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Levels of Heavy Metals in Soil, Water and Vegetables around Industrial area in Bauchi, Northeastern Nigeria

[1]SULAIMAN, BA; *[2]SULAIMAN, MB; [3]AHMED, A; [4]MAIGARI, IA; [5]TIJJANI, AF

[1]Department of Pure and Applied Chemistry, University of Maiduguri, Borno State, Nigeria
*[*2]Department of Pure and Industrial Chemistry, University of Nigeria, Nsukka, Enugu State, Nigeria*
[3]Department of Science Laboratory Technology, Federal Polytechnic Mubi, Adamawa State, Nigeria
[4]Department of Science Laboratory Technology, Gombe State Polytechnic, Bajoga, Gombe State, Nigeria
[5]Department of Science Laboratory Technology, Federal Polytechnic of Oil and Gas, Bonny Island, River's State, Nigeria
**Corresponding Author Email:sulaimanmuhammadbashir@gmail.com;mohammad.sulaiman.pg01935@unn.edu.ng*

ABSTRACT: This study examined the levels of heavy metals in soil, water, and vegetables (*amaranthus*, *hibiscussabdariffa*, and *allium cepa* leaves) around the industrial area Bauchi, Northeastern Nigeria. The composite samples of soil, water, and vegetables were collected and determine the level of heavy metals (Mn, Zn, Cd, Pb, and As) using Atomic Absorption Spectrophotometer (AAS). The level of the heavy metals decreased in the order of Mn > Zn > Pb > Cd, Pb > Zn > Mn > Cd, and Mn > Zn > Mn > Cd in the soil, water, and vegetables respectively. Among the vegetables, *amaranthus* had the highest heavy metals level followed by *allium cepa* leaves and *hibiscus sabdariffa*. The levels of heavy metals obtained were below the tolerance level recommended by the world health organization (WHO). The bio-concentration factors of the heavy metals for the studied samples were below one except Zn in *amaranthus*. The daily intake of metals for Mn was found to be the highest in *amaranthus* for children and estimated to be 1.149 mg/person/day. Health risk index of Zn for *amaranthus* and *allium cepa* leaves for children and Pb for *amaranthus*, *hibiscus sabdariffa* and *allium cepa* leaves for both children and adults were above 1, except in *hibiscus sabdariffa* for adults, signifying provable of health risks for the consumption of the vegetables in the study area. Therefore, the consumption of these vegetables as food could pose a health hazard, and regular monitoring is recommended to prevent metal accumulation with their associated health implications in the consuming public.

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Environmental pollution has been one of the most serious global challenges facing communities living in an industrial area, particularly in developing countries like Nigeria. Environmental pollution can as a result of unfavorable production of man's activities such as mining, combustion, applications of fertilizers and pesticides (Reynolds *et al*., 2015; Hazrat *et al.*, 2019). Chemical substances from the activities such as heavy metals are one of the factors which contribute to environmental pollutions and it was believed that it can disrupt the living ecosystem (Kabata-Pendias and Pendias, 2001). Currently, anthropogenic inputs of metals above the natural levels due to an increase in industrialization and urbanization (Varalakshmi and Ganeshamurthy, 2010, Sulaiman *et al.*, 2020). Industrial wastes, atmospheric deposition from crowded cities, and other domestic wastes are among the major sources of heavy metals in the surface water, groundwater, and soils (Raymond *et al.*, 2011; Qingwei *et al.*, 2020). Heavy Metals are natural constituents of the earth's crust, with an atomic density greater than 5 gcm^{-3}, an atomic number >20 and the most common heavy metal contaminants are Cd, Cr, Cu, Hg, Pb, and Zn (Garba *et al.*, 2018). Heavy metals have been given considerable concern worldwide due to their toxicity and accumulative behavior (Alinnor, 2008; Sulaiman *et al.*, 2019a). Heavy metal contamination of soil, water, and atmosphere signifies a rising environmental problem that may enter the food chain as a result of their uptake by edible plants, affecting food quality and human health (Chibuike and Obiora, 2014; Zwolak *et al.*, 2019; Hazrat *et al.*, 2019). Heavy metals in a surface, groundwater and soils could either from natural or anthropogenic sources (Duke and Williams, 2008; Vhahangwele and Khathutshelo, 2018). The consumption of vegetables and fruits as food offer rapid and least means of providing adequate vitamin supplies, minerals, and fiber. Vegetables are used as food include those used in making soups or served as integral parts of the main sources of a meal (Arora, 2008), but the accumulation of heavy metals in the soil may affect soil properties and inhibit plant growth. Moreover, several studies showed that fruits and leafy vegetables are vulnerable

