



Research Article

Toxicity and Health Effects of Heavy Metals in Soil, Water and Edible Plants in Jos South, Plateau State, Nigeria

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ABSTRACT

Keyword:

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The toxicity of heavy metal is obviously a major threat and has various health hazard related to it. This work unveils the accumulation of heavy metals in Jos South using XRF. The results of this study showed that the Geo-Accumulation Index (I_{geo}) of water for different metals is decreasing in order of Cd (0.15) > Cr and As (0.03) > Pb (-0.13) > Ni (-0.6). Heavy metals in soil decrease in the order of As and Cd (0.4) > Ni, Cr and Pb (0.2). The heavy metals in different plants is in decreasing order of Cd (0.512) > As (0.25) > Pb (0.23) > Ni (0.01) > Ni (-0.06). 26% of these points are uncontaminated, except few points which are found within the uncontaminated to moderately contaminate level. It can be concluded that the area falls within uncontaminated-moderately contamination which calls for regulation. Hence this study can be used as a reference data for regulatory bodies like NNRA and the rest.

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INTRODUCTION

Metals refer to substances that have extreme electrical conductivity, are malleable, are lustrous and can lose their electrons voluntarily to form cations. Metals are naturally found everywhere in the earth's crust with their compositions differing with difference in location, thereby resulting in

varying concentrations. The metal spreading in the atmosphere is noted by the properties of the metal and by many factors in the environment (Khlifi and Hamza-Chaffai, 2010). Heavy metals are referred to as metals with density greater than 5 g/cm³ and can pose health effect on living organisms and the

environment (Järup, 2003). These metals are expected to maintain many physiological and biochemical functions in living organisms at lower concentrations, however they become noxious as they exceed certain limit of concentrations. Though, it is obvious that heavy metals possess many extreme health effects and stay for a longer period, exposure heavy metal continues and increasing in various parts of the World. Pollution of environment by heavy metals is significant and their toxicity is also a significant problem which increases ecological, evolutionary, nutritional and environmental reasons (Jaishankar *et al.*, 2014; Nagajyoti *et al.*, 2010). The heavy metals common in waste water include arsenic, cadmium, chromium, copper, lead, nickel, and zinc, all of which pose risks in human health and environment (Lambert *et al.*, 2000). Heavy metals spread in the surroundings naturally and by human activities. Sources of heavy metals include soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff, sewage discharge, insect or disease control agents applied to crops, and so on (Morais *et al.*, 2012; Nriagu, 1996).

Though these metals have vital biological functions in plants and animals, sometimes the coordination of their chemicals and their properties of oxidation-reduction have made them beneficial for them to escape control mechanisms like homeostasis, transport, compartmentalization and binding to required cell constituents. These metals bind with protein sites that are not made for them by displacing original metals from their binding sites naturally posing malfunctioning of cells and ultimate toxicity (Flora *et al.*, 2008).

Arsenic is an important heavy metal posing disquiet from both individual health and ecological standpoints (Hughes *et al.*, 1988). It possesses the properties of semi-metal, and mostly carcinogenic and toxic, and is mostly

available in the oxides form or sulfides or as iron salt, sodium, calcium, copper, *etc.* (Singh *et al.*, 2007). Arsenic is the twentieth element that is most abundant on earth and it is in forms of inorganic such as arsenite and arsenate compounds and is lethal to the living creatures and environment. Humans may absorb arsenic naturally, industrial source, or from unintended sources. Drinking water may be contaminated by use of pesticides that has arsenic, mineral deposited naturally or wrong disposal of chemicals that contained arsenic. Intentional arsenic consumption in case of attempts for suicide or unintentional consumption by children may also result in cases of acute poisoning (Mazumder, 2008; Saha *et al.*, 1999). Arsenic is a poison in form of proto-plastic since it affects primarily the sulphhydryl cells group posing faulty functioning of cell respiration, cell enzymes and mitosis.

