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# **HEAVY METALS AND HEALTH RISK BURDEN, HOW SAFE IS THE CONSUMER POPULATION?: A STUDY ON THE HEAVY METAL CONTENT OF SOYBEANS CULTIVATED IN KATSINA STATE, NORTH WEST NIGERIA**

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## **ABSTRACT**

The level of heavy metals in soybeans samples were evaluated to ascertain their likely health risks to the Katsina State populace. Atomic absorption spectrometry method was employed for the evaluation, while the three senatorial zones of the state were used for sampling. Using methods adapted from the United States Environmental Protection Agency (US EPA), the health risks to the population from the heavy metals in the samples were determined. The results have revealed the mean concentration (mg/kg) in decreasing order of concentrations to be for Zn (range: 1.204-1.432), Pb (range: 0.658-0.998), Fe (range: 0.563-0.687), Cr (range: 0.128-0.151) and Cd (range: 0.041-0.046), with the concentrations of Mn and Ni below the level of detection. The computed non-carcinogenic health risks from consumption of the samples were below 1 (THQ and HI>1). The cancer risk to the population lies beyond the threshold limit with the heavy metal Pb being the major contributor to the violation. It may be presumed that the Soybean samples in the study may add to the cancer manifestations in the population.

**Keywords:** Soybeans, Heavy metals, Health risks, Katsina, Carcinogenic, Pollution, Cancer Risk

## **1. INTRODUCTION**

Toxicities arising from pollution by heavy metals are worrisome, due to their unique ability to persist in environmental components (soil, water and air) leading to their bioaccumulation and biomagnification in food components and can result in deleterious devastation consequences that may take the form of carcinogenesis, mutations, and neurological problems (1- 3).

“Of recent, exposures to environmental toxic metals have become a global public health concern owing to their potential bioaccumulation and their deleterious health effects in humans” (4- 7). “Environmental exposure to heavy metals is a well-known risk factor for cancers (8) as chronic exposure to high levels of toxic metals has been associated with higher risk of cancers of the bladder, kidney, liver, pancreas, lung, and skin (9) and many visceral organs diseases”. “Because of heavy metals influence on disease systems and organs heavy metals exposure may also lead to cardiovascular, nervous, urinary and reproductive disease, as well as aggravation of pre-existing symptoms and disease” (10). “Evidence suggests that these toxic metals may have adverse effects on these outcomes even at lower concentrations (7), which might be prevalent in many parts of the world”.

Research in heavy metals in foods locally produced in Katsina State and their possible health risks to the population is in its infancy, a situation that results into paucity of information on the contribution of these notable pollutants to the disease burden of the Katsina State population.

This work contributes to the monitoring of heavy metal exposure in soybeans cultivated in Katsina State, Nigeria and possible carcinogenic and non-carcinogenic risk to the population.

33 **2. MATERIALS AND METHODS**

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35 **2.1 STUDY AREA**

36 The study was conducted in Katsina State, North western part of Nigeria covering an area that span 24,192 km<sup>2</sup> (9,341  
37 m<sup>2</sup>) and globally positioned at latitude 12<sup>o</sup>15'N and longitude of 7<sup>o</sup>30'E (11). The month of April heralds the beginning of  
38 the rainy season which ends in October, with the dry season starting in November and ending in March. The average  
39 annual rainfall is 1,321 mm, an average temperature of 27.3 °C, and a relative humidity of 50.2%. The soil is alluvial flood  
40 plain that varies base on location, having good water holding capacity and low in contaminants (11). Sampling was  
41 conducted in five local government areas (Matazu; Funtua; Dabai/Danja; Malumfashi; Kafur) located in the southern part  
42 of Katsina State (Figure 1).

