Original Research Article

HEALTH RISK ASSESSMENT OF HEAVY METALS IN A VEGETABLE CULTIVATED ON LAND POLLUTED THROUGH ILLEGAL MINING

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 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 metals Fe and Mn in the adults and 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 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 sample as the vegetable may contribute to the disease burden of the population.

Keywords: Vegetables, Nutrition, Heavy metals, Katsina, Banditry, Cattle rustling, Pollutants

1. INTRODUCTION

One of the significant threats to environment and human health is the steep elevation in concentrations of heavy metals in the environment (1). The unique ability of heavy metals to cause harm to humans even at trace concentrations and coupled with their persistence and ubiquity, their presence in the environment is attracting much attention (2; 3).

It has been shown over the years that a multitude of anthropogenic and natural activities contribute to high levels of heavy metals in the environment (4). The condition is more prominent in underdeveloped and developing countries with a poor record of assessment and enforcement of environmental legislations (5).

Farmlands used for agricultural activities in Katsina State are increasingly being contaminated with heavy metals via numerous pollution channels such as horticultural practices, mining and automotive exhaust (6; 7; 8).

Katsina State which is located in the northwestern part of Nigeria has witnessed a proliferation in the activities of cattle rustlers, kidnappers and rural bandits, which have 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 situation (9). Even 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 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. This has led to the emergence of a scenario where vegetables that are cultivated on contaminated soil or irrigated with metal contaminated water forming a bulk of the diet of the internally displaced populace with the attendant consequential health risks.

The consumption of vegetables by the people is on the increase all over the world because they contain essential components that function as essential nutrients, antioxidants, and metabolites that participate as buffers for acidic products of digestion (10). Vegetables form a vital component of the normal diet because they are composed of nutritionally useful substances that are needed for human existence (11).

The worldwide increase in fresh vegetable intake instead of animal based protein is based on the capacity of vegetables to lower the incidence of chronic disease and other life-cycle related ailments (12). But on a sad note, toxicity that usually arose from human exposures to heavy metal has been attributed to the consumption 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 Lettuce leaf cultivated in Gadirge 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).