Lead is an extremely toxic metal that widespread uses have posed extreme contamination to the environment as well as health problems in different parts of the World. Lead is a silvery and bright metal, slightly bluish in a dry atmosphere. It tarnishes when direct contact with air, which makes it to form a compound with complex mixture, based on the given conditions. The exposure sources of lead include industrial processes, drinking water, domestic sources food and smoking. Sources of lead are gasoline and house paint that has extended to lead bullets, pewter pitchers, storage batteries, toys, plumbing pipes and faucets (Thürmer *et al.*, 2002). Lead is a very toxic heavy metal which discomforts the physiological processes of different plant and unlike other metals, such as zinc, copper and manganese; it does not have any biological functions (Najeeb *et al.*, 2014; Yongsheng *et al.*, 2011). Even with lower concentrations, treatment of lead was found to pose a lot of instability in ion uptake by plants,

thereby leading to significant changes in metabolism and in the capacity of photosynthesis and ultimately in a strong inhibition of plant growth (Rilwan *et al.*, 2020)

Cadmium happened to be the seventh most toxic heavy metal. It is produced after production of zinc which in turn animals or humans are exposed to in their environment or at their place of work. As human absorbed this metal, it gets accumulated in the body for a complete lifetime. Evidence indicated that in the World War I, this metal was used for the first time as alternative for tin and in paint industries as a pigment. In today's scenario, it is also used in battery rechargeables, for special alloys production and more so contained in tobacco smoke. About 3/4 of cadmium is used in alkaline batteries as a component of electrode, the other part is used in pigments, coatings, plating and as a plastic stabilizer. Inhalation and ingestion are normally the primarily rout of humans exposed to this metal which in turn, the later suffer from acute and chronic intoxications. Cadmium spreading in the environment will remain in soils and sediments for many decades. Plants eventually trap up these metals and get accumulated in them which in turn concentrates along the chain of the food, reaching finally to the human body (Bernard, 2008; Mutlu *et al.*, 2012; Han *et al.*, 2009). Cadmium is mostly found in vegetables and fruits due to its high rate of transfer from soil to plant (Satarug *et al.*, 2011). Cadmium is an extremely toxic nonessential heavy metal which is well known for its high influence on the oxidative stress, systems enzymes in cells and for inducing nutritional deficiency in plants (Irfan *et al.*, 2013).

Chromium is the number seven amongst the most abundant element on earth (Mohanty and Kumar, 2013). It occurs in many oxidation states in the environment starting from Cr²⁺ to

Cr⁶⁺ (Rodríguez *et al.*, 2009). The most common Cr are hexavalent- Cr⁺⁶ and trivalent- Cr⁺³, both with their states as toxic to humans, animals and plants (Mohanty and Kumar, 2013). Naturally, chromium occurs as a result of burning of coal and oil, pigment oxidants, petroleum from ferro chromate refractory material, chromium steel, catalyst, fertilizers, metal plating tanneries and oil well drilling. Anthropogenically, chromium is released into the environment through sewage and fertilizers (Ghani, 2011). When in reduced form, Cr(III) is immobile and is also insoluble in water whereas in an oxidized state, Cr(VI) is highly soluble in water and thus mobile (Wolińska *et al.*, 2013). In order to fine the activities of the metal ions in the environment, metal speciation is highly vital and oxidative form of Cr(III) is not an essential contaminant of the ground water in case of chromium but Cr(VI) has been toxic for humans (Gürkan *et al.*, 2012). Cr(III) stays in the soil organic matter and aquatic environment in the form of hydroxides, oxides and sulphates (Cervantes *et al.*, 2001). Chromium is widely used in industries like as chemical production, electroplating, metallurgy, tanning, production of paints and pigments, wood preservation, and pulp and paper production. These industries play an important role in chromium pollution with high effect on ecological and biological species (Ghani, 2011). A wide range of agricultural and industrial practices increase the level of its toxicity in the environment bringing concern on the pollution posed by chromium. Environment pollution by chromium, specifically hexavalent chromium, has been the biggest concern in recent years (Zayed and Terry, 2003). Tanneries discharge numerous polluting heavy metals and compounds into the streams water (Nath *et al.*, 2008). Because of the presence of excessive oxygen in environment, Cr (III) is oxidized to Cr (VI), which is highly toxic and extremely

soluble in water (Cervantes *et al.*, 2001; Zayed and Terry, 2003; Chandra and Kulshreshtha, 2004; Bielicka *et al.*, 2005; Duan *et al.*, 2010). When chromium is present in excess beyond the permissible limit, it becomes destructive to plants since it highly affects the plant's biological factors and enters the chain of the food on consumption of these plant materials (Ghani, 2011; Nath *et al.*, 2008; Chandra and Kulshreshtha, 2004).