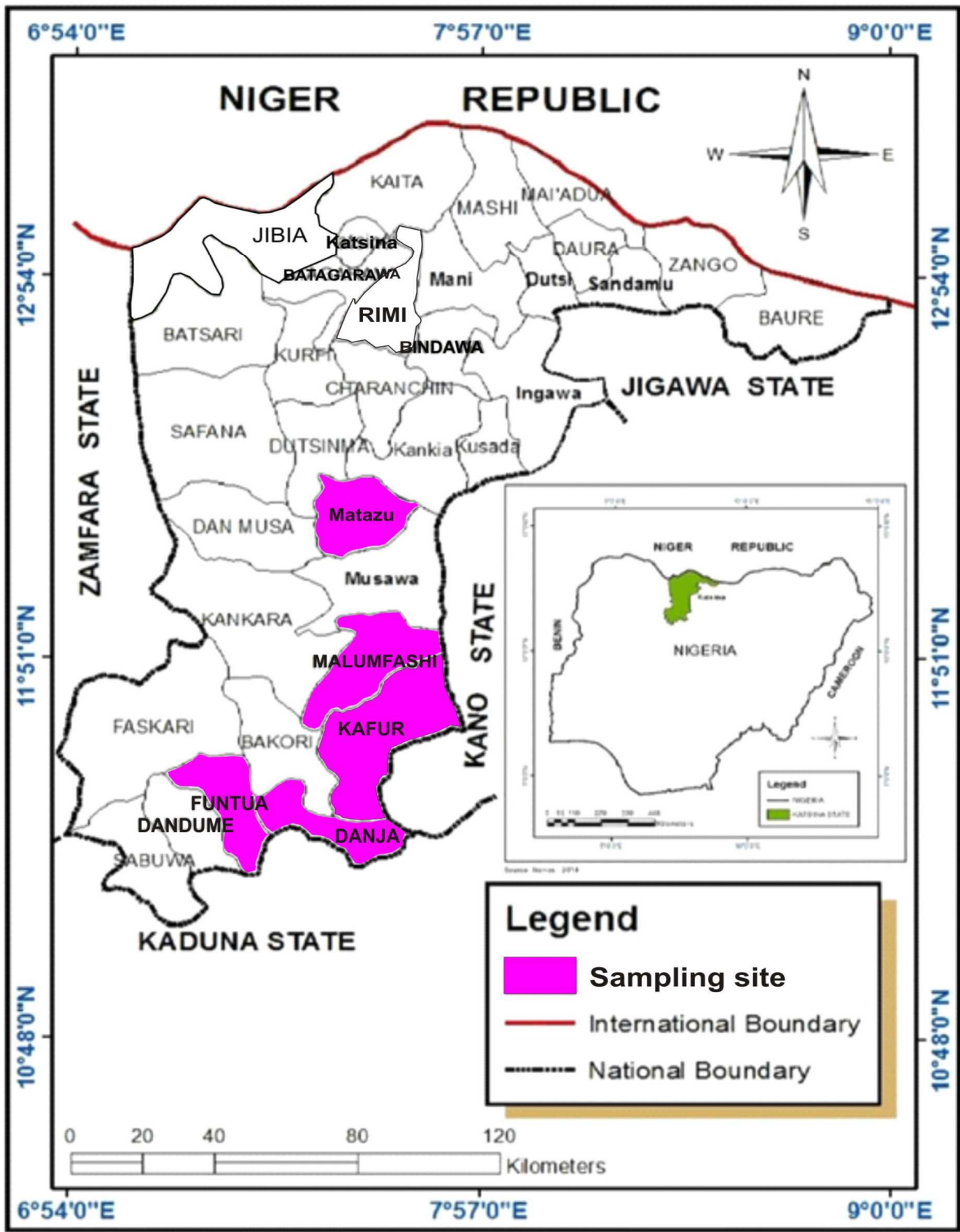


Figure 1: Map of Katsina State showing the designated sampling sites

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48 **2.2 SAMPLING**

49 The catchment areas for sampling for this work were divided into five (5) locations, which were subdivided further into  
50 twenty (20) sampling sites. Sampling (1kg per sample) was done in each of the site and thereby combined to form bulk  
51 sample, with a representative sample (1kg) obtained from the bulk. Glass Bottles (code named) were used to store the  
52 samples for protection against contamination and moisture at a temperature of 4 °C prior to analysis.

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54 **2.3 SAMPLE PREPARATION**

55 After cleaning of the samples by removing all impurities and drying at room temperature, 300 g of the sample was grinded  
56 to a fine powder and stored under the same condition as the duplicate portion prior to analysis.

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58 **2.4 HEAVY METALS DETERMINATION**

59 A Gallenkamp hotbox oven (CHF097XX 2.5) was used to dry 5 g of each of the powdered sample at 80 °C for 2 hours  
60 and then blended using an electric blender, which was followed by ashing 0.5 g of the sample in an electric muffle furnace  
61 (Thermolyne FB131DM Fisher Scientific) at 550 °C for 24 hours. The ash was diluted with a mixed ratio of 3:1  
62 concentrated hydrochloric acid (HCl) and concentrated nitric acid (HNO<sub>3</sub>) and allowed to stand for a while. To make up to  
63 100 ml mark, 50 ml of distilled water was added to the diluents. Using standard methods [method 986.15] (12), the levels  
64 of heavy (Pb, Zn, Ni, Cd, Cr, Mn and Fe) metals in the soybeans samples were determined using AA210RAP BUCK  
65 Atomic Absorption Spectrometer flame emission spectrometer filter GLA-4B Graphite furnace (East Norwalk USA)) and  
66 the metal concentrations expressed in mg/kg.

