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Health Risk Assessment of Heavy Metals in a Vegetable Cultivated in a Conflict Zone

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Authors' contributions

This work was carried out in collaboration among all authors. Author AIY[1] designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors JIB, LS, AN, FAR, NUM, ZAS, AU, IHK, ABT, ASS, RGL and HKM managed the analyses of the study. Authors AAS, AIY[2], ZGK, AYS, HGK, MMD, MIH, AA, UB, FM, BA, MH, AKS, AYS and NR managed the literature searches. Authors MAR, ANM, IAY and MNN performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

The health risk to the population from exposure to heavy metals in an area that have witnessed a surge in illegal mining activities, cattle rustling and banditry were evaluated in the current study. Sorel (*Hibiscus sabdariffa*) leaves sample from Gadirge village, Jibia local Government area, Katsina State, Nigeria was evaluated for the presence of heavy metals using Atomic Absorption Spectrophotometry. The health risks of the evaluated heavy metals in the sample to the population were assessed using the Target Hazard Quotient (THQ) and Health Risk Index (HRI)) to assess the possible non-carcinogenic effect and the Incremental Lifetime Cancer Risk (ILCR) for the cancer risks. The result of the mean concentration values of the evaluated heavy metals Fe, and Pb from the sample falls above the Maximum Allowable Concentrations (MAC) of heavy metals in leafy vegetables. The concentrations of the other metals including Cu, Zn, Ni, Mn and Cd evaluated in the sample were within the permissible values The result of the Target Hazard Quotient (THQ) associated with the evaluated heavy metals exposure through consumption of the sample for adults and children all were below 1, with exception of the THQ for the heavy metal Fe in the adults and children population and for Mn in the children population that were above 1. The combined health risks for all the metals in the sample for the adults and children population represented as the HRI were above 1, the result of the Incremental Lifetime Cancer Risk (ILCR) for both the adult and children population shows that the heavy metal Ni is beyond the threshold of the safety limit for cancer risk. There is a health risk concern from consumption of the vegetable sample as it may add to the disease burden of the population.

Keywords: Vegetables; environment; heavy metals; Katsina; banditry; cattle rustling; pollution.

1. INTRODUCTION

One of the greatest predicaments to environmental and human health is the raising concentrations of heavy metals in the environment [1]. Heavy metals being toxic at trace levels and coupled with their being persistent and ubiquitous, their presence in the environment is raising much attention [2,3].

“It has been shown over the years that various anthropogenic and natural activities contribute to high levels of heavy metals in the environment” [4]. “The scenario is more glaring in underdeveloped and developing countries with a poor record of monitoring and enforcement of environmental regulations” [5].

“Fields used for cultivation in Katsina State are increasingly being polluted with heavy metals through multiple pollution channels such as horticultural practices; mining and automobile exhaust” [6,7,8]. Katsina State, located in the northwestern part of Nigeria has witnessed a spike in cattle rustling, kidnappings and rural banditry, that has led to the displacement of the population, disrupted agricultural activities and the worsening of the already precarious food security. The activities of illicit miners are believed to be among the major drivers of the condition [9]. Though mining has been linked to economic benefits including informal employment, the poor standards of the mining operations have resulted into the degradation of the land, heavy metal pollution of the soil and water sources and an increased health risk to the population [9].

The displacement of the population due to the conflict has led to the worsening of the food security, a situation that has made the population to rely on vegetables as the cheapest available means of nutrition for their existence.

Vegetables are a prevalent nutrition for people all over the world because they have a high density of vital nutrients, antioxidants, and metabolites that serve as buffers for acidic products of digestion [10]. Vegetables are an essential component of the normal diet because they are made up of essential nutrients that are vital for human existence [11].

The increase in the use of fresh vegetable as food compared to animal based protein is harped on the capacity of vegetables to reduce the manifestation of chronic disease and other age-related diseases in humans [12]. “But on a sad note, human exposures to heavy metal toxicity have been linked to the consumption of vegetables cultivated on metal polluted soils” [13].

As such, the present study was aimed at evaluating the heavy metal load and the health risk indices to the population from consumption of Sorrel leaf cultivated in Gadirge village, Jibia local Government area (a conflict zone), Katsina State, Nigeria. It is hoped that the findings from the study will provide information on the level of heavy metal pollution and the possible impact on food safety standard and the inherent risk to the consumer population.