Nickel is silvery-white, mostly hard, is malleable, and high ductility metal. It belongs to iron group with a high polish. It is slightly a good conductor of electricity and heat. In its familiar compounds nickel is bivalent, though assumes other valences. It also forms a number of compounds that are complex. Most nickel compounds are green or blue. Nickel dissolves gradually in dilute acids but like iron, when treated with nitric acid becomes passive. Finely divided nickel adsorbs hydrogen. Nickel is commonly used in the preparation of alloys and is characterized by their ductility, strength and resistance to corrosion and heat. About 65 % of the nickel consumed in the Western World is used to make stainless steel, whose composition can vary but is typically iron with around 18% chromium and 8% nickel. 12 % of all the nickel consumed goes into super alloys. The remaining 23% of consumption is divided between alloy steels, rechargeable batteries, catalysts and other

chemicals, coinage, foundry products, and plating (Rilwan *et al.*, 2020; Usman *et al.*, 2020). The larger part of all nickel compounds that are released to the environment will adsorb to sediment or soil particles and become immobile as a result. In acidic ground however, nickel is bound to become more mobile and it will often rinse out to the groundwater. There is no much evidence on the effects of nickel on organisms apart from humans. We are aware that high nickel concentrations on sandy soils can obviously damage plants and high nickel concentrations in surface waters can decrease the growth rates of algae. Microorganisms also suffer from growth decline because of the presence of nickel, but they usually develop resistance to nickel after a while. Nickel is an essential foodstuff in animals when they consume small amounts. But can also be dangerous when they exceed the maximum tolerable limit. This can pose many kinds of cancer within the bodies of the animals, mainly of those that live near refineries.

Geo-accumulation Index (I_{geo})

This method assesses the metals accumulation in terms of seven (0 to 6) enrichment classes, ranging from background concentration to very heavily polluted. The index can be calculated according to WHO (2017) by equation 1.

$$I_{geo} = \log_2 \left[\frac{C_m \text{ Sample}}{1.5 \times (C_m \text{ Background})} \right] = \frac{\log_{10} \left(\frac{CF}{1.5} \right)}{\log_{10} 2} = \frac{\log_{10} \left(\frac{CF}{1.5} \right)}{0.3} \quad 1$$

The factor 1.5 is introduced in the equation to minimize the effects of possible variations in the background values. The recommended

World Average Values and Ranges of Geo-Accumulation Index are presented in Table 1.

Table 1: World Average Values and Ranges of Geo-Accumulation Index

I_{geo} Values	I_{geo} Class	Description of Soil Quality
Greater than 5	Sixth	Highly contaminated
4 to 5	Fifth	High to extremely contaminated
3 to 4	Fourth	High contaminated
2 to 3	Third	Medium to high contaminated
1 to 2	Second	Medium contaminated
0 to 1	First	Not contaminated to medium contaminated
0	Zero	Not contaminated

The purpose of this work is to unveil the extent to which heavy metals (Ni, Cr, As, Cd and Pb) accumulates in soil, water and edible plants in Jos South and assess their carcinogenic role to biological tissue that might result in cancer. This work will compare its results with the world standard limits and unveil whether the inhabitants of the study are liable to be affected by cancer in the long round or not.

MATERIALS AND METHODS

Materials

The materials that were used in carrying out this research are hand trowel, plastic containers, hand gloves, polyethylene sampling bottles, Geo-positioning System meter (GPS meter), Masking tape, Permanent

marker and Jotter and X-Ray Fluorescence Spectrometry System (XRF)

Method

Study Area

Plateau is the 25th largest state in Nigeria. Approximately at the north central part of the country, it is unique geographically in Nigeria because of its boundaries of elevated hills surrounding the Jos Plateau being its capital, and the entire plateau itself.

Plateau State is always referred to as the Home of Peace and Tourism. Though, the tourism sector doesn't thrive as it should because of the meagre allocations to it by the State Government.

The coordinates of the study were presented in Table 2 and the coordinates were further used to design a map of the study area as can be seen in Figure 1.