67  
68 **Table 1: Background Information of the Atomic Absorption Spectrophotometer Used in the Study**

| Metal | Detection limit mg/l | Sensitivity check mg/l | Wavelength Nm | Linear range | Slit Nm |
|-------|----------------------|------------------------|---------------|--------------|---------|
| Fe    | 0.050                | 2.5                    | 248.3         | 5.0          | 0.2     |
| Pb    | 0.080                | 10.0                   | 283.3         | 20           | 0.7     |
| Mn    | 0.030                | 1.25                   | 279.5         | 2.50         | 0.7     |
| Zn    | 0.005                | 0.5                    | 213.9         | 2.50         | 0.7     |
| Cd    | 0.010                | 0.75                   | 228.9         | 2.0          | 0.7     |
| Cr    | 0.040                | 2.0                    | 357.9         | 2.0          | 0.7     |

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71 **2.5 HEAVY METAL HEALTH RISK ASSESSMENT**

72 **2.5.1 Daily intake of metals (DIM)**

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

75 
$$DIM = \frac{C_{meta} \times C_{factor} \times D_{intake}}{B_{weight}} \dots\dots\dots \text{eqn. (1)}.$$

76 With C metal standing for heavy metal concentration sample, C factor representing the conversion factor (CF) which was  
77 taken as 0.085 used in converting the soybean samples to their dry weight, D intake representing the daily intake of the  
78 sample taken from literature as 0.527 kg person<sup>-1</sup> d<sup>-1</sup> (13), and B weight representing the average body weight which is  
79 also taken from the literature as 60 kg (14) for adults and 24 kg (15) for children. The same values were used to evaluate  
80 the HRI.

82 **2.5.2 Non-cancer risks**

83 The target hazard quotient (THQ), which gives an idea of the non-carcinogenic risks to the consumer population from  
84 intake of heavy metals were determined using the following equation (16).

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

86 CDI represent the chronic daily heavy metal intake expressed in mg/kg/day and RfD represents the oral reference dose  
87 (mg/kg/day) which is quantification the maximum permissible risk to the consumer from daily exposure throughout an  
88 individual life span (17). Individual reference doses taken from literature were used (Pb = 0.6, Cd = 0.5, Zn = 0.3, Fe =  
89 0.7, Ni = 0.4, Mn = 0.014, Cr = 0.3) (18; 19). In conjunction with the THQ this research also uses the chronic hazard index  
90 (HI) that evaluate the potential risk to the population from exposure from more than one heavy metal, which is the  
91 summation of all the hazard quotients (THQ) for each heavy metal for a particular exposure pathway (20), which is  
92 computed using the formula below:

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

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

95 It is taken that the severity of the effect is equal to the total metal exposures and that organs affected by the exposure  
96 have similar working mechanism (21). HI less than 1 infer that the consumer population is safe, while HI above 1 raise the  
97 level of concern to the consumer population (22).

98 **2.5.3 Cancer risks**

99 The risks of cancer to the consumer population from intake of the soybeans samples in the study were evaluated with the  
100 use of Incremental Lifetime Cancer Risk (ILCR) (23).

101  $ILCR = CDI \times CSF \dots \dots \dots \text{eqn. (4)}$ .

102 With CDI representing the chronic daily intake of individual carcinogenic heavy metal from a lifelong ingestion of the  
103 sample expressed in mg/kg, BW/day and CSF representing specific cancer factors for each heavy metal in the sample  
104 comparable to the individual weight (16). Adapted from literature, the cancer slopes for Pb = 0.0085 mg/kg/day (24), Cd =  
105 0.38 mg/kg/day (25) where used in this study.

106 ILCR value in a particular sample is representative possibility of the consumer lifetime health risks from exposure to heavy  
107 metal carcinogens (26). The range  $10^{-6}$  to  $10^{-4}$  is considered safe for the consumer population (17). The CDI was  
108 computed by the use of the below equation (23).

