Original Research Article

HEALTH RISK ASSESSMENT OF HEAVY METALS IN VEGETABLE: THE CONTRIBUTION OF ILLEGAL MINING AND ARMED BANDITRY TO HEAVY METAL POLLUTION IN KATSINA STATE, NIGERIA

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. Moringa leaves sample from Jabiyawa 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, Cu 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 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 Cu in the children population that was 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 Life Cancer Risk (ILCR) for both the adults 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 sample as the vegetable may contribute to the disease burden of the population.

Keywords: Vegetables, Children, Heavy metals, Katsina, Banditry, Cattle rustling, Population

1. INTRODUCTION

One of the substantial dangers to environmental and human health is the ever increasing concentrations of heavy metals in the environment (1). Heavy metals are harmful to humans even at low concentrations and are persistent and ubiquitous, as such, their presence in the environment is of grave concern (2; 3).

It has been reported over the years that multiple anthropogenic and natural activities have contributed to the high concentrations of the environmental heavy metal load (4). The scenario is more pronounced in the third world countries with little, or no monitoring and enforcement of environmental regulations (5).

Diverse studies have reported that farmlands that are used for agricultural activities in Katsina State are continuously being loaded with heavy metals from several pollution sources such as agricultural practices, mining and vehicular exhaust (6; 7; 8). The northwestern part of Nigeria where Katsina State is located has of recent, recorded a surge in cattle rustling, kidnappings and rural banditry, with most of the bandits been drawn to the region by illicit and artisanal mining

(9). Although the mining activities have been linked to generation of rural employment with unprecedented poor mining operational practices. This has resulted into the degradation of the land rendering heavy metal pollution of the soils and water sources, which increased heavy metal health risk to the population (9).

The displacement of the population 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 nourishment for their existence.

Vegetables are the most preferred nutrition for people all over the world due to their high content of needed essential nutrients, antioxidants, and metabolites that perform the action of buffers for acidic metabolic intermediates that are produced during the course of digestion (10). Vegetables are a most ingredient of the normal diet because they contain nutritionally vital substances that are required for healthy living (11). The rise in fresh vegetable intake instead of animal protein is based on the ability of vegetables to reduce the prevalence of chronic degenerative diseases and other life cycle related diseases (12).

Vegetables are either eaten fresh or cooked with other food ingredients. But on a sad note, human exposures to heavy metal toxicity have been linked to the intake of vegetables grown on polluted soils (13).

Therefore the present study was aimed at evaluating the heavy metal load and the health risk indices to the population from consumption of Moringa leaves cultivated in Jabiyawa village, Jibia Local Government Area (a conflict zone), Katsina State, Nigeria. 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 consumers.

2. MATERIAL AND METHODS

2.1 SAMPLING AREA

Jibia Local Government Area was created in May 1989 in Katsina State of Nigeria. The coordinate 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 census (Figure 1).