Table 2: Sample Points and Geographical Coordinates

Village	Sample Points	Geographical Coordinates	
		East	North
Jos South	PT01	8° 49' 48"	9° 50' 42"
	PT02	8° 52' 33.6"	9° 49' 37.2"
	PT03	8° 49' 4.8"	9° 47' 34.8"
	PT04	8° 55' 55.2"	9° 46' 51.6"
	PT05	8° 48' 21.6"	9° 45' 10.8"
	PT06	8° 52' 48"	9° 44' 24"
	PT07	8° 53' 34.8"	9° 43' 22.8"
	PT08	8° 51'	9° 43' 1.2"
	PT09	8° 44' 2.4"	9° 42' 54"
	PT10	8° 43' 8.4"	9° 40' 19.2"
	PT11	8° 45' 46.8"	9° 40' 1.2"
	PT12	8° 49' 51.6"	9° 39' 32.4"

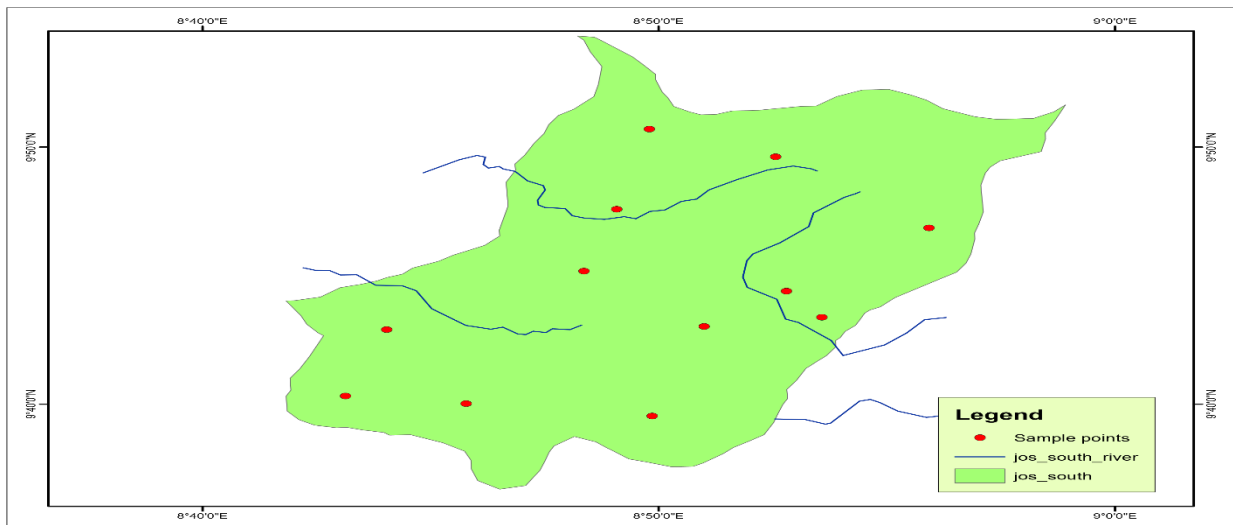


Figure 1: Map of the Study Area Showing Sample Location

Sample Population

The population of the study includes all the notable towns where mining activities takes place within Jos South, Plateau State include 12 settlements.

Collection of Sample

The samples of soil, samples of water and samples of edible plants were collected in pair. The random sampling method was used to collect twelve (12) samples of soil, twelve

(12) sample of edible plant and twelve (12) samples of water from Jos South Local Government in Plateau State making a total of thirty-six (36) samples. Edible plants rooted samples were collected at 0-20 cm depth. Each sample for water, edible plants and soil was divided into three (3) subsamples.

Collection of Soil Sample

Twelve samples of soil were collected. Coring tool to a depth of 5 cm was adopted for the sample collection. The samples which were collected are approximately 4 kg in wet weight and were transferred to a high-density polyethylene lock plastic bag immediately to shield it from cross contamination. Each of the samples collected was given a unique ID (sample ID) so as to be able to trace it easily and the coordinates of each of them were recorded for reference purposes using GPS meter.

Collection of Edible Plant Sample

Twelve samples of edible plants were collected. The samples which were collected were transferred immediately to a high-density polyethylene lock plastic bag to protect it from cross contamination. Each of the samples collected was given a unique ID (sample ID) so as to be able to trace it easily.

Collection of Water Sample

Twelve samples of water were collected from streams. The samples which were collected were transferred immediately to a high-density polyethylene lock plastic bag to protect it from cross contamination. Each of the samples collected was given a unique ID (sample ID) so as to be able to trace it easily.

Sample Preparation of Edible Plant

The edible part of the plant samples was extracted and used for analysis. The samples of the plants were washed twice with water

(ultrapure water). After evaporation of the water, the samples of the plants were weighed, they were oven-dried at 65 °C for 48 hours, after that, they were weighed again and then grinded into fine powder. A wet weight basis was then used to determine the heavy metal concentrations of the edible part of the plants using XRF analysis.

