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Evaluation of Some Heavy Metals Levels in Soil and Rice Samples from Some Selected Agricultural Sites in Bauchi State, Nigeria

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ABSTRACT

Heavy metals are persistent metals that bio accumulate in human body through an exposure process and put human health at risk. These metals can be absorbed by crops from the soil used for cultivation, which goes into the human body through consumption of these food products. This study determined the mean concentration of some heavy metals (As, Cd, Cr, Pb, Ni, Zn) in soil and rice cultivated from some selected agricultural sites, Gadau, Giade and Jama'are in Bauchi State using Atomic Absorption Spectrophotometer (AAS). Also Metal Transfer Factor (MTF), Estimated Daily Intake (EDI), Target Hazard Quotient (THQ) and Hazard Index (HI) were calculated to assess the rate of absorption of these metals by rice and health risk associated with consumption of the rice crop. The soil showed a mean concentration order: Zn>Cr>Ni>Pb>Cd>As in gadau, Cr>Zn>Cd>Ni>As>Pb in giade and Cd>Zn>As>Cr>Pb>Ni in Jama'are while rice are in the following order Pb>Cr>Zn>Ni>As>Cd, As>Cr>Zn>Cd>Pb>Ni, and Cr>As>Zn>Cd>Pb>Ni from Gadau site, Giade site and Jama'are site respectively. The determined MTF values were found lower than 1 except Pb, As and Cr in Gadau, Giade and Jama'are sites respectively. This study also shows no health risk associated with consumption of this rice samples because the THQ and HI values were less than 1.

Keywords: Heavy Metals, Soil, Rice, Agricultural Sites

INTRODUCTION

Industrialization plays a vital role that adversely affect the environment by discharging various unwanted and harmful substances such as heavy metals into the surface and subsurface aquifers (Ullah *et al.,* 2022). Toxic heavy metals have certain penetrating mechanisms, including swallowing, dermal absorption, and inhalation, which cause health effects resulting from heavy metals exposure. The effects of heavy metals on children's health have become more severe than adults. More consideration should be given to heavy metals due to their high toxicity risk, extensive application, and prevalence (Yang and Massey, 2019).

When heavy metals accumulates to toxic levels in agricultural soils, these non-biodegradable elements adversely affects crops health and productivity. The toxicity of heavy metals on crops depends upon factors such as crop type, growth condition and developmental stage (Rashid *et al.,* 2023).

Soil-related problems have grown up to be a major threat to human society (Zhao *et al.,* 2022).the presence of heavy metals in soil is detrimental to food crops and humans, and have their way through waste water irrigation and production in contaminated soil (Abdullahi *et al.,* 2021). Heavy metals persistently present in the soil can be absorbed by plants tissues, enter the biosphere and bio accumulate in the tropic levels of the food chain (Priya *et al.,* 2023).

Rice crop cultivation in Nigeria has become one of the most farming crop.

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This study's objective was to investigate and quantitatively analyze the concentration of some selected heavy metals in soil and rice cultivated at the study area (gadau, giade and jama'are local government areas) in Bauchi state, Nigeria. In a country like Nigeria, where most farmers live in a rural areas, are unaware of the potential risk heavy metals accumulation in the soil and agricultural products cultivated on that soil. Although, few studies have been conducted in relevance that shows the determined concentrations of heavy metals in soil and food crops on other areas in the country, Also, Metal Transfer Function (MTF): an important factor of human exposure from soil to crop has also been determined. The Hazard Index (HI) associated with daily intake of the accumulated heavy metals through the contaminated rice crop has also been investigated so as to estimate the level of health risk associated with consuming such crop from these agricultural sites.

MATERIALS AND METHODS

Study Area

Bauchi State is a State in the North-East geopolitical zone of Nigeria, with Kano and Jigawa as borders to the north, Taraba and Plateau to the south, Gombe and Yobe to the east and Kaduna to the west. The targeted sampling areas are Gadau, Giade and Jama'are local government area of Bauchi state which are located within (Abdulhameed *et al*., 2004).