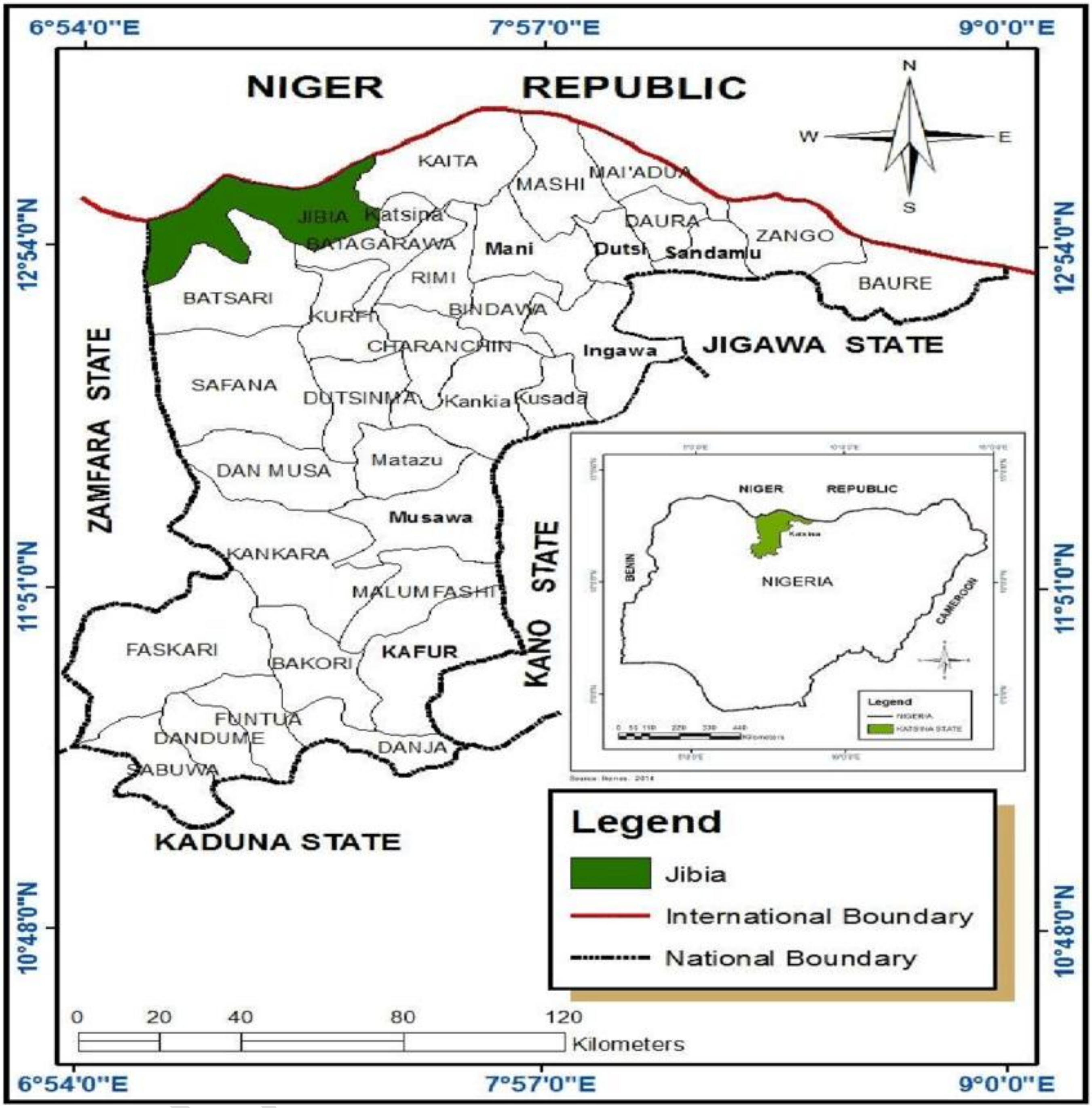

Fig.1. Map of Katsina State showing Jibia Local Government Area (sampling site)

2.2 SAMPLING AND SAMPLE PREPARATION

The selection of Lettuce 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. After grinding the powdered sample was stored in a stoppered plastic bottle.

2.3 SAMPLE DIGESTION

The plant sample was digested using a procedure adopted from Awofolu (14); in brief, 0.5 g of the powdered sample was measured into a 100 mL beaker and 5 mL of concentrated HNO_3 and 2 mL $HClO_4$ were added and then heated on a hot plate at 95^0C until a clear solution was formed. The solution 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 the heavy metals in the sample was evaluated 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 = $\frac{Cmetal\ x\ Cfactor\ x\ Dintakel}{Bweight}$ …………………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 x 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 x EFr x 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 represent 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 LETTUCE LEAVES

The result of the mean concentration values of the evaluated heavy metals Pb and Fe in the lettuce leaf 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 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>Zn>Cu>Pb>Ni>Cd. The observation that the heavy metals Pb and Fe have values that were higher than the regulatory bodies permissible limits is a pointer that the consumption of sample by the population is not safe because of the potentially high health risk. Also, the mean heavy metals concentrations of the sample was higher than the reported mean heavy metals concentrations in studies that evaluate heavy metals in various food samples that were earlier conducted in Katsina State, Nigeria (33; 34; 35; 36; 37; 38; 39). The Apparent higher value obtained may not be unconnected with the illegal mining and metal artisanal sites that are located within the vicinity of the sampling 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 Lettuce Leaves Sample from Gadirge Village, Jibia Local Government Area

Heavy metal	Concentration
Pb	4.9741 ± 0.0568
Cu	5.0526 ± 0.0465
Zn	6.5061 ± 0.0013
Ni	1.5078 ± 0.0185
Fe	3000.1560 ± 0.0538
Mn	22.7785 ± 0.0613
Cd	0.0654 ± 0.0041

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 metals Fe and Mn in the adults and 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 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 Lettuce Leaves Sample from Gadirge Village, Jibia Local Government Area

Heavy metal	EDI	THQ
Pb	3.7136E-03	6.1893E-03
Cu	3.7722E-03	0.0943
Zn	4.6859E-03	0.0156
Ni	1.1257E-03	2.8143E-03
Fe	2.2399	3.1999
Mn	0.0170	1.2143
Cd	4.8827E-0S	9.7654E-05
HRI		4.5332

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

Heavy metal	EDI	THQ
Pb	9.2840E-03	0.0155
Cu	9.4305E-03	0.2358
Zn	0.0117	0.0390
Ni	2.8143E-03	7.0358E-03
Fe	5.5997	7.9996
Mn	0.0425	3.0357
Cd	1.2207E-04	2.4414E-04
HRI		11.3329

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, 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).