2. MATERIALS AND METHODS

2.1 Sampling Area

Jibia Local Government Area was created in May 1989 in Katsina State of Nigeria. The coordinates of Jibia local government area falls within latitude 13°05’18.00’’N and longitude 7°13’2.00’’E, covering an area of 1037km^2, with an average temperature and relative humidity of 29° C and 67% respectively. The local government is bordered to the north by the Niger Republic, to the South by Batsari Local Government, to the east by Katsina Local government, and to the west by Zurmi Local Government area of Zamfara State. The population of the local government area was approximately 169,748 as of 2006 population census (Fig. 1).

2.2 Sampling and Sample Preparation

The selection of sorrel as sample among the vegetables grown in the sampling area was mainly based on its availability and the frequency of its consumption. The leaves of the vegetable sample were collected with the consent of the farmers from the site of sampling using a cleaned and decontaminated polyethylene bag. The edible portion of the vegetable sample was cut into small pieces, washed with tap water and then rinsed with distilled deionized water. These were placed on cardboard papers and dried in open-air in the laboratory for three weeks. The dried samples were then grinded into fine powder using a ceramic pestle and mortar and stored in a stoppered plastic bottle.

2.3 Sample Digestion

The plant sample was digested according to the procedure adopted by Awofolu [14]; whereby 0.5 g of the powdered sample was weighed into a 100 mL beaker and 5 mL of concentrated HNO_3 and 2 mL $HClO_4$ were added. The mixture was then heated on a hot plate at 95^0 C until the solution became clear. It was then filtered into a 100 mL volumetric flask and made up to the mark with distilled water.

2.4 Heavy Metals Determination

“The concentration of heavy metals in the sample was determined using Atomic Absorption Spectrophotometer (Buck 210 VGP Model) equipped with a digital read-out system. Working standards were used, after serial dilution of 1000 ppm metal stock solution in each case. Calibration curves were generated by plotting absorbance values versus concentrations. By interpolation, the concentration of the metals in sample digest was determined as described by Audu and Lawal” [15].

2.5 Heavy Metal Health Risk Assessment

2.5.1 Daily Intake of Metals (DIM)

The ingestion of heavy metals in the samples depicted as daily intake of metals (DIM) was calculated using the following equation.

$$DIM = \frac{Cmetal \ x \ Cfactor \ x \ Dintake}{Bweight} \quad \text{..........eqn. (1)}$$

With Cmetal standing for heavy metal concentration in the sample, Cfactor represents the conversion factor (CF) which was taken as 0.085 [16] used in converting the sample to it dry weight, Dintake represents the daily intake of the sample taken from literature as 0.527 kg person^{-1} d^{-1} [17], and Bweight represents the average body weight which was also taken from the literature as 60 kg [18] for adults and 24 kg [19] for children. The same values were used to evaluate the HRI.

2.5.2 Non-cancer risks

The non-carcinogenic health hazard individual heavy metal to the population around the sampling area from intake of the vegetable sample was evaluated by the computation of the target hazard quotient (THQ) using the equation taken from the literature [20] below.

$$THQ=CDI/RfD \quad \text{………. eqn. (2)}$$

CDI represents the chronic daily heavy metal intake expressed in mg/kg/day and RfD represents the oral reference dose (mg/kg/day) which is a quantification the maximum permissible risk to the consumer from daily exposure throughout an individual life span [21]. Individual reference doses taken from literature were used (Pb = 0.6, Cd = 0.5, Zn = 0.3, Fe = 0.7, Ni = 0.4, Mn = 0.014, Cu=0.04)) [22,23]. In conjunction with the THQ, this research also uses the chronic hazard index (HI) that evaluate the potential risk to the population from exposure from more than one heavy metal, which is the summation of all the hazard quotients (THQ) for each heavy metal for a particular exposure pathway [24], which is computed using the formula below:

$$HI=THQ_1+THQ_2+\cdots+THQ_n \quad \text{……...eqn. (3)}$$

Where the subscripts 1, 2 …., n represent each heavy metal in the sample.

It is taken that the severity of the effect is equal to the total metal exposures and that organs affected by the exposure have similar working mechanism [25]. HI less than 1 infer that the consumer population is safe, while HI above 1 raise the level of concern to the consumer population [26].

2.5.3 Cancer risks

The risk of cancer to the consumer population from intake of the vegetable sample in the study was evaluated with the use of Incremental Lifetime Cancer Risk (ILCR) [27].

$$ILCR= CDI \times CSF \quad \text{...…………………eqn. (4)}$$

With CDI representing the chronic daily intake of individual carcinogenic heavy metal from a lifelong ingestion of the sample expressed in mg/kg, BW/day and CSF representing specific cancer factors for each heavy metal in the sample comparable to the individual weight [20]. Adapted from literature, the cancer slopes for Pb = 0.0085 mg/kg/day [28], Cd = 0.38 mg/kg/day [29,30] where used in this study.