Sample Preparation of Soil

All samples of soil were air-dried naturally until it attained a constant. The dried samples of soil were pulverized with mortar and pestle, and were allowed to pass through 0.9 mm sieve and make it a fine powder and finally taken for XRF analysis.

Sample Preparation of Water

The samples of water for heavy metals detection was acidified with two (2) drops of concentrated HNO₃; for Dissolved oxygen detection, samples were fixed with 2 mL of Manganese (II) sulphate solution each (Winkler A) and Alkali-iodide Azide reagent (Winkler B) for each sample. The operations were done in the field. The collected samples were then placed in an ice-chest and taken to the laboratory after digestion for XRF analysis.

Analysis of Data

Heavy Metals analysis was done using XRF analysis available at Centre for Solid Minerals Research and Development (CSMRD), Kaduna State Polytechnic, Kaduna State, Nigeria. The results obtained was used to assess the extent of the accumulation of these heavy metals in water, soil and plants through an index called the geo-accumulation index as reported by Rilwan *et al.*, (2020), Usman *et al.*, (2020), and WHO, (2017) in equation 1.

RESULTS AND DISCUSSION**Results****Table 3:** Geo-Accumulation Index of Heavy Metals in Water from Jos South

S/P	Ni	Cr	As	Cd	Pb	Total
P01	-1.3	0.3	-0.18	-0.13	0.05	-1.260
P02	-1.0	0.1	-0.35	0.347	-0.35	-1.253
P03	-0.6	0.2	1.125	0.569	-0.05	1.244
P04	-0.8	0.5	0.648	0.171	-0.65	-0.131
P05	-0.7	-0.4	-0.05	0.472	0.82	0.142
P06	-0.7	-0.1	0.192	0.569	-0.05	-0.089
P07	-0.1	0.2	-0.35	-0.13	0.13	-0.250
P08	-0.6	0.2	0.949	0.347	-0.35	0.546
P09	-1.3	0.3	-0.65	0.648	-0.05	-1.052
P10	-0.5	-0.1	1.125	0.347	0.125	0.997
P11	-1.3	-0.4	-0.18	-0.13	-0.65	-2.660
P12	-0.6	0.4	-0.05	0.569	-0.05	0.269
Mean	-0.8	0.1	0.186	0.303	-0.09	-0.291

S/P = Sample Point; P = Points; Ni = Nickel; Cr = Chromium; As = Arsenic; Cd = Cadmium; Pb = Lead.

It could be observed from Table 3 that the accumulation of heavy metals in water for Ni, Cr, As, Cd and Pb has the mean of -0.8, 0.1, 0.186, 0.303 and -0.09 respectively.

Total Geo Accumulation Index from Water Samples of Jos South Local Government Area

is in descending order trend with P03 (1.244) > P10 (0.997) > P08 (0.546) > P12 (0.269) > P05 (0.142) > P06 (-0.089) > P04 (-0.131) > P07 (-0.250) > P09 (-1.052) > P01 (-1.260) > P02 (-1.253) > P11 (-2.660).

Table 4: Geo-Accumulation Index of Heavy Metals in Soil from Jos South

S/P	Ni	Cr	As	Cd	Pb	Total
P01	0.4	0.2	0.4	0.2	0.1	1.3
P02	0.2	0.3	0.1	0.5	0.2	1.3
P03	0.3	0.3	0.3	0.5	0.3	1.7
P04	0.2	0.2	0.1	0.1	0.1	0.7
P05	0.3	0.3	0.3	0.6	0.3	1.8
P06	0.3	0.3	0.1	0.3	0.2	1.2
P07	0.4	0.2	0.4	0.5	0.1	1.6
P08	0.1	0.3	0.5	0.3	0.3	1.5
P09	0.2	0.3	0.2	0.2	0.1	1.0
P10	0.0	0.2	0.1	0.3	0.3	0.9
P11	0.4	0.2	0.7	0.3	0.2	1.8
P12	0.3	0.3	0.3	0.3	0.3	1.5
Mean	0.3	0.3	0.3	0.3	0.2	1.4

S/P = Sample Point; P = Points; Ni = Nickel; Cr = Chromium; As = Arsenic; Cd = Cadmium; Pb = Lead.

