



Research Article

Assessment of Some Heavy Metals in Cereal Samples from Bayo and Hawul Local Government Areas, Borno State, Nigeria

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ABSTRACT

Bayo and Hawul local government areas are known for large production of cereal for consumption and commercial purposes, and uses tones of agrochemicals to increase yield. Long-term use of agrochemicals result in accumulation of heavy metals in soil and subsequent absorption by plant, hence the need to asses level of heavy metals in the cereal samples (sorghum and maize). Atomic Absorption Spectroscopy (AA-6800 SHIMADZO) was used to determine concentration of heavy metals in cereal samples collected from agricultural locations in Bayo and Hawul local government areas. When compared with joint safety limit of WHO/FAO, the levels of heavy metals in cereal samples were higher in most of the agricultural locations. The average daily dose (ADD) of the heavy metals computed for cereal samples were above the tolerable daily intake. The levels of heavy metals exposure due to consumption of cereals were above the acceptable risk levels ($ILCR > 10^{-4}$), suggesting an individual developing cancer over a lifetime is of high probability. There is potential health risk for humans through the consumption of the studied cereal as revealed by high values of hazard quotient (HQ). Moreover, hazard indices (HI) of all the metals due combined non-cancer effects in the study were greater than one (1), suggesting potential health risk. As, Cd and Pb show consistency through consumption of the studied cereal samples and should be given priority to public health concern because of health risk associated with these heavy metals

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INTRODUCTION

A toxic heavy metal is any relatively dense metal or metalloid that is noted for its potential toxicity, especially in environmental contexts (Baldwin and Marshall, 1999). The term has particular application to cadmium, mercury, lead and arsenic (Bánfalvi, 2011). All of which appear in the World Health Organisation's list of 10 chemicals of major public concern (Barceloux and Barceloux, 1999). Other examples include manganese, chromium, cobalt, nickel, copper, zinc, selenium, silver, antimony and thallium. Heavy metals are dangerous because they tend to bioaccumulate. This means that the concentration of a chemical in a biological organism becomes higher relative to the environmental concentration (Kampa and Castanas, 2008). Heavy metal pollution of soil enhances plant uptake causing accumulation in plant tissues and eventual phytotoxicity and change of plant community (Gimmler *et al.*, 2002). In environments with high nutrient levels, metal uptake can be inhibited because of complex formation between nutrient and metal ions (Göthberg *et al.*, 2004). Therefore, a better understanding of heavy metal sources, their accumulation in the soil and the effect of their presence in water and soil on plant systems seems to be a particularly important issue (Sharma *et al.*, 2004). Accumulation of heavy metals can also cause a considerable detrimental effect on soil ecosystems, environment and human health due to their mobilities and solubilities which determine their speciation (Kabata-pendias, 1992). The soil to plant transfer factor is one of the important parameters used to estimate the possible accumulation of toxic elements, especially radio nuclides through food ingestion (El-ghawi *et al.*, 2005). Several studies have indicated that crops grown on soils contaminated with heavy metals have higher concentrations of heavy metals than those grown on uncontaminated soil (Nabulo, 2006). Heavy metals accumulating in soil directly (or through

plants indirectly) enter food chains, thus endangering herbivores, indirectly carnivores and not least the top consumer humans (Kádár, 1995).

Heavy metals are naturally found in the environment, but as a result of natural (volcano) and anthropogenic (industrial waste dump, mining, vehicle discharge) activities their concentration increases (Muray *et al.*, 2004). The introduction of heavy metals through anthropogenic processes were reported by Cortes *et al.* (2003), Aziz *et al.* (2004), Navarro *et al.* (2008) and Bruelis *et al.* (1999) as cited by Lawan *et al.* (2020).