**Corresponding Author Email: sulaimanmuhammadbashir@gmail.com; mohammad.sulaiman.pg01935@unn.edu.ng*

to heavy metals contamination from air, water, and soil (Sulaiman *et al.*, 2019b). The consumption of vegetable growth in contaminated soils is one of the contributing factors to human exposure to heavy metals (Zhuang *et al.*, 2009; Ogbonna and Okezie, 2011; Sulaiman *et al.*, 2019b). On the other hand; Pb is relatively highly toxic to higher animals. It is absorbed and translocated to plant tissues, from which it affects animals and humans when consumed with plants (Rodríguez *et al.*, 2018). Thus, the evaluation of the levels of heavy metals in environmental samples is very important. The present work, evaluate levels of heavy metals in soils, water, and some of the vegetables and assessed the health associated with consumption of the vegetables from Bauchi industrial area, Northeastern Nigeria.

MATERIALS AND METHODS

Study area: The study was conducted at Gwallaga along Bauchi industrial area, Bauchi State, northeastern part of Nigeria (Fig1). It is located between longitude 10.10^0 N-10.33^{0}N and latitude 9.40^{0}E-10.13^{0}E. It occupies an estimated land area of 3,687 km^2 and altitude is 690.2 m above sea level. The climate is tropical with two distinct seasons; rainy (May-October) and dry/harmattan (November-April) seasons; with a temperature of between 23 ^{o}C and 40 ^{o}C and an average rainfall of 1.0914 mm^3. The daily humidity increases to 94% in the middle of the rainy season but falls to less than 10% during the dry season (Sulaiman *et al.*, 2018; Barambu *et al.*, 2020).

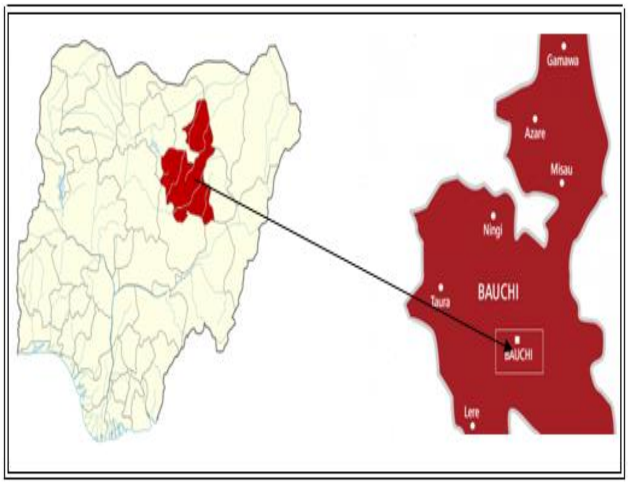

Fig 1: A map shows the study area in Bauchi, Bauchi State, Nigeria**.**

Samples collection: Samples of soil, water, and vegetables (*amaranthus, hibiscus sabdariffa*, and *allium cepa* leaves) were collected from Gwallaga along Bauchi industrial area, Bauchi state. All samples were randomly collected; at the sampling point, three sub-samples were collected to form a composite sample. Soil samples were collected using plastic spade up 15 cm depth and vegetable samples were collected from the study site. The collected soil and vegetable samples were put into clean polythene bags and labeled, while water samples were put in previously washed, rinsed, and dried bottles. A total of 12, 12, and 36 of soil, water, and vegetable samples were collected respectively. The samples were brought to the laboratory for analysis.