It could be observed from Table 4 that the accumulation of heavy metals in water for Ni, Cr, As, Cd and Pb has the mean of 0.3, 0.3, 0.3, 0.3 and 0.2 respectively.

The Total Geo Accumulation Index from Soil Samples of Jos South Local Government Area

is in descending order trend with P05 and P11 (1.8) > P03 (1.7) > P07 (1.6) > P08 and P12 (1.5) > P01 and P02 (1.3) > P06 (1.2) > P10 (0.9) > P04 (0.7).

Table 5: Geo-Accumulation Index of Heavy Metals in Edible Plants from Jos South

S/T (<i>Botanical Name</i>)	Ni	Cr	As	Cd	Pb	Total
Zogale (<i>Moringa Olifera</i>)	0.03	0.19	-0.35	0.35	0.33	0.55
Kuka (<i>Adansonia Dijitata</i>)	0.08	0.15	-0.65	0.05	0.35	-0.02
Rama (<i>Ocimum Tenuiflorum</i>)	0.32	0.15	-0.35	0.35	0.25	0.72
Yateya (<i>Terminalia</i>)	0.22	0.25	-0.65	0.52	0.39	0.73
Alayyahu (<i>Amarantus Esculenta</i>)	-0.01	0.28	-0.45	0.13	0.37	0.32
Shuwaka (<i>Arnonia App</i>)	0.27	0.01	-0.54	0.39	0.19	0.32
Yakuwa (<i>Hibiscus Sabdariffa</i>)	0.17	0.13	-0.11	0.30	0.33	0.82
Karkashi (<i>Sesamum Radiatum</i>)	0.07	0.23	-0.37	0.39	0.30	0.62
Ugu (<i>Telfairai Occidentalis</i>)	0.01	0.09	-0.24	0.41	0.31	0.58
Rogo (<i>Magnihot Esculenta</i>)	0.14	0.20	-0.29	0.19	0.22	0.46
Water Leaf (<i>Talinum Fruticosum/Triangulare</i>)	0.06	0.16	-0.15	0.30	0.16	0.53
Kabeji (<i>Brassica Oleracea Var. Capitata</i>)	-0.04	0.07	-0.03	0.54	0.33	0.87
Mean	0.11	0.15	-0.35	0.33	0.29	0.54

S/T = Sample Type

It could be observed from Table 5 that the accumulation of heavy metals in water for Ni, Cr, As, Cd and Pb has the mean of 0.11, 0.15, -0.35, 0.33 and 0.29 respectively.

The total Geo Accumulation Index from Edible Plant Samples of Jos South Local Government Area is in descending order trend with Kabeji (*Brassica Oleracea Var. Capitata*) (0.87) > Yakuwa (*Hibiscus Sabdariffa*) (0.82) > Yateya (*Terminalia*) (0.73) > Rama (*Ocimum Tenuiflorum*) (0.72) > Karkashi (*Sesamum Radiatum*) (0.62) > Ugu

(*Telfairai Occidentalis*) (0.58) > Zogale (*Moringa Olifera*) (0.55) > Water Leaf

(*Talinum Fruticosum/Triangulare*) (0.53) > Rogo (*Magnihot Esculenta*) (0.46) > Shuwaka (*Arnonia App*) and Alayyahu (*Amarantus Esculenta*) (0.32) > Kuka (*Adansonia Dijitata*) (-0.02).

Comparing the Results of the Present Study with World Health Organization (WHO)

The results of the present study presented on Table 3, Table 4 and Table 5 were used to plot charts in order to compare the results of the present study with World Health Organization (WHO) as seen in Figure 1, Figure 2 and Figure 3.