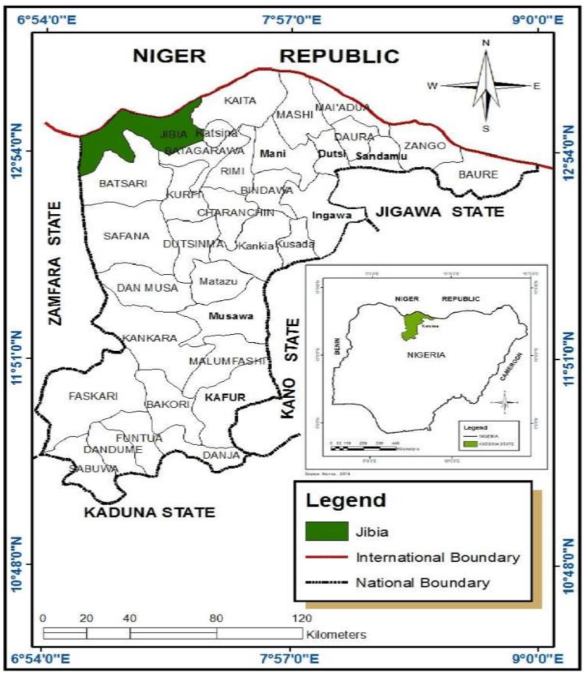

Fig.1. Map of Katsina state showing Jibia local government area (a conflict zone)

ILCR value in a particular sample is representative possibility of the consumer lifetime health risks from exposure to heavy metal carcinogens [31]. The range 10^{-6} to 10^{-4} is considered safe for the consumer population [21]. The CDI was computed by the use of the below equation [27].

$$CDI = (EDI \times EFr \times EDtot)/AT \quad \text{.........eqn. (5)}$$

In which the EDI is the estimated daily intake of metal from intake of the sample; EFr represents the frequency of exposure (365 days/year); EDtot is the length of exposure which is taken as the average life time of 60 years for Nigerians; AT represents the duration of exposure for non-carcinogenic effects (EFr × EDtot), and 60 life years for carcinogenic effect [20]. The Human exposure to more than one carcinogenic heavy metal through food intake may result in cumulative cancer risk, which is the summation of the individual heavy metal increment risks and it is computed as below [27].

$$\sum 1_n = ILCR_1 + ILCR_2 + \cdots + ILCR_n \quad \text{.......... eqn. (6)}$$

With the subscripts 1, 2 …, n representing each carcinogenic heavy metal.

3. RESULTS AND DISCUSSION

3.1 Heavy Metal Concentrations in Cultivated Sorrel Leaves

The result of the mean concentration values of the evaluated heavy metals Pb and Fe from the sample as depicted in Table 1 were higher than the Maximum Allowable Concentrations (MAC) of heavy metals in vegetables [32]. The concentrations of other metals including Cu, Zn, Ni, Mn and Cd evaluated in the sample were within the permissible values as can be observed from Table 1. The order of the sequence of the mean metal concentrations is as follows Fe>Mn>Cu>Zn>Pb>Ni>Cd. The observation that the heavy metals Pb and Fe have values that were above permissible limits suggests that the sample is not safe for human consumption because of the high risk potential. However, the mean values were higher when compared to previously reported values obtained for heavy metals in vegetable samples from Katsina State Nigeria [33,34,35,36,37,38,39]. An observation that can be attributed to the multiple metal contamination sites that are in close proximity to the study site. Mining and smelting activities have been reported to facilitate heavy metals deposition on vegetable leaves (40).

3.2 Non-Cancer Risks

Health risks associated with heavy metals intake through the consumption of food is often evaluated using the target hazard quotient (THQ) and the health risk index (HRI). The result of the Target Hazard Quotient (THQ) associated with the evaluated heavy metals exposure through consumption of the sample for adults and children all were below 1, with exception of the THQ for the heavy metal Fe in the adults and children population and for Mn in the children population that were above 1 (Tables 2 and 3). This is a pointer that the heavy metals Fe and Mn may pose a health risk (non-carcinogenic) to the population living in the area. From the Tables (2 and 3) the combined health risks for all the metals in the sample for the adults and children population represented as the HRI were above 1, an indication that the sample is not safe for consumption. The current result is in disagreement to what was previously reported in studies that evaluated heavy metals in food samples from Katsina State, Nigeria [33,34,35,36,37,38,39].

