Original Research Article

ILLEGAL MINING AND ARMED BANDITRY IN KATSINA STATE, NIGERIA: WHAT IS THEIR CONTRIBUTION TO THE HEAVY METAL POLLUTION OF A POPULARLY CONSUMED VEGETABLE?

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 Makiya 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 metal Pb from the sample falls above the Maximum Allowable Concentrations (MAC) of heavy metals in leafy vegetables. The concentrations of the other metals including Fe, 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. The combined health risks for all the metals in the sample for the adults and children population represented as the HRI were below 1, the result of the Incremental Life Cancer Risk (ILCR) for both the adults and children population shows that all the heavy metals have ILCR that falls within the safety limit for cancer risk. It can be deduced that the vegetable sample is safe for consumption.

Keywords: Vegetables, Health risk, Heavy metals, Katsina, Banditry, Cattle rustling, Pollution

1. INTRODUCTION

Among the most important danger to environmental and human health is an increase in the levels of heavy metals in the environment (1). Heavy metals are toxic even at low concentrations and coupled with their being persistent and ubiquitous, their presence in the environment is a cause for increased health security concern (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 condition is more prevalent in underdeveloped and developing countries with a poor record of monitoring and enforcement of environmental regulations (5).

Studies carried out in Katsina State, Nigeria, have reported that agricultural fields used for cultivation in the state are increasingly being polluted with heavy metals through multiple pollution channels such as horticultural practices; mining and automobile exhaust (6; 7; 8).

The northwestern part of Nigeria where Katsina State is located has of recent, 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 main motivators of the situation (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 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 and are an integral portion of the normal diet for people all over the world because they contain nutritionally vital substances that are high in important nutrients, antioxidants, and metabolites that function as buffers for acidic compounds created during digestion (10; 11).

World over, the increase in fresh vegetable intake instead of animal based protein is based on the ability of vegetables to reduce the occurrence of chronic diseases and other age-related diseases (12). But on a sad note, human exposures to heavy metal toxicity have been linked to the consumption of vegetables grown on polluted soils (13).

Therefore the present study was aimed at evaluating the heavy metal loads and the health risk indices to the population from consumption of Cabbage leaf cultivated in Makiya 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).