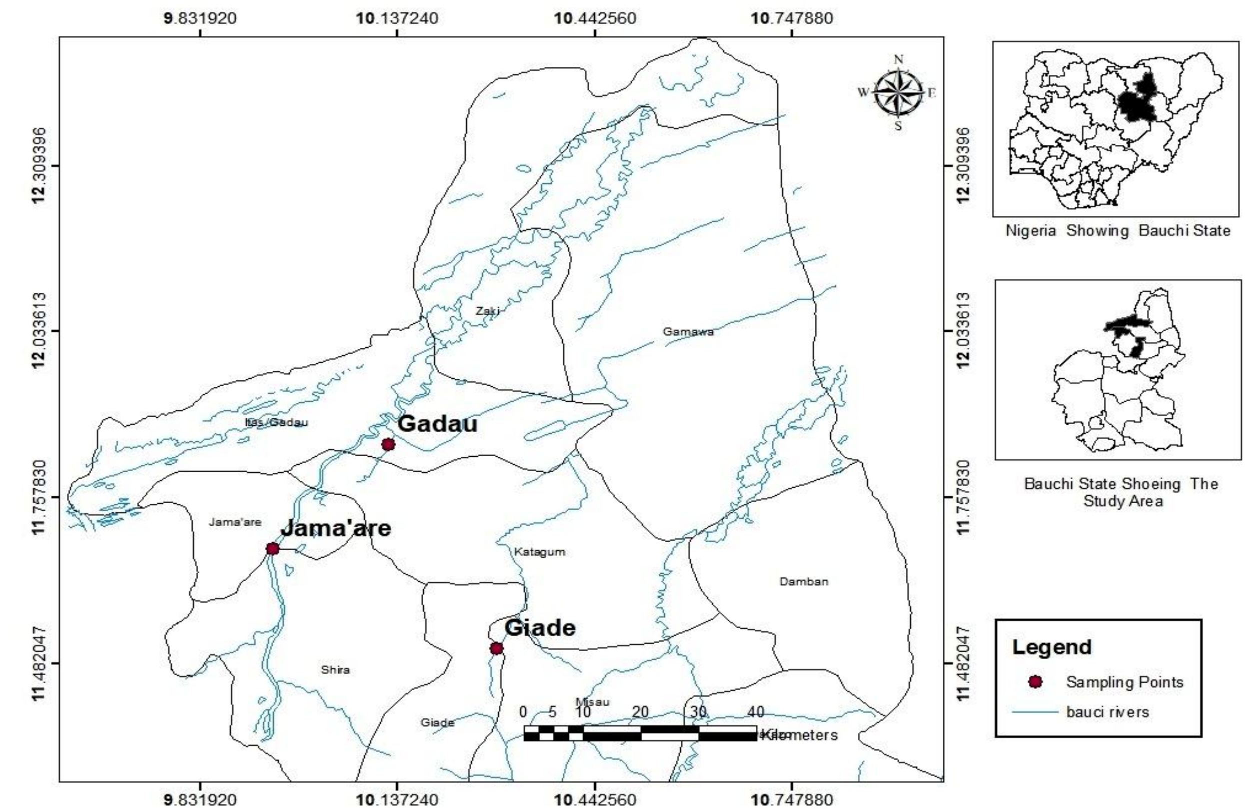

Figure 1: Map showing the sampling location.

Sample Collection

The samples comprises of soil (at 0 – 30cm) and rice crops from each of the 3 agricultural sites. The samples were collected in a sample container and polyethylene bags and transported to the laboratory.

Sample preparation

The soil samples were dried, removed particles, grinded and sieved. The required portion was taken by quartering and conning technique then stored in a well labeled clean dried container for further analysis. The rice grain samples were washed with tap water and then rinsed with distilled water to remove impurities, air dried, grinded using mortar and pestle and sieved to form a homogeneous powder.

Digestion of soil samples for heavy metals

Two (2) g of the soil samples were weighed into 250 cm^3 beaker. The soil sample was digested by the addition of 10cm^3 of HNO_3, 4cm^3 of $HClO_4$ and 2cm^3 of H_2SO_4. The beakers were covered with a watch glass, and heated over a hot plate at 90°C for two hours. The samples were then allowed to cool then filtered and each was transferred into a 100 cm^3 volumetric flask and made up to the mark with deionized water (Usman *et al.,* 2022)

Digestion of rice samples for heavy metals analysis

0.5g of the rice samples were weighed into 250 cm^3 beaker. It was digested by the addition of 20cm^3 of aqua regia (mixture of HCl and HNO_3 ratio 3:1) and 10cm3 of 30% H_2O_2. The H_2O_2 was added in small portions to avoid any possible overflow leading to loss of material from the beaker. The beakers were covered with a watch glass, and heated over a hot plate at 90^{o}C for two hours. The samples were filtered and each was transferred into a 100 cm3 volumetric flask and made up to the mark with deionized water (Yusuf *et al.,* 2019)