109  $CDI = (EDI \times EFr \times ED_{tot}) / AT \dots \dots \dots \text{eqn. (5)}$

110 In which the EDI is the estimated daily intake of metal from intake of the samples; EFr represents the frequency of  
111 exposure (365 days/year); ED<sub>tot</sub> is the length of exposure which is taken as the average life time of 60 years for  
112 Nigerians; AT represent the duration of exposure for non-carcinogenic effects (EFr x ED<sub>tot</sub>), and 60 life years for  
113 carcinogenic effect (16). The Human exposure to more than one carcinogenic heavy metal through food intake may result  
114 in cumulative cancer risk is the summation of the individual heavy metal increment risks and it is computed as below (23).

115  $\sum I_n = ILCR_1 + ILCR_2 + \dots + ILCR_n \dots \dots \dots \text{eqn. (6)}$ .

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

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119 **3. RESULTS**

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121 The current work evaluated the presence of heavy metals in soybeans, one of the major legumes that are consumed by  
122 the population of Katsina State, Nigeria. As portrayed in table 2, the mean concentration (mg/kg) in decreasing order of  
123 concentrations to be Zn (range: 1.204-1.432), Pb (range: 0.658-0.998), Fe (range: 0.563-0.687), Cr (range: 0.128-0.151)  
124 and Cd (range: 0.041-0.046), with the concentrations of Mn and Ni below the level of detection. The heavy metal Pb mean

125 value in the sample was above the permissible values for Pb in legumes, while the remaining heavy metals evaluated  
126 exhibited mean values that were within the permissible range.

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**Table 2: Heavy Metal Concentration (mg/kg) in Cultivated Soybean Samples from Katsina State**

| Location    | Heavy metal |                |               |               |     |               |               |
|-------------|-------------|----------------|---------------|---------------|-----|---------------|---------------|
|             | Mn          | Zn             | Pb            | Cd            | Ni  | Fe            | Cr            |
| Kafur       | BDL         | 1.204 ± 0.0130 | 0.658± 0.0002 | 0.045± 0.0003 | BDL | 0.687± 0.0010 | BDL           |
| Malumfashi  | BDL         | 1.347± 0.0002  | 0.998± 0.0003 | 0.046± 0.0001 | BDL | 0.563± 0.0002 | 0.15± 0.0006  |
| Dabai/Danja | BDL         | 1.432± 0.0002  | 0.926± 0.0008 | 0.041± 0.0003 | BDL | 0.648± 0.0004 | 0.128± 0.0003 |
| Funtua      | BDL         | 1.381± 0.0004  | 0.673± 0.0003 | 0.046± 0.0003 | BDL | 0.652± 0.0002 | 0.147± 0.0002 |
| Matazu      | BDL         | 1.257± 0.0008  | 0.913± 0.0003 | 0.042± 0.0006 | BDL | 0.574± 0.0004 | 0.132± 0.0007 |