Subsequently, the heavy metal uptake from soil by plant eventually enters the food chain and finally ingested by humans. The ingestion of these heavy metals and subsequent accumulation pose health threat and therefore must be minimized. Hence, it becomes of paramount importance to monitor the undergarments of soil by heavy metals due to their influence on ground and surface water (Clemente *et al.*, 2008), on flora (Pandey and Pandey, 2008) and animals and humans (De-Vries *et al.*, 2007).

Few of ailments associated with heavy metals include gastrointestinal irritation, vomiting, diarrhea (cadmium), impairment of kidney, weakening of immune system (lead), anemia (copper), carcinogenic (arsenic, lead and cadmium), damage of DNA, protein, lipid (iron). Bayo and Hawul local government areas are located in Biu province (10.611° N and 12.195° E) are known of their intensive agricultural activities. They produce cereal and other agricultural products of large commercial scales which are not only consumed but transported to other states. The need to improve agricultural yields has resulted in intentional addition of tones of agrochemicals and other soil amendments, and this has been the tradition for a long time. Hence, the need to assess the levels of heavy metals and to carry out risk assessment to

ascertain the safety of consumption of these cereals. Therefore, the objectives of this study is to Assessed some heavy metals in cereal samples from Bayo and Hawul Local Government Areas, Borno State, Nigeria

MATERIALS AND METHODS

Sampling Collection

The cereals (maize and sorghum) samples were collected from Azare, Ghung and Thlila in Hawul Local Government area and Balbiya and Bayo from Bayo Local Government area. The cereals were collected before plantation and after harvesting to signify pre and post-harvest. The pre and post-harvest cereals were collected in a new polythene bags, and transported to Research Laboratory Chemistry Department, University of Maiduguri after appropriate labelling and storage. Cereal samples were collected from the agricultural locations for a period of two years, three times a month

Preparation of Samples

Digestion of the Cereals Samples (Heavy Metals Analysis)

The digestion of the cereals and analysis of the heavy metals were carried out as described in our earlier published work (Lawan *et al.*, 2020).

Average Daily Dose (ADD: mg kg⁻¹ day)

Average daily dose through the consumption of cereals was calculated using Reference dose approach (USEPA, 2013) as describe by Lawan *et al.*, 2020.

Hazard Quotient (HQ)

The potential health risk of individual cereals heavy metal is characterized using a hazard quotient (HQ), as described by Human Health

Risk Assessment Protocol, (USEPA, 2005a), adopted by Lawan *et al.* (2020), and used in this work.

Hazard Index (HI)

This is sum of hazard quotient for all metals, known as total chronic hazard index (THI) = $\sum HQ$, as developed by USEPA (2010), cited by Lawan *et al.* (2020), and adopted in this study.

Cancer Risks

Incremental lifetime cancer risk (ILCR) and chronic daily intake (CDI) approach is used in estimation of cancer risk as described by USEPA (2013), cited by Lawan *et al.*, 2020, and adopted in the present study.

RESULTS

The concentrations of heavy metals in sorghum samples from different agricultural locations in Hawul Local Government Area during pre and post-harvest are as presented in Figure 1 The concentrations of Mn ranged between 0.01 and 5.93 mg/kg; 0.74 and 2.98 mg/kg Fe; 0.08 and 0.46 mg/kg Ni; 0.16 and 0.36 mg/kg Co; 0.06 and 1.05 mg/kg Cu; 0.22 and 1.79 mg/kg Zn; 0.02 and 0.48 mg/kg Pb; 0.09 and 1.03 mg/kg Cd and 0.01 and 0.80 mg/kg As.

The concentrations of heavy metals in sorghum samples from different agricultural locations in Bayo Local Government Area during pre and post-harvest are as presented in Figure 2. The concentrations of Mn ranged between 4.68 and 7.98 mg/kg; 13.27 and 18.03 mg/kg Fe; 0.20 and 0.62 mg/kg Ni; 0.17 and 0.36 mg/kg Co; 0.09 and 0.81 mg/kg Cu; 0.27 and 2.19 mg/kg Zn; 0.01 and 0.65 mg/kg Pb; 0.04 and 0.43 mg/kg Cd and 0.10 and 0.70 mg/kg As.