Metal Transfer Function (MTF)

From soil to plant is one of the main factors of human exposure, which describes the transfer of metal from soil to plant body. The MTF was calculated by the following: (Ullah *et al.,* 2022):

$$MTF = Crice / Csoil \quad (1)$$

Where *Crice* and *Csoil* is the concentration of heavy metal in crop and soil, respectively. It helps to assess the potential ability of agricultural produce to transfer heavy metals from soil to their edible parts and explains the absorption phenomenon of heavy metals transfer from the contaminated soil (Gupta *et al.,* 2021)

HEALT RISK ASSESSMENT OF RICE

To evaluate the level of health hazard, Hazard Index HI was calculated using

$$HI = THQ_{As} + THQ_{Cd} + THQ_{Cr} + THQ_{Pb} + THQ_{Ni} + THQ_{Zn} \quad (2)$$

HI of a specific heavy metal determines the level of its risk that the consumer is facing.

Value of *HI* > 1 for any metal in food crops means that the consumer population faces a health risk. Value of *HI* < 1 for any heavy metal represents that the subject crop in the food chain is safe to consume (Ullah *et al.,* 2022).

Target Hazard Quotients (THQ) also known as non-carcinogenic risk index refers to the ratio of the daily intake of metals (EDI, *mg metal/kg body weight/day*) in the agricultural produces (vegetables, crops, fruits) to the oral reference dose (*RfD*). *THQ* was calculated from

$$THQ = EDI / RfD \quad (3)$$

RfD (mg/kg bw/day) is the reference dose values of the targeted metals. The R*f*D values for Pb, Ni, Cr, Cd, As and Zn are 0.004, 0.02, 1.5, 0.001, 0.0003 and 0.3 mg/kg bw/day, respectively are given in the literature (Ullah *et al.,* 2022, Ezeofor *et al.,* 2019).

Estimated Daily Intake was calculated using:

$$EDI = \frac{Cm \times EF \times ED \times IR}{BW \times AT} \quad (4)$$

Where *Cmetal*, *EF*, *ED*, *IR*, *BW*, *and AT* represent the heavy metal concentrations in rice (mg/kg), exposure frequency to the trace element (day/year), the exposure duration (year), the food ingestion rate per day for the respective food item (kg/day), the reference bodyweight (kg), and the averaged exposure time (day), respectively (Ullah *et al.,* 2022).

RESULTS AND DISCUSSION

Heavy Metals in Soil

Figure 1 shows the mean concentration of heavy metals in soil samples from the sampling zones.

Arsenic highest concentration was found in Jama'are soil sample (0.078ppm) therefore it can be concluded that the site contains more arsenic than the other corresponding sites. The cadmium concentration level ranged from 0.019ppm to 0.28ppm in soil samples. This study shows a higher concentration of cadmium to the one obtained by (0.51mg/kg) Ezeofor *et al.,* (2019), and are found to be below the maximum permissible limit of 0.3mg/kg as set by MACC.

Chromium, Lead and Nickel have the highest metals concentration in giade soil (0.57ppm), gadau soil (0.0414ppm) and giade soil (0.090ppm) which are all found to be below the recommended allowable limit of 90, 80 and 40 mg/kg respectively. Zinc concentrations were also below the Chinese maximum allowable limit of 50mg/kg. The concentrations of Zn, Cd, Cr, Pb and Ni were lower than the values reported by Ezeofor *et al.,* 2019 and Ullah *et al.,* (2022) in soil.

This study shows a trend of these heavy metals as Zn>Cr>Ni>Pb>Cd>As in gadau soil which is different to that obtained by (Ezeofor *et al.,* 2019) Fe>Mn>Zn>Cd>Cr>Pb>Cu>Ni>Hg and had a higher values of same metals analyzed.