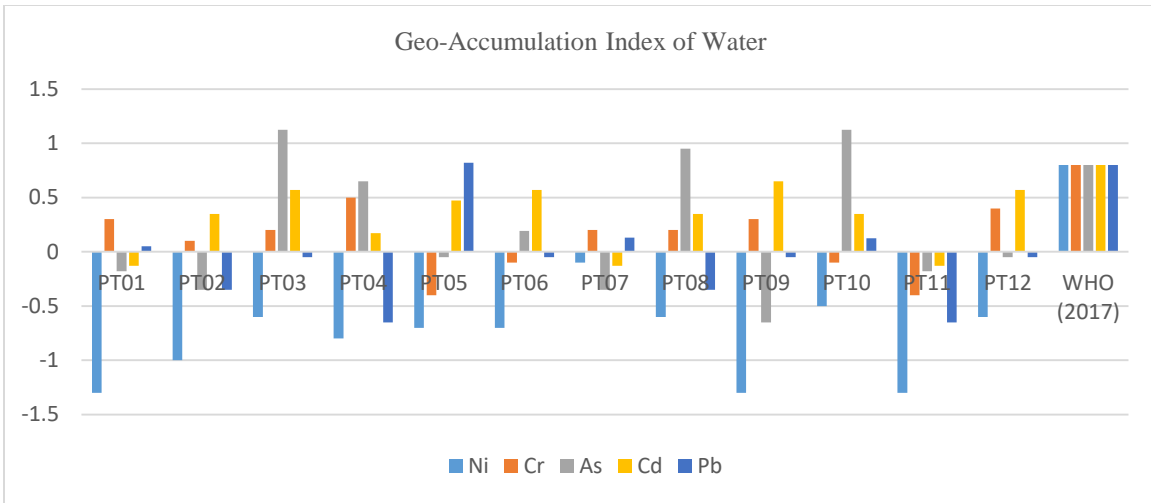


Figure 1: Comparison of Geo-Accumulation Index of Water with World Health Organization

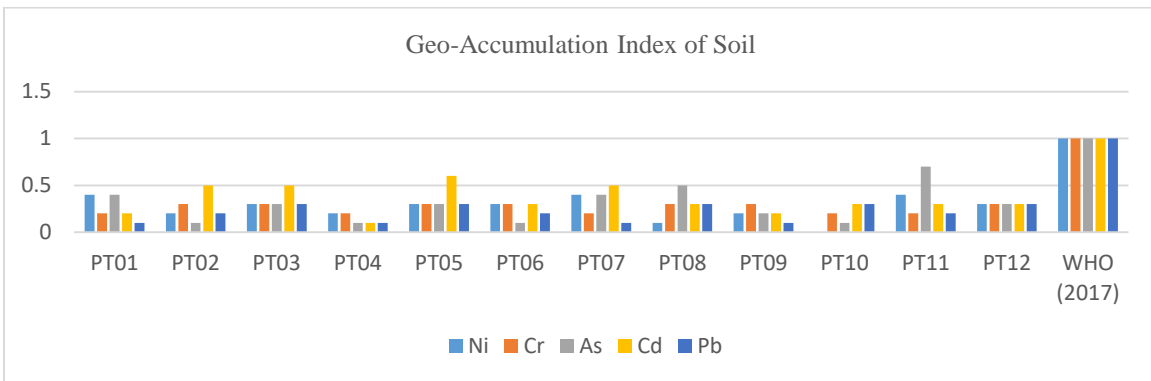


Figure 2: Comparison of Geo-Accumulation Index of Soil with World Health Organization

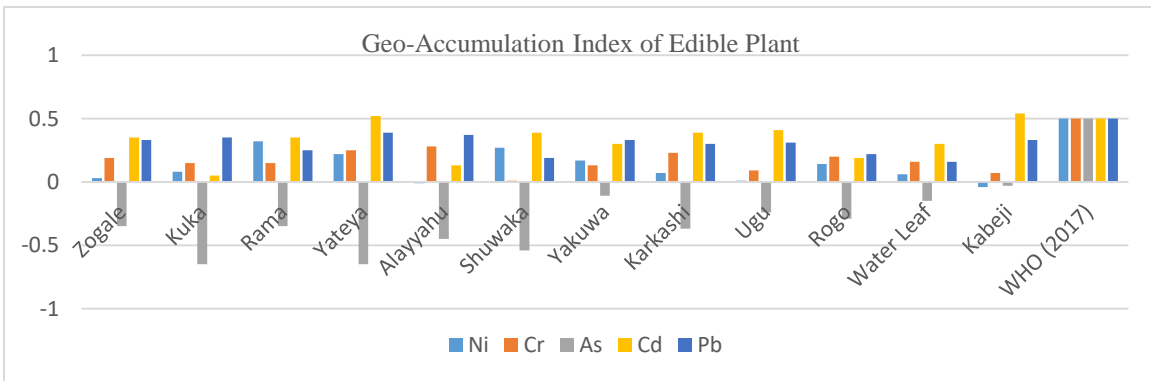


Figure 3: Comparison of Geo-Accumulation Index of Edible Plant with World Health Organization

DISCUSSION

The results of this study showed that the Geo-Accumulation Index (I_{geo}) of water for different heavy metals (Ni, Cr, As, Cd and Pb) in all the sample points decreased in the order of P03 (1.244) > P10 (0.997) > P08 (0.546) >

P12 (0.269) > P05 (0.142) > P06 (-0.089) > P04 (-0.131) > P07 (-0.250) > P09 (-1.052) > P01 (-1.260) > P02 (-1.253) > P11 (-2.660) with heavy metals decreasing in the order of Cd (0.15) > Cr and As (0.03) > Pb (-0.13) > Ni (-0.6).