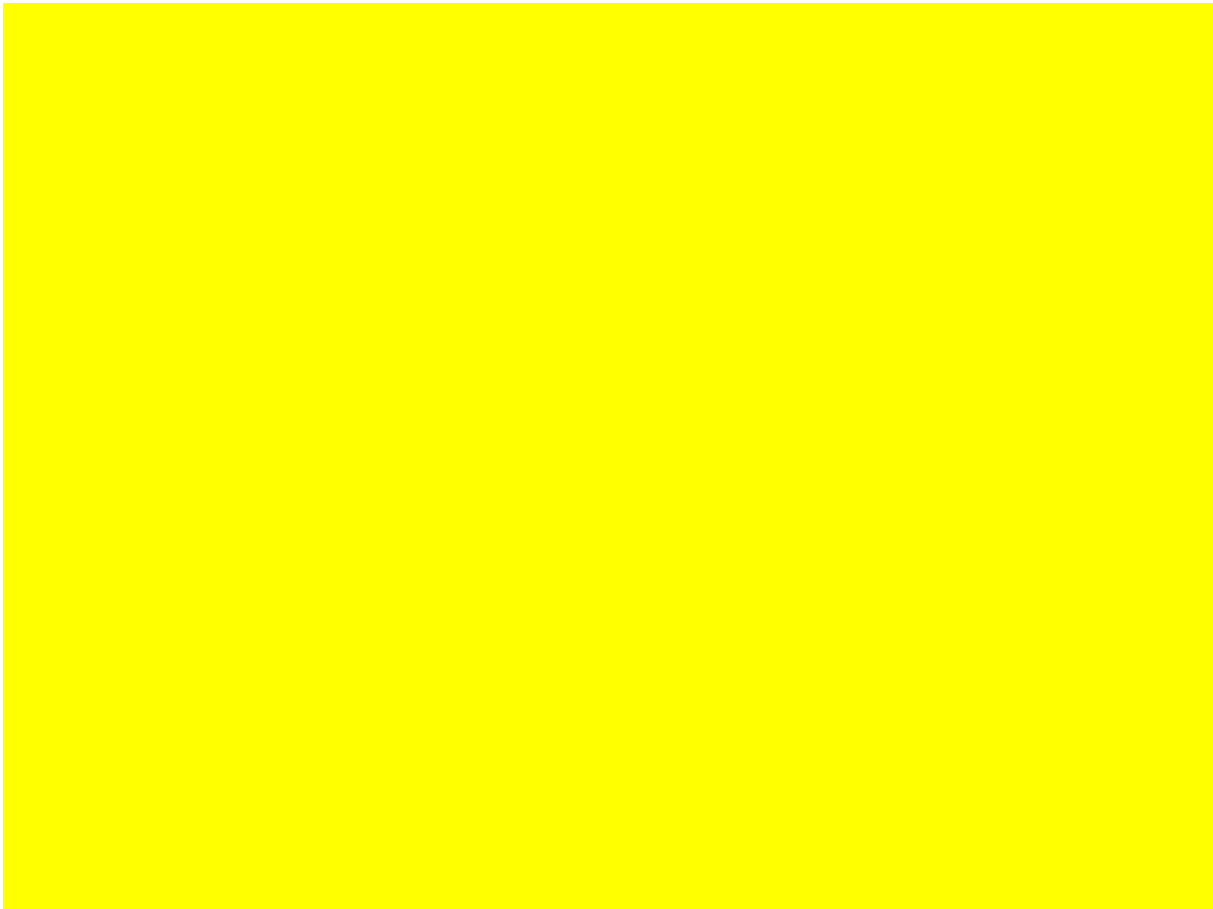
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132 The results for the calculated daily intake of the heavy metals from ingestion of the soya bean samples were displayed in  
133 Figures 1 and 2. Compared to the daily intake limit for heavy metals in legumes as set by the USEPA (27), all the  
134 calculated metal intakes were within the permissible limit. The sequential order for the daily metal intake of heavy metals  
135 from the designated sampling locations is represented as: Kafur (Zn>Pb>Fe>Cd); Malumfashi (Zn>Pb>Fe>Cr>Cd);  
136 Dabai/Danja (Zn>Pb>Fe>Cr>Cd); Funtua (Zn>Pb>Fe>Cr>Cd); Matazu (Zn>Pb>Fe>Cr>Cd). The sequential order being  
137 the same in both the children and adult's consumer population.

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Tables 3 and 4 represent the THQ and HRIs in the children and adult population from consumption of the soybean samples. It is observable from the displayed results that the THQ value is below 1, with the heavy metal Zn of the sample from Dabai/Danja with the highest THQ (0.0036 in adult; 0.0084 in children) and the heavy metal Cd in the Dabai/Danja sample (0.00006 in adult; 0.00015 in children) having the lowest THQ. Similarly the HRIs were below 1 in both the children and adult population, with the sample from Dabai/Danja (0.0073 in adult; 0.0139 in children) manifesting the highest HRI and the sample from Kafur (0.0046 in adult; 0.0115 in children) having the lowest HRI.

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**Table 3: Heavy Metal Target Hazard Quotient and Health Risk Index in Adults from Consumption of Cultivated Soybeans from Katsina State**

| Location    | Heavy metal |        |        |        |     |        |        | Target Hazard Quotient | Health Risk Index (HRIs) |
|-------------|-------------|--------|--------|--------|-----|--------|--------|------------------------|--------------------------|
|             | Mn          | Zn     | Pb     | Cd     | Ni  | Fe     | Cr     |                        |                          |
| Kafur       | BDL         | 0.0030 | 0.0008 | 0.0001 | BDL | 0.0007 | BDL    | 0.0046                 |                          |
| Malumfashi  | BDL         | 0.0034 | 0.0012 | 0.0001 | BDL | 0.0006 | 0.0004 | 0.0056                 |                          |
| Dabai/Danja | BDL         | 0.0036 | 0.0012 | 0.0001 | BDL | 0.0007 | 0.0019 | 0.0073                 |                          |
| Funtua      | BDL         | 0.0034 | 0.0008 | 0.0001 | BDL | 0.0007 | 0.0004 | 0.0057                 |                          |
| Matazu      | BDL         | 0.0031 | 0.0011 | 0.0001 | BDL | 0.0006 | 0.0003 | 0.0053                 |                          |

The consumer is believed to be safe when  $HI < 1$  and in a degree of concern when  $1 < HI < 5$ . THQ is taken as either above 1 ( $>1$ ) or below 1 ( $<1$ ), where  $THQ >1$  indicate a degree of concern to human health.