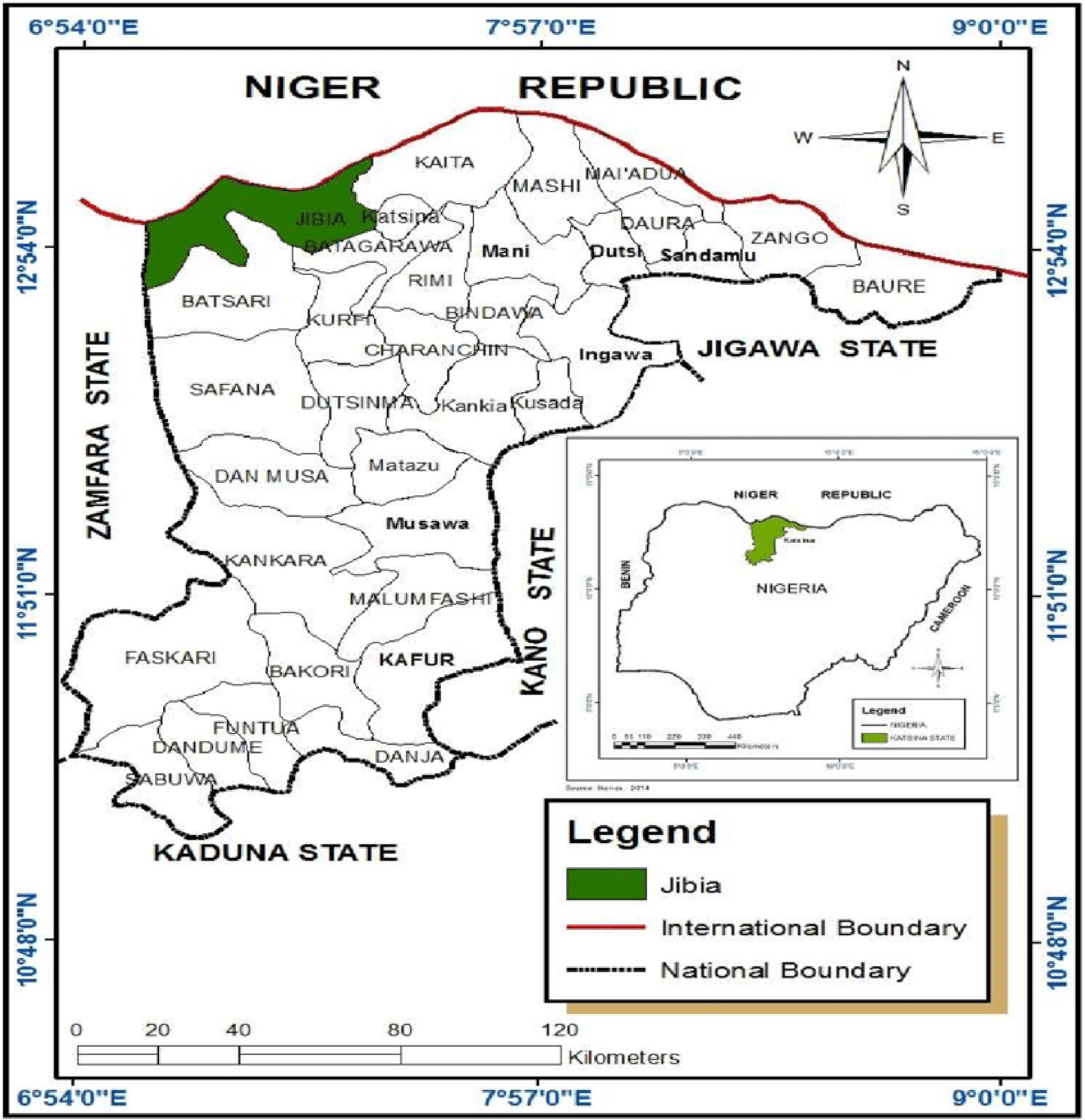

Fig.1. Map of Katsina State showing Jibia Local Government Area (sampling site)

2.2 SAMPLING AND SAMPLE PREPARATION

The selection of Moringa leaves as sample among the vegetables cultivated 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 sampling site 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 the daily intake of metals (DIM) was calculated using the following equation.

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

With Cmetal standing for heavy metal concentration in the sample, Cfactor representing the conversion factor (Cf) which was taken as 0.085 (16) used in converting the sample to it dry weight, Dintake representing the daily intake of the sample taken from literature as 0.527 kg $person^{-1}$ d^{-1} (17), and Bweight representing the average body weight which is 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.

$THQ=CDI/RfD$………..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 of 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:

$HI=THQ_1+THQ_2+\cdots+THQ_n$………..eqn. (3)

Where the subscripts 1, 2 …., n represents 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).

$ILCR= CDI \times CSF$………………………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), Ni = 1.7 mg/kg/day (30) where used in this study.

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).

$CDI = (EDI \times EFr \times EDtot)/AT$……………eqn. (5)

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).

$\sum 1_n = ILCR_1 + ILCR_2 + \cdots + ILCR_n$……………..eqn. (6)

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

3. RESULTS AND DISCUSSION

3.1 HEAVY METAL CONCENTRATIONS IN CULTIVATED CABBAGE LEAVES

The result of the mean concentration values of the evaluated heavy metals Fe, Cu and Pb from the sample as displayed in Table 1 lies above the Maximum Allowable Concentrations (MAC) of heavy metals in leafy vegetables (32). The concentrations of other metals including 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>Cu>Pb>Mn>Zn>Ni>Cd. The observation that the heavy metals Fe, Cu and Pb have mean concentrations that were above the permissible limits suggests that the sample is not safe for human consumption due to the heightened risk potential. However, the mean values were higher when compared to previously reported values obtained for heavy metals in vegetable samples from Katsina State (33; 34; 35; 36; 37; 38; 39). An observation that can be attributed to the multiple mining sites those are in close proximity to the study area. Mining and smelting activities have been reported to facilitate heavy metals deposition on vegetable leaves (40).

Table 1: Heavy Metal Concentration (mg/kg) in Cultivated Cabbage Leaves Sample from Jabiyawa Village, Jibia Local Government Area

Heavy metal	Concentration
Pb	11.4292 ± 0.0666
Cu	25.7401 ± 0.0767
Zn	4.8919 ± 0.0005
Ni	0.5180 ± 0.0137
Fe	732.2059 ± 0.0282
Mn	7.3686 ± 0.0438
Cd	0.0375 ± 0.0043

Values represent Mean ± Standard deviation of five determinations

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 Cu in the children population that was above 1 (Tables 2 and 3). This is a pointer that the heavy metal Cu may pose a health risk (non-carcinogenic) to the children 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 Katsina State (33; 34; 35; 36; 37; 38; 39).