Based on the chart presented in Figure 1, water has not been contaminated by Nickel (Ni) in all the points. The water also was not contaminated by Cadmium (Cd) in P01, P07 and P11, while other points are within uncontaminated to contaminated level. Figure 1 also showed that Chromium (Cr) in P05, P06, P10 and P11 has their values at uncontaminated level, whereas in other points, Chromium (Cr) is within uncontaminated to contaminated level. The same figure also showed that Arsenic (As) in P01, P02, P05, P07, P09, P11 and P12 has their values at uncontaminated level, whereas in other points, Arsenic (As) are within uncontaminated to contaminated level. Lastly, Figure 1 showed that Lead (Pb) in P02, P03, P04, P06, P08, P09, P11 and P12 has their values at uncontaminated level, whereas in other points, Lead (Pb) are within uncontaminated to contaminated level considering the World Health Organization recommended value of $I_{geo} \leq 0$ as not contaminated, $0 < I_{geo} \leq 1$ as not contaminated to medium contamination, $1 < I_{geo} \leq 2$ as medium contamination.

On the Geo-Accumulation Index (I_{geo}) of soil for different heavy metals (Ni, Cr, As, Cd and Pb) in all the sample points increased in the order of P05 and P11 (1.8) > P03 (1.7) > P07 (1.6) > P08 and P12 (1.5) > P01 and P02 (1.3) > P06 (1.2) > P10 (0.9) > P04 (0.7) with heavy metals decreasing in the order of As and Cd (0.4) > Ni, Cr and Pb (0.2).

The chart presented in Figure 2 showed that, soil has been uncontaminated by all heavy metals in all the points considering the World Health Organization recommended value of $I_{geo} \leq 0$ as not contaminated, $0 < I_{geo} \leq 1$ as not

CONCLUSION

It can therefore be concluded that the soil, water and edible plants in the study area falls within the uncontaminated to moderately contaminated values which calls for serious

contaminated to medium contamination, $1 < I_{geo} \leq 2$ as medium contamination.

On the Geo-Accumulation Index (I_{geo}) of edible plants for different heavy metals (Ni, Cr, As, Cd and Pb) in all the sample points decreased in the order of Kabeji (*Brassica Oleracea Var. Capitata*) (0.87) > Yakuwa (*Hibiscus Sabdariffa*) (0.82) > Yateya (*Terminalia*) (0.73) > Rama (*Ocimum Tenuiflorum*) (0.72) > Karkashi (*Sesamum Radiatum*) (0.62) > Ugu (*Telfairai Occidentalis*) (0.58) > Zogale (*Moringa Olifera*) (0.55) > Water Leaf (*Talinum Fruticosum/Triangulare*) (0.53) > Rogo (*Magnihot Esculenta*) (0.46) > Shuwaka (*Arnonia App*) and Alayyahu (*Amarantus Esculenta*) (0.32) > Kuka (*Adansonia Dijitata*) (-0.02) with heavy metals decreasing in the order of Cd (0.512) > As (0.25) > Pb (0.23) > Ni (0.01) > Ni (-0.06).

Lastly, the chart presented in Figure 3, all the edible plants has been uncontaminated by Arsenic (As) while other heavy metals were found within uncontaminated to contaminated level considering the World Health Organization recommended value of $I_{geo} \leq 0$ as not contaminated, $0 < I_{geo} \leq 1$ as not contaminated to medium contamination.

The results presented showed that only 26 % of the investigation areas has their soil, water and edible plants at uncontaminated level, whereas all the remaining points are found within uncontaminated to contaminated level considering the World Health Organization recommended value of $I_{geo} \leq 0$ as not contaminated, $0 < I_{geo} \leq 1$ as not contaminated to medium contamination.

concern and regulatory control especially for those points within moderate contamination level. Hence this study can be used as a

reference data for regulatory bodies like

NNRA and the rest.

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