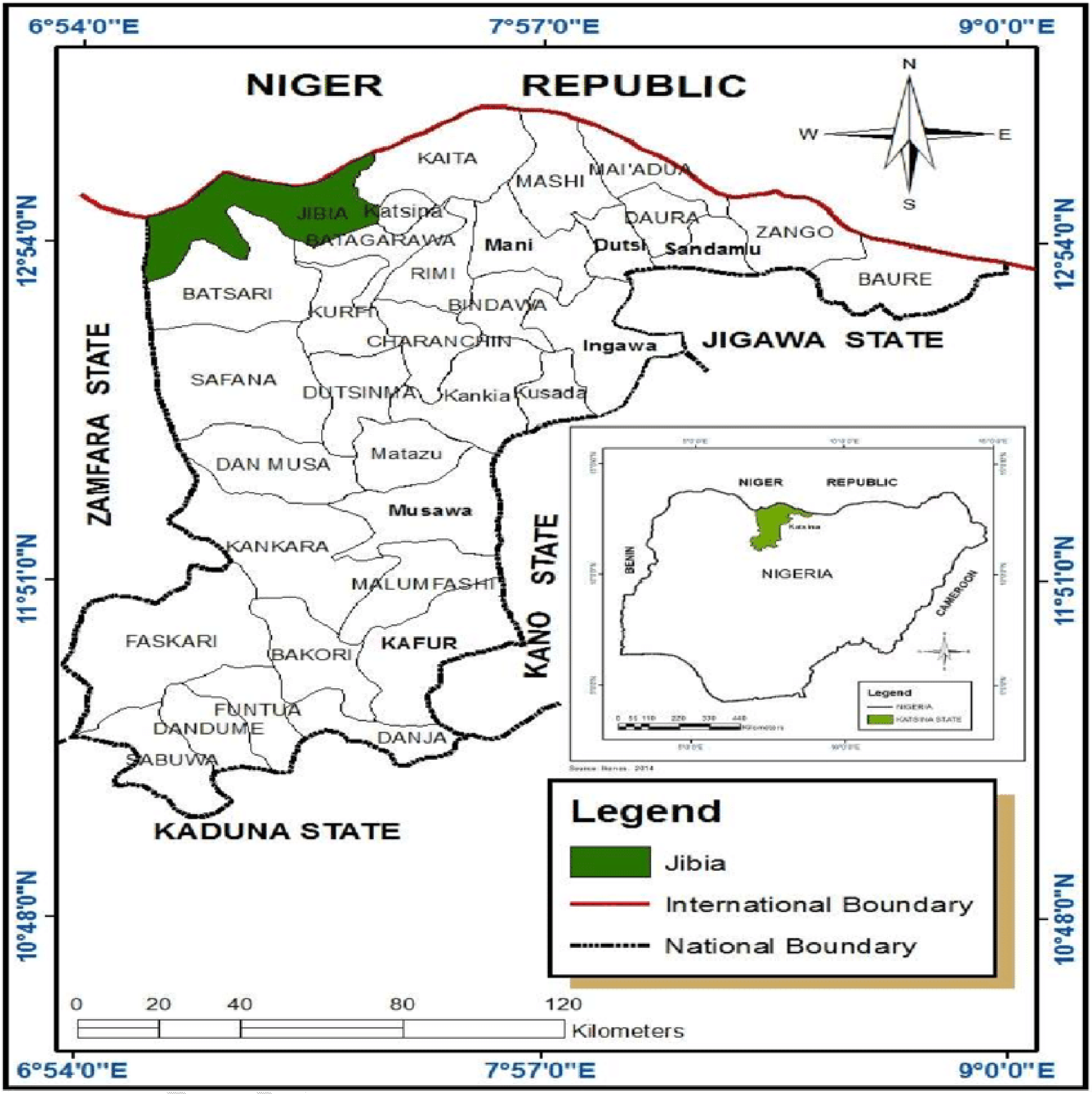

Fig.1. Map of Katsina State showing Jibia Local Government Area (sampling site)

2.2 SAMPLING AND SAMPLE PREPARATION

The selection of Cabbage 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 95^0C 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.

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

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.

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

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 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:

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

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 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 in the cabbage leaf sample as displayed in Table 1 lies within the Maximum Allowable Concentrations (MAC) of heavy metals in leafy vegetables (32), with the exception of the mean concentration value of the heavy metal Pb that was above the permissible limit. The order of the sequence of the mean metal concentrations is as follows Pb>Mn>Fe>Cu>Zn>Ni. As seen from the results, the heavy metal Pb concentration that was above permissible limit of Pb in vegetables offers the suggestion that the sample is not safe for human consumption because of the high risk potential. In addition, the Pb and Mn mean values of the sample were higher than the reported mean values 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 values obtained may not be unconnected with the illegal mining 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 Cabbage Leaves Sample from Makiya Village, Jibia Local Government

Heavy metal	Concentration
Pb	4.3310 ± 0.0252
Cu	0.4310 ± 0.0128
Zn	0.1773 ± 00555
Ni	0.0094 ± 0.0002
Fe	1.0635 ± 0,0040
Mn	1.2054 ± 0.0003
Cd	BDL

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 (Tables 2 and 3). 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 below 1, an indication that the sample is safe for consumption. The current result is in agreement 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 Cabbage Leaves Sample from Makiya Village, Jibia Local Government

Heavy metal	EDI	THQ
Pb	3.2335E-03	5.3892E-03
Cu	3.3671E-04	8,4178E-03
Zn	1.3237E-04	4.4123E-04
Ni	7.0179E-06	1.7545E-05
Fe	7.9399E-04	1.1343E-03
Mn	8.9993E-04	0.0643
Cd	BDL	BDL
HRI		0.0797

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

Heavy metal	EDI	THQ
Pb	8.0836E-03	0.0135
Cu	8.4177E-04	0.0210
Zn	3.3092E-04	1.1031E-03
Ni	1.7545E-05	4.3863E-05
Fe	1.9850E-03	2.8357E-03
Mn	2.2498E-03	0.1607
Cd	BDL	BDL
HRI		0.1992

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 all the carcinogenic heavy metals have ILCR values that falls within the safe level for cancer risks (10^{-5}). This is an indication that consumption of the sample may not pose a cancer risk to the population. The result is in contrast to earlier studies on heavy metal cancer risks in various food samples conducted in Katsina State that have implicated heavy metals in the food samples as possible contributors to the population cancer burden (41; 42; 43).