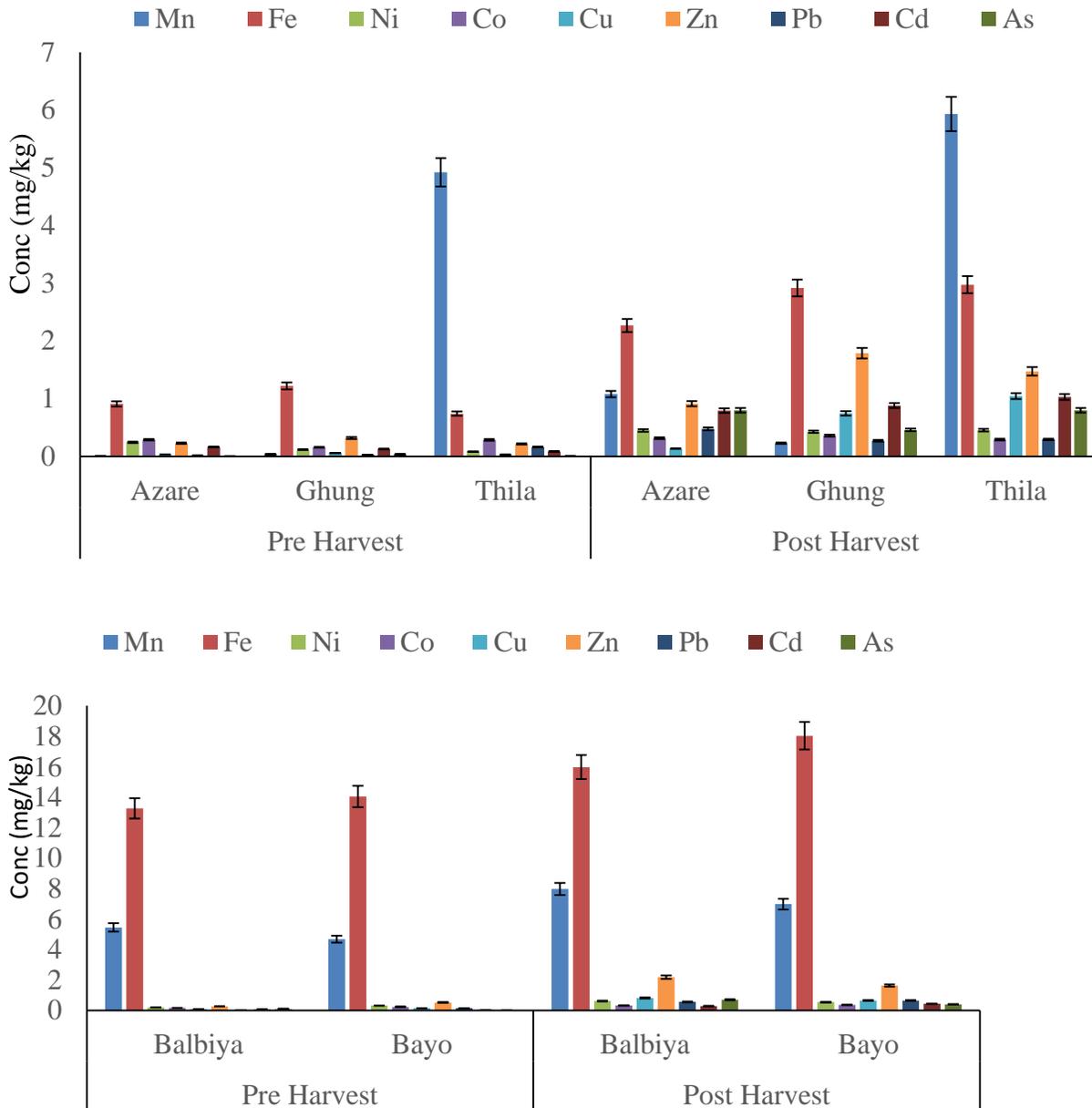


Figure 2. Mean Concentrations of Some Metals in Sorghum Samples from Bayo

The concentrations of heavy metals in maize samples from different agricultural locations in Hawul Local Government Area during pre and post-harvest are as presented in Figure 3. The concentrations of Mn ranged between 0.01 and 0.45 mg/kg; 0.08 and 3.23