Soil ***s****amples preparation and analysis*: The soil samples were air-dried and crushed in a mortar and pestle and passed through a 2 mm mesh sieve to remove debris. 2.0 g of air-dried sample was weighed in a beaker and few drops of distilled water were used. 15cm^3 of aqua regia (3:1 $HCl:HNO_3$) was added and the mixture was heated for 1 hour at 120 ^{o}C, 2.0 cm^3 $HClO_4$ was added and evaporated to approximately 0.5 cm after cooling the residue was dissolved with 2%HNO_3, filtered before transferred to a 50 cm^3 volumetric flask and made up to the mark with 2% HNO_3 (Kudirat and Fummilayo, 2011).

Vegetable ***s****amples preparation and analysis*: The vegetables were air-dried and grounded with mortar and pestle sieved through 2 mm mesh sieve, 2.0 g portion of the sample was weighed into 100cm^3 Kyeildal digestion flask, 15 ml of concentrated HNO_3 was added followed by 3 ml each of concentrated H_2SO_4 and 12 ml 60-62% $HClO_4$, in the ratio of 5:1:4 ratio respectively. The flask was cooled and the content was made up to the mark with deionized water and transferred to 125 cm^3 polyethene cans and stored for heavy metal determination with (unicam 919 AAS).

Water samples preparation and analysis: 50 cm^3 of water sample was measured into a beaker. A mixture of 10 cm^3 of concentrated HNO_3 and HCl in the ratio of 1:3 was added, it was evaporated to a smaller volume and the filtrate was transferred into a 100 cm^3 volumetric flask and made up to a mark with distilled water and ready for atomic absorption spectrophotometer (Unicam 919 AAS).

Bioaccumulation factor: The bioaccumulation factor is the ratio of the concentration of heavy metals in a plant to the concentration of heavy metals in soil, i.e the translocation of heavy metals from soil to vegetables (Naser *et al.*, 2012; Sharma *et al.*, 2018; Sulaiman *et al.*, 2019; Gebeyehu and Bayissa 2020; Gemeda *et al.*, 2020).

$$\text{BCF} = \frac{C_{plant}}{C_{soil}}$$

Where: BCF= bioaccumulation, C_{plant}= concentration of heavy metals in plants, and C_{soil}= concentration of heavy metals in soil.

Daily Intake of Metal: The daily intake of metals (DIM) is the average estimated the daily metal loading into the body system of specified body weight of a consumer which notify the relative phyto-availability of metal (Mahmood and Malik, 2014; Adedokun *et al.*, 2016; Ftsum and Abraha, 2018; Sulaiman *et al.*, 2019).The daily intake metals (DIM) was determined using the following equation:

$$\text{DIM} = \frac{\text{Cm} \times \text{Cf} \times \text{Dft}}{\text{Bw}}$$

Where: DIM= daily intake of metals, Cm= concentrations of metal in plants (mg/kg), Cf= conversion factor (0.085), Dft= food intake (daily intake of vegetables), Bw= average body weight (kg).

Health Risk Index: The health risk assessment is a multi-step process that consists of data collection, and analyzing the site data appropriate to human health (Grzetic and Ghariani, 2008; Sulaiman *et al.*, 2016; Sulaiman *et al.*, 2019). The health risk index (HRI) was determined using the following equation:

$$\text{HRI} = \frac{\text{DIM}}{R_{fd}}$$

Where: HRI= health risk index, DIM= daily intake of metals, and Rfd= reference oral dose. Rfd values employed in this study were obtained from (US-EPA IRIS, 2006).

If the value of HRI is less than 1 then the exposed population is said to be safe (US-EPA IRIS, 2003).

