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

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ABSTRACT: This study examined the levels of heavy metals in soil, water, and vegetables (amaranthus, hibiscus sabdariffa, 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.

DOI: https://dx.doi.org/10.4314/jasem.v25i8.37

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Dates: Received: 10 May 2021; Revised: 28 June 2021; Accepted: 01 July 2021

Keywords: Heavy Metals, vegetable, daily intake of metals, health risk index

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 Ganesamurthy, 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

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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°N-10.33°N and latitude 9.40°E-10.13°E. It occupies an estimated land area of 3,687 km² 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 °C and 40 °C and an average rainfall of 1.0914 mm³. 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.](image)

**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 samples 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. 15 cm³ of aqua regia (3:1 HCl:HNO₃) was added and the mixture was heated for 1 hour at 120 °C. 2.0 cm³ HClO₄ was added and evaporated to approximately 0.5 cm after cooling the residue was dissolved with 2%HNO₃, filtered before transferred to a 50 cm³ volumetric flask and made up to the mark with 2% HNO₃ (Kudirat and Fummilayo, 2011).

**Vegetable samples 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 100 cm³ Kyyildal digestion flask, 15 ml of concentrated HNO₃ was added followed by 3 ml each of concentrated H₂SO₄ and 12 ml 60-62% HClO₄, 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 cm³ polyethylene cans and stored for heavy metal determination with (unicam 919 AAS).
**Water samples preparation and analysis:** 50 cm³ of water sample was measured into a beaker. A mixture of 10 cm³ of concentrated HNO₃ 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 cm³ 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).

\[ BCF = \frac{C_{\text{plant}}}{C_{\text{soil}}} \]

Where: BCF= bioaccumulation, C_{\text{plant}}= concentration of heavy metals in plants, and C_{\text{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; Ftsun and Abraha, 2018; Sulaiman et al., 2019). The daily intake metals (DIM) was determined using the following equation:

\[ \text{DIM} = \frac{C_m \times Cf \times Dft}{Bw} \]

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:

\[ \text{HRI} = \frac{\text{DIM}}{\text{Rfd}} \]

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

**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 *hibiscussa bdariffa* and that of Pb was *allium cepa* leaves, *amaranthus*, and *habiscussa bdariffa*.

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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

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

BDL= below detectable limit

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

<table>
<thead>
<tr>
<th>Samples</th>
<th>Mn</th>
<th>Zn</th>
<th>Cd</th>
<th>Pb</th>
<th>As</th>
<th>Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaranthus</td>
<td>0.329</td>
<td>1.136</td>
<td>0.00</td>
<td>0.111</td>
<td>0.00</td>
<td>0.315</td>
</tr>
<tr>
<td>Habiscussa bdariffa</td>
<td>0.160</td>
<td>0.327</td>
<td>0.00</td>
<td>0.089</td>
<td>0.00</td>
<td>0.115</td>
</tr>
<tr>
<td>Allium cepa leaves</td>
<td>0.158</td>
<td>0.519</td>
<td>0.00</td>
<td>0.155</td>
<td>0.00</td>
<td>0.166</td>
</tr>
</tbody>
</table>

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 were 1.149, 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.

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

<table>
<thead>
<tr>
<th>Metals</th>
<th>Age group</th>
<th>Amaranthus</th>
<th>Habiscussa bdariffa</th>
<th>Allium cepa leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn</td>
<td>Children</td>
<td>1.149</td>
<td>0.560</td>
<td>0.553</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.246</td>
<td>0.120</td>
<td>0.118</td>
</tr>
<tr>
<td>Zn</td>
<td>Children</td>
<td>0.766</td>
<td>0.022</td>
<td>0.350</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.164</td>
<td>0.047</td>
<td>0.075</td>
</tr>
<tr>
<td>Cd</td>
<td>Children</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Pb</td>
<td>Children</td>
<td>0.018</td>
<td>0.015</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.004</td>
<td>0.003</td>
<td>0.006</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Metals</th>
<th>Age group</th>
<th><em>Amaranthus</em></th>
<th><em>Habiscussa bdariffa</em></th>
<th><em>Allium cepa</em> leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn</td>
<td>Children</td>
<td>0.104</td>
<td>0.051</td>
<td>0.050</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.022</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td>Zn</td>
<td>Children</td>
<td>2.553</td>
<td>0.073</td>
<td>1.167</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.547</td>
<td>0.157</td>
<td>0.250</td>
</tr>
<tr>
<td>Cd</td>
<td>Children</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Pb</td>
<td>Children</td>
<td>5.143</td>
<td>4.285</td>
<td>7.429</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>1.143</td>
<td>0.857</td>
<td>1.714</td>
</tr>
</tbody>
</table>

**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 *amaranthus* 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 the level of the investigated metals in soil and water were below FAO/WHO and WHO of soil and water standards respectively.

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