**Table 4: Heavy Metal Target Hazard Quotient and Health Risk Index in Children from Consumption of Cultivated Soybeans from Katsina State**

| Location    | Heavy metal |        |        |        |     |        |        | Target Hazard Quotient (THQ) | Health Risk Index (HRIs) |
|-------------|-------------|--------|--------|--------|-----|--------|--------|------------------------------|--------------------------|
|             | Mn          | Zn     | Pb     | Cd     | Ni  | Fe     | Cr     |                              |                          |
| Kafur       | BDL         | 0.0075 | 0.0021 | 0.0002 | BDL | 0.0018 | BDL    | 0.0115                       |                          |
| Malumfashi  | BDL         | 0.0075 | 0.0031 | 0.0002 | BDL | 0.0015 | 0.0010 | 0.0132                       |                          |
| Dabai/Danja | BDL         | 0.0084 | 0.0029 | 0.0002 | BDL | 0.0017 | 0.0010 | 0.0139                       |                          |
| Funtua      | BDL         | 0.0089 | 0.0021 | 0.0002 | BDL | 0.0017 | 0.0009 | 0.0138                       |                          |
| Matazu      | BDL         | 0.0086 | 0.0028 | 0.0002 | BDL | 0.0015 | 0.0008 | 0.0119                       |                          |

The consumer is believed to be safe when  $HI < 1$  and in a degree of concern when  $1 < HI < 5$ . THQ is taken as either above 1 ( $>1$ ) or below 1 ( $<1$ ), where  $THQ >1$  indicate a degree of concern to human health.

The risk of cancer from consumption of the samples for the carcinogenic heavy metals Cd, and Pb are displayed on Tables 5 and 6. From the results in the Soybeans samples in adults, the ILCR for Cd has reached the safety threshold risk limit ( $>10^{-4}$ ) in all the studied samples, while the ILCR for Pb lies within the moderate risk limit ( $>10^{-3}$ ). In children population, the calculated cancer risk for Pb and Cd was within the moderate risk limit ( $>10^{-3}$ ). The sequential order of risk for developing cancer from likely ingestion of the samples is: Malumfashi > Dabai/Danja > Matazu > Funtua > Kafur. The soybeans samples have a calculated cumulative cancer risk ( $\sum ILCR$ ) that has reached the moderate risk limit ( $>10^{-3}$ ). The Soybeans sample from Malumfashi has the greatest possibility of cancer risks to the Katsina State population (ILCR  $5.2 \times 10^{-3}$  in adults,  $1.3 \times 10^{-2}$  in children) and the studied soybean from Kafur has the least possibility of cancer risk (ILCR  $3.5 \times 10^{-3}$  in adults,  $8.9 \times 10^{-3}$  in children). The observed values implies that there is a possibility of 52 cancer manifestations in 10,000 of the adult population and 13 cancer manifestations in 1000 of the children population, that may likely arose from the consumption of the sample from Malumfashi. While consumption of the sample from Kafur would likely result in a possibility of 35 cancer manifestations in adults and 89 cancer manifestations in children for every 10,000 people that are exposed.

**Table 5: Incremental Life Time Cancer Risk in Adults from Consumption of Cultivated Soybeans from Katsina State**

| Location    | ILCR       |            | ΣILCR      |
|-------------|------------|------------|------------|
|             | Pb         | Cd         |            |
| Kafur       | 3.0952E-03 | 5.0400E-04 | 3.5992E-03 |
| Malumfashi  | 4.6941E-03 | 5.1450E-04 | 5.2086E-03 |
| Dabai/Danja | 4.3533E-03 | 4.5900E-04 | 4.8123E-03 |
| Funtua      | 3.1689E-03 | 5.1450E-04 | 3.6834E-03 |
| Matazu      | 4.3004E-03 | 4.7100E-04 | 4.7714E-03 |

The limit of safety for cancer risk is less than about 1 incidence in 1,000,000 lifetime exposure ( $ILCR < 10^{-6}$ ) and threshold risk limit ( $ILCR > 10^{-4}$ ) for incidence of cancer is above 1 in 10,000 exposure where remedial steps are desirable, and moderate risk level ( $ILCR > 10^{-3}$ ) is above 1 in 1,000, where public health safety consideration is of paramount importance.