RESULTS AND DISCUSSIONS

Levels of heavy metals in soil and water samples: Table 1 presents the levels of heavy metals in soil and water. The levels of heavy metals in soil were 9.47 mg/kg, 1.83 mg/kg, and 0.45 mg/kg for Mn, Zn, and Pb respectively. The highest level was found for Mn followed by Zn and Pb, while the Cd and As were below the detectable limit. The observed levels in soil samples were below the permissible limits in agricultural soils (Table 1) FAO/WHO. The findings of the studied samples suggest that the soil samples were not polluted by the referred heavy metals. Thus, the results concluded that the soil sample of the study area was not polluted by the investigated heavy metals. The level of heavy metals in the water is in the following trend; Mn > Pb > Zn > Cd > As, the values obtained were 0.5 mg/L, 0.11 mg/L, 0.08 mg/L, 0.00 and 0.00 mg/L for Mn, Pb, Zn, Cd, and As respectively. The obtained levels of metals in this were below the permissible limit of water set by WHO, this indicated that activities of the study area have not affected the water quality, but regular monitoring is recommended to prevent metal accumulation.

Table 1: Heavy metals levels soil and water from Gwallaga, Industrial area, Bauchi State

Samples	Mn	Zn	Cd	Pb	As
Soil (mg/kg)	9.47 ± 0.021	1.83 ± 0.013	0.00 ± 0.00	0.45 ± 0.022	BDL
FAO/WHO	100	300	3.00	50.00	20.00
Water (mg/L)	0.05 ± 0.013	0.08 ± 0.010	0.00 ± 0.00	0.11 ± 0.021	BDL
WHO	0.5	0.2	-	0.01	-

BDL=below detectable limit

Levels of heavy metals in vegetable samples: The results of vegetable samples are presented in Table 3. The results showed that the level of Mn ranged from 3.12 - 1.50 mg/kg, Zn 0.60 - 2.08 mg/kg, and Pb 0.04 - 0.07 mg/kg, while Cd and As were below the detectable limit. Among the vegetables, *amaranthus* had the highest heavy metals level followed by *allium cepa* leaves and *hibiscus sabdariffa*. The higher concentration of Mn was obtained in *amaranthus* followed by *habiscussa bdariffa* and*allium cepa* leaves, while that of Zn highest concentration *amaranthus* followed by *allium cepa* leaves and *habiscussa bdariffa* and that of Pb was *allium cepa* leaves, *amaranthus*, and *aabiscussa bdariffa*.

Generally, the level of heavy metal in the vegetables was decreasing in the order of Mn > Zn > Pb. The levels of Mn, Zn, and Pb in vegetables were below the permissible limits in vegetable by FAO/WHO in (Table 2).

Bio-concentration factor: The results of the bio-concentration factor (BCF) of the heavy metals are presented in Table 3. Soil to plant bio-concentration factor coefficient is an essential factor of human exposure to heavy metals through the food chain as it describes the transfer of contaminants from soil to plants (Gupta *et al.*, 2013; Tasrina *et al.*, 2015; David and Minati, 2018). The results showed that the highest bio-concentration factor (BCF) value was obtained for Zn in *amaranthus* and the lowest value was obtained for Pb in *habiscussa bdariffa*. The bio-concentration factor of the heavy metals for the studied samples was below one except Zn in *amaranthus*, suggesting the possibility of health risk for consumption of vegetables grown in the study area.

Table 2: Heavy metals levels (mg/kg) vegetables from Gwallaga, Industrial area, Bauchi State

Samples	Mn	Zn	Cd	Pb	As
Amaranthus	3.12 ± 0.023	2.08 ± 0.012	BDL	0.05 ± 0.014	BDL
Habiscussa bdariffa	1.52 ± 0.033	0.60 ± 0.021	BDL	0.04 ± 0.015	BDL
Allium cepa leaves	1.50 ± 0.032	0.95 ± 0.032	BDL	0.07 ± 0.012	BDL
FAO/WHO	0.001	27.3	0.20	0.3	Nil

BDL= below detectable limit

Table 3: Soil-vegetable bio-concentration factor coefficients (%) of heavy metals