3.3 Cancer Risks

The result of the Incremental Lifetime Cancer Risk (ILCR) for both the adults and children population as represented in Fig. 2. shows that the heavy metal Ni is beyond the threshold of the safety range for cancer risk. This is an indication that, it can pose a threat of cancer risk to the population living in the area. Earlier studies on heavy metal cancer risks in various food samples conducted in Katsina State have implicated heavy metals in the food samples as possible contributors to the population cancer burden [41,42,43].

Table 1. Heavy metal concentration (mg/kg) in cultivated sorrel leaves sample from Gadirge village, Jibia local government area

Heavy metal	Concentration
Pb	2.5417 ± 0.0532
Cu	6.6229 ± 0.0847
Zn	5.9523 ± 0.0018
Ni	0.9683 ± 0.0162
Fe	2508.1040 ± 0.0342
Mn	11.5811 ± 0.0231
Cd	0.0551 ± 0.0026

Values represent Mean ± Standard deviation of five determinations

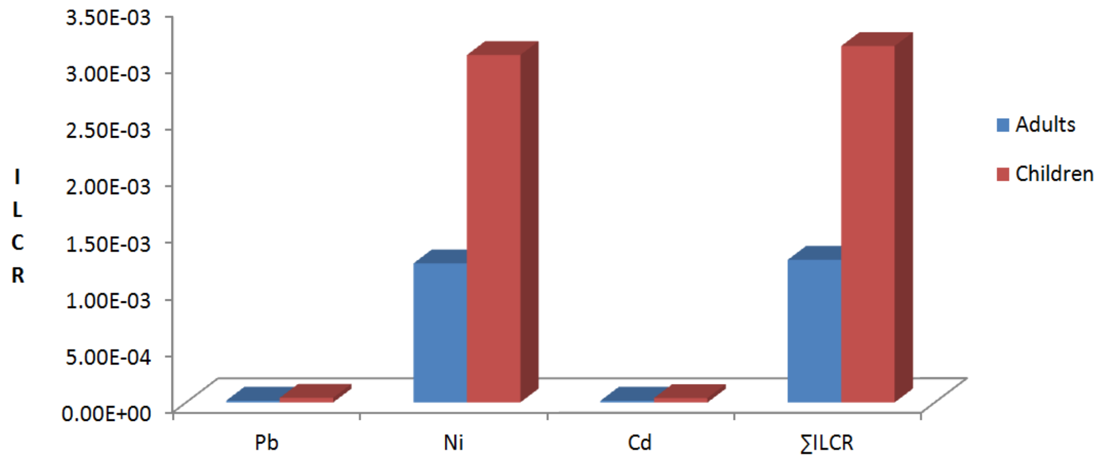

Fig. 2. Incremental life time cancer risk in children and adults from consumption of cultivated sorrel leaf sample from Gadirge village, Jibia local government area, Katsina state, Nigeria

Key: ILCR= Incremental Lifetime Cancer Risk; ∑ILCR= Cumulative Incremental Lifetime Cancer Risk.

Table 2. Estimated daily intake, target hazard quotient and heavy metal health risk index in adults from consumption of cultivated sorrel leaves sample from Gadirge village, Jibia local government

Heavy metal	EDI	THQ
Pb	1.8976E-03	3.1627E-03
Cu	4.9446E-03	0.1236
Zn	4.4439E-03	0.0148
Ni	7.2292E-04	1.8073E-03
Fe	1.8725	2.6750
Mn	8.6463E-03	0.6176
Cd	4.1137E-05	8.2274E-05
HRI		3.4361

Table 3. Estimated daily intake, target hazard quotient and heavy metal health risk index in children from consumption of cultivated sorrel leaves sample from Gadirge village, Jibia local government

Heavy metal	EDI	THQ
Pb	4.7440E-03	7.9067E-03
Cu	0.0124	0.3100
Zn	0.0111	0.0370
Ni	1.8073E-03	4.5183E-03
Fe	4.6813	6.6876
Mn	0.0216	1.5429
Cd	1.0284E-04	2.0568E-04
HRI		8.5901

4. CONCLUSION

The result of the mean concentration values of the evaluated heavy metals Pb and Fe from the sample were higher than the Maximum Allowable Concentrations (MAC) of heavy metals in vegetables. However, the Target Hazard Quotient (THQ) of the sample for adults and children were below 1, with exception of the THQ for the heavy metal Fe in the adults and children population and for Mn in the children population that was above 1. An indication of a health risk to the population. Furthermore, the Incremental Lifetime Cancer Risk (ILCR) for both the adult and children population shows that the heavy metal Ni is beyond the threshold of the safety range for cancer risk. A likelihood of the sample to contribute to the cancer burden of the population.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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