**Table 6: Incremental Life Time Cancer Risk in Children from Consumption of Cultivated Soybeans from Katsina State**

| Location    | ILCR       |            | ΣILCR      |
|-------------|------------|------------|------------|
|             | Pb         | Cd         |            |
| Kafur       | 7.7372E-03 | 1.2599E-03 | 8.9971E-03 |
| Malumfashi  | 1.1735E-02 | 1.2879E-03 | 1.3023E-02 |
| Dabai/Danja | 1.0889E-02 | 1.1479E-03 | 1.2036E-02 |
| Funtua      | 7.9136E-03 | 1.2879E-03 | 9.2015E-03 |
| Matazu      | 1.0736E-02 | 1.1759E-03 | 1.1912E-02 |

The limit of safety for cancer risk is less than about 1 incidence in 1,000,000 lifetime exposure ( $ILCR < 10^{-6}$ ) and threshold risk limit ( $ILCR > 10^{-4}$ ) for incidence of cancer is above 1 in 10,000 exposure where remedial steps are desirable, and moderate risk level ( $ILCR > 10^{-3}$ ) is above 1 in 1,000, where public health safety consideration is of paramount importance.

#### 4 DISCUSSION

Lead was seen in all the samples at a higher concentration than the 0.01mg/kg, 0.02 mg/kg and 0.05 mg/kg safety limits set by the WHO/FAO, EU and USEPA respectively, raises a level of concern. The recorded Pb concentrations in the study were low when compared to the reported Pb concentration range for soybeans samples from Iran (28) and the reported concentrations for soybean samples from Northeast China (29). These values are also lower than the WHO safe limit for Pb in Cereals reported in literature (30). But the results are higher when compared to results reported for the concentration of Pb from Kano State Nigeria, the result of a study conducted in Southeast Nigeria, Anhui province in China and in Zhejiang also in China (31- 34). A possible explanation for the difference may be due to disparities in anthropogenic contribution to heavy metal pollution in the various sites where the studies were conducted, or contamination during production or handling process, and from industrial or vehicular exhaust (35).

Studies conducted in Zhejiang China that evaluate heavy metals in Romaine lettuce and cabbage (34) and in Katsina State, Nigeria that evaluate heavy metals in unprocessed and processed bean samples (36) and for locust beans from Odo-Ori market Iwo, Nigeria (37) all reported Cd concentrations similar to the results of the present study. But the reported Cd in the present study concentrations were above the concentrations of Cd reported for wheat flours from Calabar, Nigeria (38). Likewise, the reported Cd values in the present study were lower than Cd values reported for soybean samples, cereals, and cereal products (29-31, 33; 39). These differences could be due to differences in the concentration of the metal in the soils where these various food produce were grown.

The Fe concentrations in this study were above the concentrations recorded in wheat flours from Calabar, Nigeria (38), but still fall within the FAO/WHO 40.7 mg/kg Fe permissible limit in legumes (40). The result is similar to the results reported for market sold beans from Katsina, Nigeria (36). But the concentrations are lower to values reported in a study in eastern Nigeria (33) and that recorded by Zahir *et al.* (41) in a study conducted in Pakistan and the results for the study conducted by Li *et al.* (29).

234 "The heavy metal Zn values obtain in this study are similar to values of Zn in food reported in some studies" (31; 42), but  
235 are higher than the range (0.04 to 0.19 mg/kg) reported by Edem *et al.* in wheat flours (38). But the values far below the  
236 range reported by Ahmed and Mohammed (30) and the values reported in a study conducted by Sulyman *et al.*  
237 (43). These values also falls below the WHO permissible limit for Zn as reported by Umar *et al.* (44).

238 In the Soybeans samples, risk levels of Target Hazard Quotient (THQ < 1) were observed for all the evaluated heavy  
239 metals for both adults and children. Which is an Indication that intake of these heavy metals through consumption of the  
240 Soybeans will not pose a considerable non-cancer risk to the population. The THQs for the samples were in the  
241 decreasing order Zn>Pb>Fe>Cr>Cd, in both the samples respectively. The sequence of risks was the same for both  
242 adults and children although the children had higher THQ values in all cases compared to the adults. Further, the non-  
243 cancer risks for each sample were expressed as the cumulative HI, which is the sum of individual metal THQ. All the  
244 studied samples showed the risk level (HI < 1) with highest in the sample from Dabai/Danja and lowest in the sample from  
245 Kafur. It suggests that the inhabitants of Katsina State might not be exposed to non-carcinogenic health risk through the  
246 intake of heavy metals from soya beans.