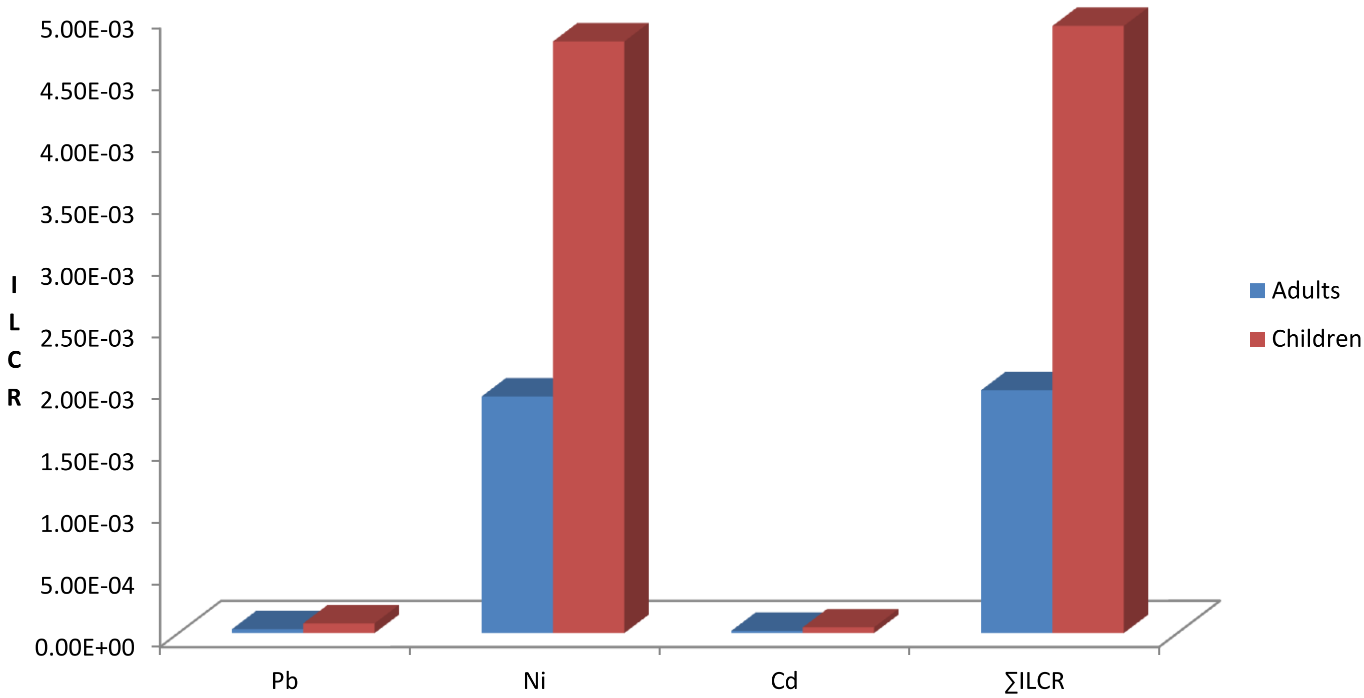

Fig. 2 Incremental Life Time Cancer Risk in Children and Adults from Consumption of Cultivated Lettuce Leaves Sample from Gadirge Village, Jibia Local Government Area, Katsina State, Nigeria

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 Pb and Fe in the lettuce leaves sample lies above the Maximum Allowable Concentrations (MAC) of heavy metals in leafy vegetables. However, 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 metals Fe and Mn in the adults and children population that were above 1. Moreover, 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 risks.

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