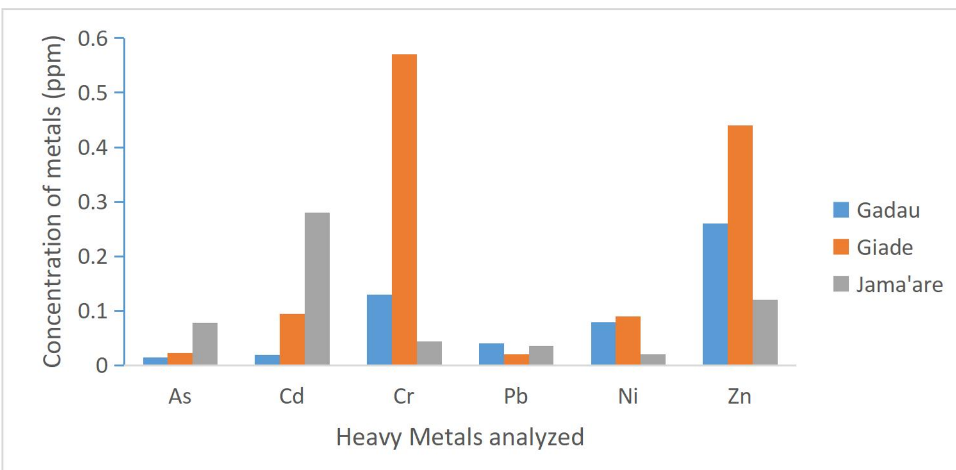

Figure 2: Concentration of heavy metals in soil samples from three sites (ppm).

Heavy Metals in Rice

The mean concentration of heavy metals in rice crop were shown in figure 3. The chart showed the following ranged values (ppm) for rice from gadau site (0.0038 to 0.105), from giade site (0.0106 to 0.041) and jama'are site (0.0012 to 0.054). The mean concentration of the rice are in the following order Pb>Cr>Zn>Ni>As>Cd, As>Cr>Pb>Zn>Cd>Ni, and Cr>As>Zn>Cd>Pb>Ni from gadau site, gadau site and jama'are site respectively. All concentrations of Pb, Zn, Ni, Cr and Cd in this study were found to be lower than the maximum permissible limit (0.2, 50, 10, 1.0 and 0.1 respectively) in rice as set by FAO/WHO 2002.

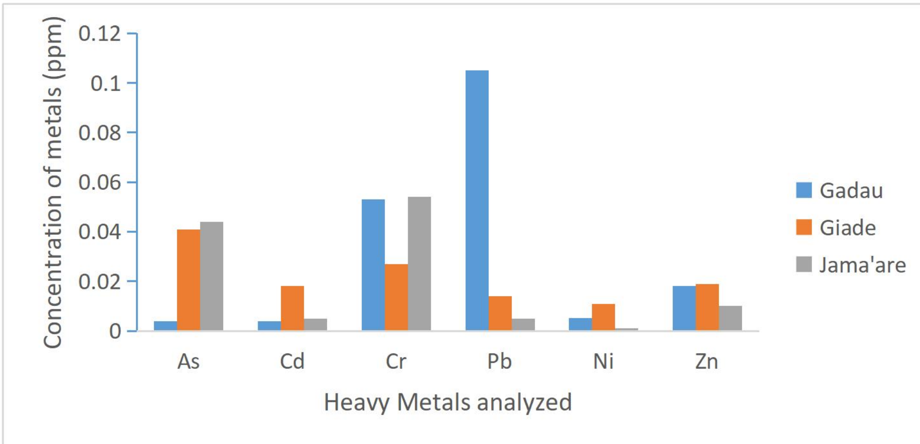

Figure 3: Concentration of heavy metals in rice samples from three sites (ppm).

Metal Transfer Factor and Health Risk Assessment

The MTF explains the absorption phenomenon of heavy metals from the contaminated soil into rice sample cultivated (Ullah *et al.,* 2022). The MTF decreased in the order of Pb>Cr>As>Cd>Zn>Ni, As>Pb>Cd>Ni>Cr>Zn and Cr>As>Pb>Zn>Ni>Cd in rice samples from gadau, giade and jama'are sites respectively. Figure 4 indicates that the highest MTF values were found in Pb (2.54) in gadau, As (1.78) in giade and Cr (1.23) in jama'are rice samples which have all exceeded a value of 1. These rice samples are said to have a high metal absorption capacity (maximum MTF) therefore, they are susceptible to easily been contaminated with these heavy metals and can cause health risk to the consumers. The risks of heavy metal transfer into the food chain are dependent on the mobility of the heavy metal species and their availability in the soil (Ezeofor *et al.,* 2019).