247 "The THQs of less than 1 reported for all the samples analyzed were lower than the results of THQ for cabbage and  
248 tomato" in a study conducted by Gebeyehu and Bayissa (45) in Mojo, Ethiopia that reported a THQ of more than 1 and  
249 that of a study conducted by Yi *et al.* (46), that reported "a THQ of more than 1 in fish samples from upper Yangtze river,  
250 China, and in a study conducted in Enyigba, south eastern Nigeria for Pb in lemon grass and Mn in leafy vegetables" (47).  
251 The value is also lower than the THQ values above 1 reported by Bhalkhair and Ashraf (13) in a study conducted in the  
252 western region of Saudi Arabia on Okra vegetable, "they are also lower than the THQ values for cereals, green leafy  
253 vegetables, roots and tubers from Vadodara" (48) and the values reported by Mahfuza *et al.* (49) for vegetables and fruits  
254 from Bangladesh. But the results are similar to the THQ of less than 1 reported for Shrimp samples from Selangor,  
255 Malaysia (50) and in tea leaves from Puan County, Guizhou province China (51).

256 The samples evaluated in the study showed the risk level (HI < 1) in both adults and children. "The HI in the samples  
257 differs from the HI values reported for vegetables from Tamale metropolis, Ghana that showed that the hazard index (HI)  
258 for both adult and children exceeded 1" (52). "The value is also lower than the HI values of more than 1 for cabbage and  
259 tomato from Mojo, Ethiopia" (45), the report of Obiora *et al.* (47) in a study conducted in Enyigba, south eastern Nigeria for  
260 Pb in lemon grass and Mn in leafy vegetables. The HRI values of above 1 reported by Bhalkhair and Ashraf (13) in a  
261 study conducted in the western region of Saudi Arabia on Okra vegetable, the values for cereals, green leafy vegetables,  
262 roots and tubers from Vadodara (48) and the values reported by Mahfuza *et al.* (49) for vegetables and fruits from  
263 Bangladesh are all higher than the reported HRI of the current study.. But the HRI values are similar to what was reported  
264 for *Clarias gariepinus* from Imo River, Nigeria (53) and the reported studies conducted in Katsina State, Nigeria on leafy  
265 and fruit Vegetables, and on cereals (54- 56).

266 "The range of ILCR and  $\sum$ ILCR from consumption of all the evaluated samples as highlighted above, which raises the  
267 level of health concern for the consumer population as they may contribute to the population cancer burden is similar" to  
268 what was reported by Gebeyehu and Bayissa (45), in vegetables from Mojo Ethiopia, the ILCR and  $\sum$ ILCR reported from  
269 consumption meat and sea food samples from Xiamen, China (57). The ILCR and  $\sum$ ILCR in Vegetables from Pearl River  
270 Delta South China (58), in fruits and vegetables from Jamaica (59), in vegetables from a Pb/Zn smelter in Central China  
271 (60) in vegetables grown in Patuakhali province Bangladesh (61) and in fruit, root and leafy vegetables, and fruits in a  
272 study conducted in a sub urban industrial area of Bangladesh (47). are also in line with the result of the present study. But  
273 the results differ from the results for vegetables from some selected communities from ONELGA Rivers State, Nigeria that  
274 reported non carcinogenic cancer risks from the vegetable samples in the study (62).

## 277 5 CONCLUSION

278 This work contributes to the monitoring of heavy metal exposure in soybeans cultivated in Katsina State and the possible  
279 carcinogenic and non-carcinogenic risk to the population that may results from consumption of the samples. With the  
280 exception of the heavy metal Pb whose values were above their permissible values, the rest of the metals have  
281 concentrations that were within the permissible limit. The metal target hazard quotient (THQ) and the hazard index (Hi) for  
282 the heavy metals evaluated falls within the safety limit. The overall cancer risk to the adults based on pseudo-total metal  
283 concentrations exceeded the target value, mainly contributed by the heavy metal Pb. Zn is the primary heavy metal  
284 posing non cancer risks while Pb caused the greatest cancer risk. The study has revealed that low non-carcinogenic risks  
285 exist for the population on consumption of the samples but the cancer risk is a cause for public health concern.  
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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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