Table 2: Estimated Daily Intake, Target Hazard Quotient and Heavy Metal Health Risk Index in Adults from Consumption of Cultivated Moringa Leaves Sample from Jabiyawa Village, Jibia Local Government

Heavy metal	EDI	THQ
Pb	8.5328E-03	0.0142
Cu	0.0192	0.4800
Zn	3.8373E-03	0.0121
Ni	3.8673E-04	9.6683E-04
Fe	0.5467	0.7810
Mn	5.5013E-03	0.3930
Cd	2.7997E-05	5.5994E-05
HRI		1.6813

Table 3: Estimated Daily Intake, Target Hazard Quotient and Heavy Metal Health Risk Index in Children from Consumption of Cultivated Moringa Leaves Sample from Jabiyawa Village, Jibia Local Government

Heavy metal	EDI	THQ
Pb	0.0213	0.0355
Cu	0.0481	1.2025
Zn	9.0932E-03	0.0303
Ni	9.6683E-04	2.4171E-03
Fe	1.3666	1.9523
Mn	0.0138	0.9857
Cd	6.9992E-05	1.3998E-04
HRI		4.2089

3.3 CANCER RISKS

The result of the Incremental Lifetime Cancer Risk (ILCR) for both the adults and children population as represented in Figure 2 shows that the heavy metal Ni is beyond the threshold of the safety limit for cancer risk. This is an indication that the vegetable 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).

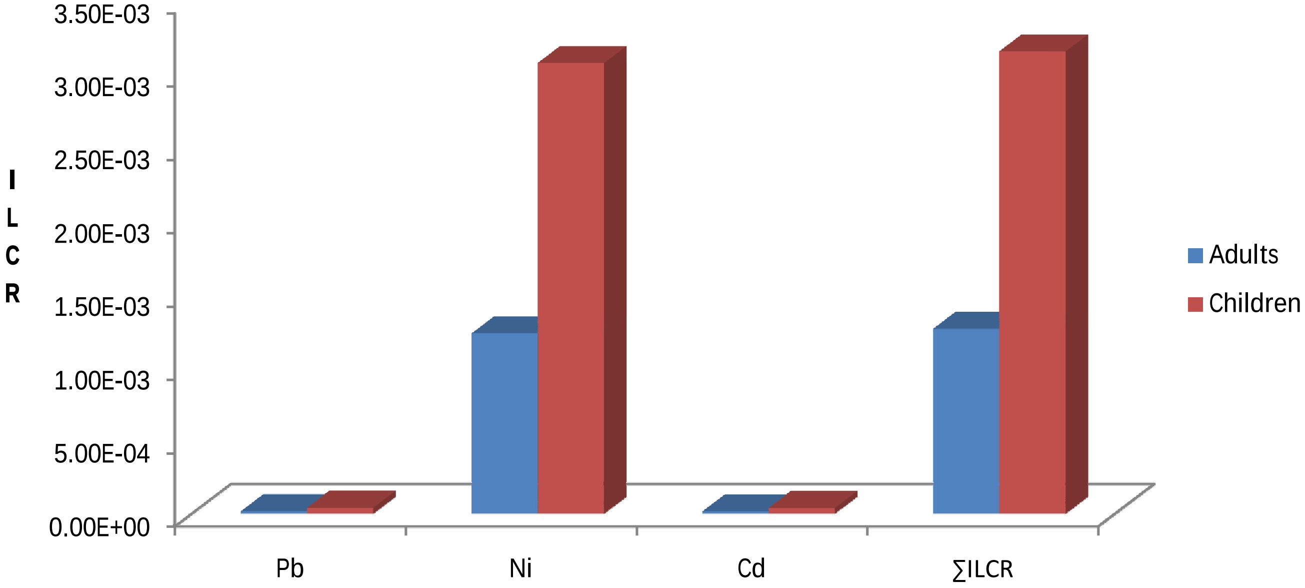

Fig. 2 Incremental Life Time Cancer Risk in Children and Adults from Consumption of Cultivated Moringa Leaf Sample from Jabiyawa Village, Jibia Local Government Area, Katsina State, Nigeria

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

4. CONCLUSION

The result of the mean concentration values of the evaluated heavy metals Fe, Cu and Pb from the sample lies above the Maximum Allowable Concentrations (MAC) of heavy metals in leafy vegetables. However, the Target Hazard Quotient (THQ) for adults and children all were below 1, with exception of the THQ for the heavy metal Cu in the children population that was above 1. Furthermore, the Incremental Lifetime Cancer Risk (ILCR) for both the adults and children population shows that the heavy metal Ni is beyond the threshold of the safety limit for cancer risk.

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