mean having the same capital letters along the row are not significantly different. ND = Not detected

Table 2b. Heavy metal concentration in plant parts (shoot and root) of the various dumpsites sampled

	Dumpsites			
Properties	**Control**	**Eke Eziachi market**	**Nkwoji market**	**Nkwommiri market**
Shoot				
Fe	7.686^{cD}±0.77	27.342^{bA}±3.04	24.854^{gB}±2.76	15.536^{aC}±1.73
Cd	ND	0.038^{gA}±0.004	ND	0.06^{fB}±0.007
Cu	ND	0.142^{fA}±0.02	0.053^{gB}±0.006	0.020^{fC}±0.002
As	ND	ND	ND	ND
Mn	0.028^{hC}±0.003	0.543^{fA}±0.06	0.055^{gB}±0.006	0.049^{fB}±0.005
Pb	ND	0.128fA±0.01	ND	0.036^{fB}±0.004
Zn	1.034^{fD}±0.10	4.190^{dA}±0.47	1.158^{eC}±0.13	2.036^{dB}±0.23
Root				
Fe	9.367^{bD}±1.23	26.921^{bA}±2.99	22.474^{bB}±2.50	11.658^{bC}±1.30
Cd	ND	0.067^{dA}±0.07	0.015^{gB}± 0.002	0.016^{fB}±0.002
Cu	ND	0.029^{gA}±0.003	0.024^{gA}±0.003	ND
As	ND	ND	ND	ND
Mn	0.107^{gC}±0.01	0.402^{fB}±0.05	0.037^{gD}±0.004	0.668^{fA}±0.07
Pb	ND	0.348^{fA}±0.04	ND	0.268^{fB}±0.03
Zn	1.789^{eC}±0.20	4.495^{dA}±0.50	1.480^{dC}±0.76	2.203^{cB}±0.24

Mean having the same small letters along the column are not significantly different, and mean having the same capital letters along the row are not significantly different. ND = Not detected

Table 3. Bioconcentration Factor (BCF) and Transfer factor (TF) of the vegetable samples relative to their soil sources

Location	**Metals**						
	Fe	**Cd**	**Cu**	**As**	**Mn**	**Pb**	**Zn**
BCF							
Site A	4.18	1.77	0.20	ND	2.52	ND	2.53
Site B	3.21	ND	0.12	ND	0.42	1.83	ND
Site C	3.31	0.89	ND	0.81	0.51	ND	3.61
CONTROL	**0.51**	**ND**	**ND**	**ND**	**0.41**	**ND**	**0.41**
TF							
Site A	1.85	1.567	0.233	ND	1.512	1.33	1.92
Site B	0.15	0.05	0.451	0.40	0.21	0.06	0.81
Site C	0.32	1.66	0.01	ND	0.31	0.03	0.11
CONTROL	**0.40**	**ND**	**ND**	**ND**	**0.03**	**ND**	**0.09**

ND = Not Detected; BCF = Bioconcentration Factor; TF = Transfer Factor
Site A = Eke Eziachi Market; Site B = Nkwoji Market; Site C = Nkwommiri Market

Table 4. Pearson's Correlation Coefficient (R) for metal levels between soil and plant

	Metals						
	Fe	Cd	Cu	As	Mn	Pb	Zn
Soil-to-plant r values	0.981	0.720	0.823	0.945	0.830	0.704	0.913

Results of coefficient of correlation (r) values between the heavy metal contents in soil and plant from Pearson's correlation coefficient is presented in Table 4. It was observed that a strong positive correlation exist for all the metals studied, Fe (r = 0.981), Cd (r = 0.720), Cu (r = 0.823), As (r =0.945), Mn (r = 0.830), Pb (r = 0.832) and Zn (r = 0.913), was observed. This implies that the metal level in the refuse dumpsite soil is the major factor responsible for the heavy metal contents in the plants species studied. This findings agrees with that of [40], [41] who carried out a similar research in the Northern part of Nigeria.

Generally, the concentrations of heavy metals in the plant and soil samples across the dumpsites were observed to be higher than those of their control counterparts. However, concentration of Fe and Zn were slightly above permissible limits set by the Joint Food and Agricultural Organisation and World Health Organization [42].

4. CONCLUSION

Evaluation of physicochemical characteristics and heavy metal levels at selected refuse dumpsites in Nkwerre Local Government Area of Imo State was carried out in this study. The results showed that the overall physicochemical parameters assayed were fertile to support plant species diversity, changes and growth. Heavy metal analysis of the soils and plants studied were observed to be below WHO/FAO permissible limit for soil and plants for Cd, Cu, As, Mn, and Pb. The plant species encountered at the refuse dumpsite absorbed one form metal or the other, indicating that *Talinum triangulare* can be used as bioindicator and hyperaccumulators for phytoremediation of polluted sites. A strong positive correlation was observed between soil and plant uptake of metals implying that metal level in the refuse dumpsite soil is the major factor responsible for the heavy metal contents in the plants species studied. The indiscriminate dumping of these solid wastes in the environment has caused great harm to our ecosystem through the release of pollutants such as heavy metals which in a high concentration in the soil can be harmful to humans if ingested directly or indirectly and plants which depend on the nutrient from the soil for their growth and development. Considering the above results, it can be concluded that *T. triangulare* could be a useful candidate for phytoextraction technologies in naturally contaminated soils.

5. RECOMMENDATIONS

- The habit of using dumpsite soil for agricultural purpose and consumption of dumpsite plant 'vegetable' should be avoided by the farmers and the resident around the dumpsite.
- More studies should be carried out in this dumpsites to ascertain the potential ecological risks.
- Other heavy metals not considered in this study be considered by other researchers.
- *T. triangulare* can be used as a good hyperaccumulator
- The relevant Government bodies (e.g. ENTRACO) should be encouraged to reduce the number of waste dumpsites in Nkwerre.
- More studies should be carried out to ascertain the phytoextraction efficacy of *Talinum triangulare*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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