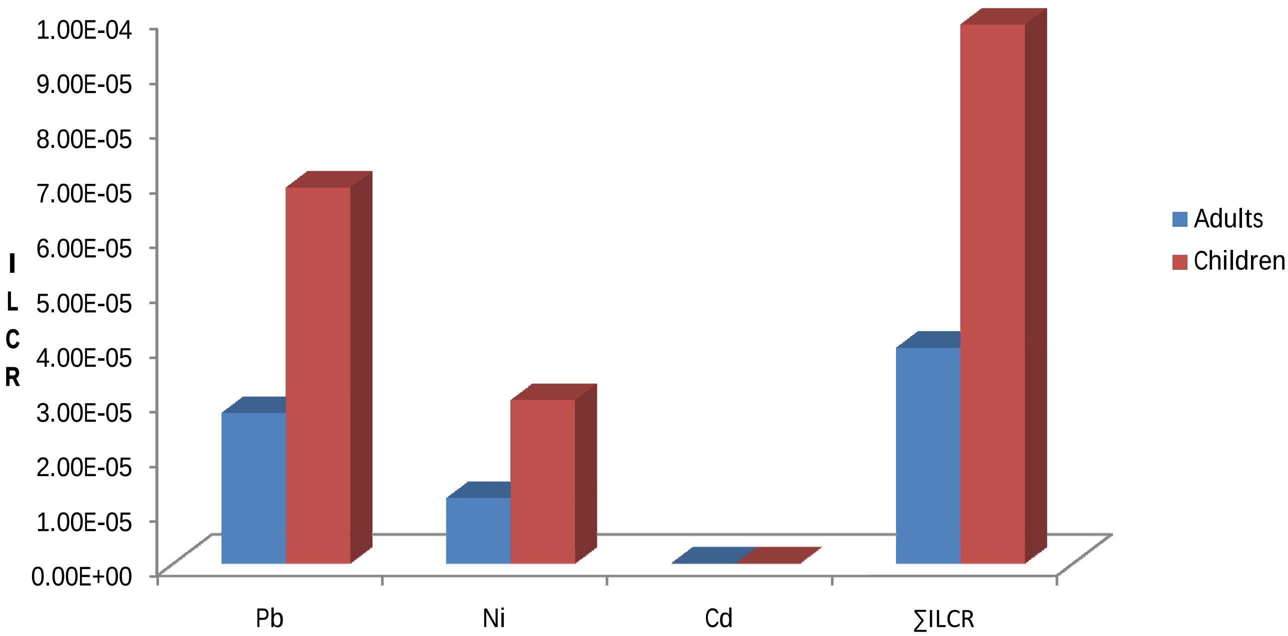

Fig. 2 Incremental Life Time Cancer Risk in Children and Adults from Consumption of Cultivated Cabbage Leaves Sample from Makiya Village, Jibia Local Government Area, Katsina State, Nigeria
Key: ILCR= Incremental Lifetime Cancer Risk; ∑ILCR= Cumulative Incremental Lifetime Cancer Risk.

4. CONCLUSION

The result of the mean concentration values of the evaluated heavy metals in the cabbage leaves sample as displayed in Table 1 lies within 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 were below 1, the combined health risks for all the metals in the sample for the adults and children population represented as the HRI were below 1. Moreover, the Incremental Lifetime Cancer Risk (ILCR) for both the adults and children population shows that all the carcinogenic heavy metals have ILCR values that falls within the safe level for cancer risks (10^{-5}).

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