Samples	Mn	Zn	Cd	Pb	As	Efficacy
Amaranthus	0.329	1.136	0.00	0.111	0.00	0.315
Habiscussa bdariffa	0.160	0.327	0.00	0.089	0.00	0.115
Allium cepa leaves	0.158	0.519	0.00	0.155	0.00	0.166

Daily Intake of Metal through Vegetables: Table 4 presents the results of daily intake of metal (DIM) for heavy metals in vegetable samples. Various routes of exposure to humans do exist, yet the most significant is the food chain (David and Minati, 2018). The DIM of Mn, Zn and Pb were1.149, 0.766 and 0.018; 0.560, 0.022 and 0.015; 0.553, 0.350 and 0.026 for children and 0.246, 0.164 and 0.004; 0.120, 0.047 and 0.003, 0.118, 0.075 and 0.006 for adult in *amaranthus, habiscussa bdariffa and allium cepa* leaves respectively. Estimating heavy metal exposure levels is indispensable in determining organism health risk (Singh *et al.*, 2010).

The DIM for Mn was found to be the highest in *amaranthus* for children and estimated to be 1.149 mg/person/day, which greater than one; these signifying children were found to be more prone to heavy metal contagion than the adult. The order of DIM for the metals is as follows: Mn > Zn > Pb in the same order for all vegetable samples.

Hazard index: Table 5 presents the results of the hazard index (HI) for heavy metals in vegetable samples. The findings show that HI values of Zn for *amaranthus* and *allium cepa* leaves for children and Pb for *amaranthus*, *hibiscus sabdariffa* and *allium cepa* leaves for both children and adults were above 1, except in *hibiscus sabdariffa* for adults. When HI exceeds one, this means there are potential health effects from exposure (David and Minati, 2018).

The high HI for Zn observed in *amaranthus* (7.12) and *allium cepa* leaves (2.46) for children, and Pb for *amaranthus, hibiscus sabdariffa*, and *allium cepa* leaves for both children and adults, except in *hibiscus sabdariffa* for adults has signifying provable of health risks for the consumption of the vegetables in the study area. High HQ for Pb was also reported in Ghana (David and Minati, 2018).

Table 4: Daily Intake of Metal (DIM) in *Amaranthus, Habiscussa bdariffa, and Allium cepa* leaves

Metals	Age group	*Amaranthus*	*Habiscussa bdariffa*	*Allium cepa* leaves
Mn	Children	1.149	0.560	0.553
	Adult	0.246	0.120	0.118
Zn	Children	0.766	0.022	0.350
	Adult	0.164	0.047	0.075
Cd	Children	0.000	0.000	0.000
	Adult	0.000	0.000	0.000
Pb	Children	0.018	0.015	0.026
	Adult	0.004	0.003	0.006

Table 5: Health Risk Index (HRI) in*Amaranthus, Habiscussa bdariffa, and Allium cepa* leaves

Metals	Age group	*Amaranthus*	*Habiscussa bdariffa*	*Allium cepa* leaves
Mn	Children	0.104	0.051	0.050
	Adult	0.022	0.011	0.011
Zn	Children	2.553	0.073	1.167
	Adult	0.547	0.157	0.250
Cd	Children	0.000	0.000	0.000
	Adult	0.000	0.000	0.000
Pb	Children	5.143	4.285	7.429
	Adult	1.143	0.857	1.714

Conclusion: This study determined the level of heavy metals (Mn, Zn, Cd, Pb, and As), the results revealed that the level of the investigated metals in soil and water were below FAO/WHO and WHO of soil and water standards respectively. The bio-concentration factor value revealed that a*maranthus* had the highest factor for Mn and Zn, while *allium cepa* leaves had a higher factor for Pb and, *habiscussa bdariffa* had the lowest factor for Mn, Zn, and Pb. Furthermore, the findings on the DIM, and HI revealed that consumption of *amaranthus* and *allium cepa* leaves of Zn for children and Pb for *amaranthus*, *hibiscus sabdariffa* and *allium cepa* leaves for both children and adults could pose human health risks due to high level of Zn and Pb.

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