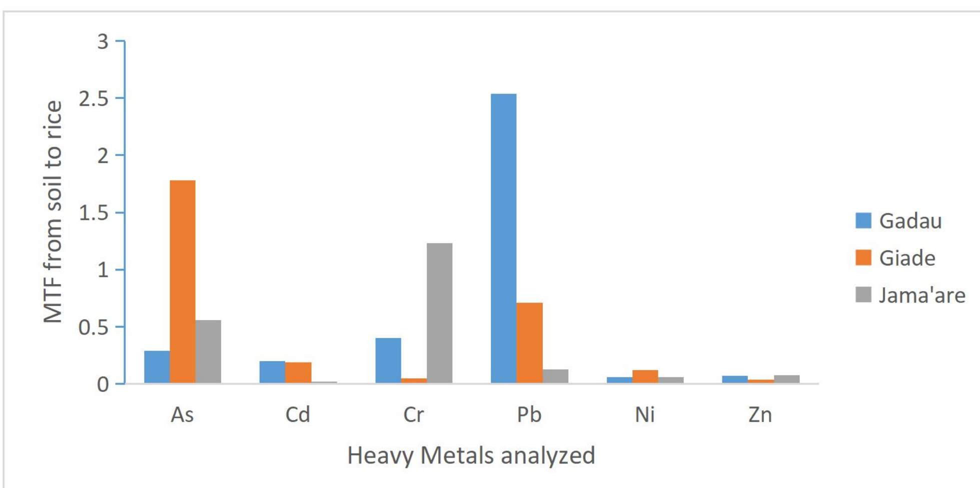

Figure 4: Metal Transfer Factor from soil to rice from all agricultural sites.

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Table 1 shows the estimated daily intake (EDI), Target Hazard Quotient (THQ) and Hazard Index (HI) through rice consumption in adults. EDI was evaluated using the mean concentration of the each heavy metal in rice samples and the ingestion rate. 70g/person/day (0.07kg) is the daily consumption of rice in Nigeria (IRRI 2001, Ezeofor *et al.,* 2019). The values ranged from 6.0E-6 to 1.23E-4 in gadau rice, 1.28E-5 to 4.78E-5 in giade rice and 1.16E-6 to 6.3E-5 in jama'are rice. Ezeofor *et al.,* 2019 reported a higher EDI values (54 Ni, 279 Pb, 909 Zn, 1050 Cr and 29 Cd ug/person/day) of these metals than in the present study.

Table 1: Health Risk Assessment of rice samples from the agricultural sites.

	EDI			THQ		
Metals	GD	GI	JM	GD	GI	JM
As	4.55E-6	4.78E-5	5.13E-5	1.5E-2	1.6E-1	1.7E-1
Cd	4.55E-6	2.1E-5	5.83E-6	4.55E-3	2.1E-2	5.83E-3
Cr	6.18E-5	3.15E-5	6.30E-5	2.0E-2	1.1E-2	2.1E-2
Pb	1.23E-4	1.63E-5	5.83E-6	3.0E-2	4.0E-3	1.5E-3
Ni	6.07E-6	1.28E-5	1.16E-6	3.0E-4	6.4E-4	5.8E-5
Zn	2.1E-5	2.2E-5	1.17E-5	7.0E-5	7.3E-5	3.9E-5
HI				0.06997	0.1967	0.1984

Key: GD = Gadau, GI = Giade and JM = Gadau

The Hazard Quotient has been considered as an important parameter for evaluating the risk associated with consumption of food contaminated with heavy metals (Ezeofor *et al.,* 2019). The THQ of the determined heavy metals for a 60kg adult from rice consumption were all lea than Unity (1). Therefore, the findings from this study indicates that there is no possible potential health risk associated with the intake of rice from these agricultural site unlike that of Ezeofor *et al.,* (2019) that found a risk with Pb in rice from Ugbawka farm, which could be harmful to consumers.

The HI mean value for rice consumption of adults are 0.06997, 0.1967, and 0.1984 in gadau, giade and jama'are sites respectively. These values are less than 1, therefore indicates that there is no health risk by consuming the samples from these sampling sites. This is in agreement with that obtained by Ullah *et al.,* 2022 who also concluded that there was no health risk to consuming the vegetable samples under investigation. However, Ezeofor *et al.,* 2019 obtained a higher THI value in adult as 2.118 which is greater than Unity and can pose health risk to the consumer.

CONCLUSION

The concentrations of all the heavy metals except Pb, As and Cr of Gadau, Giade and Jama'are were higher in the soil samples than the rice samples. This could be attributed to the weak adsorption properties from the soil to other parts of the plants by the other heavy metals at the site. The estimated Daily Intake were lower than the maximum tolerable daily intake level as set by some organization, likewise THQ of all heavy metals and HI values were found to be less than 1. Therefore, these rice samples from the sampling site are safe for consumption and cannot cause health risk to the consumers.

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