mg/kg Fe; 0.01 and 0.32 mg/kg Ni; 0.01 and 0.54 mg/kg Co; 0.02 and 0.09 mg/kg Cu; 0.23 and 0.44 mg/kg Zn; 0.01 and 0.32 mg/kg Pb; 0.07 and 0.24 mg/kg Cd and 0.02 and 0.15 mg/kg As.

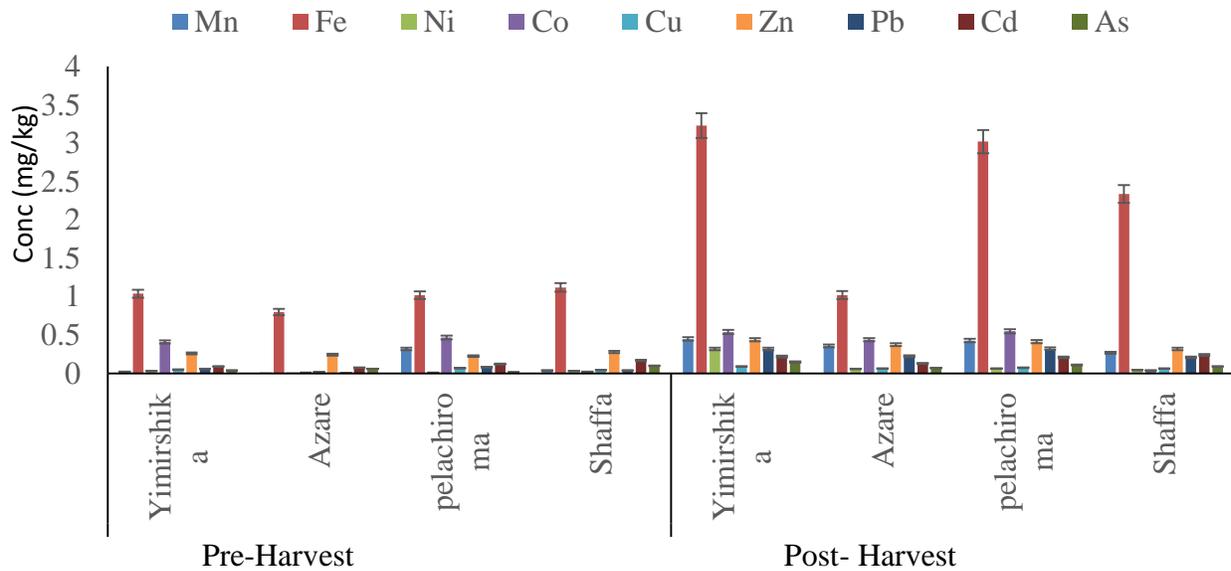


Figure 3: Mean Concentrations of Some Metals in Maize Samples from Hawul Local Government Area

The concentrations of heavy metals in maize samples from different agricultural locations in Bayo Local Government Area during pre and post-harvest are as presented in Figure 4. The concentrations of Mn ranged between 0.04 and

0.34 mg/kg; 0.08 and 0.27 mg/kg Fe; 0.01 and 0.05 mg/kg Ni; 0.01 and 0.47 mg/kg Co; 0.01 and 0.07 mg/kg Cu; 0.09 and 0.23 mg/kg Zn; 0.02 and 0.08 mg/kg Pb; 0.09 and 0.16 mg/kg Cd and 0.01 and 0.12 mg/kg As.

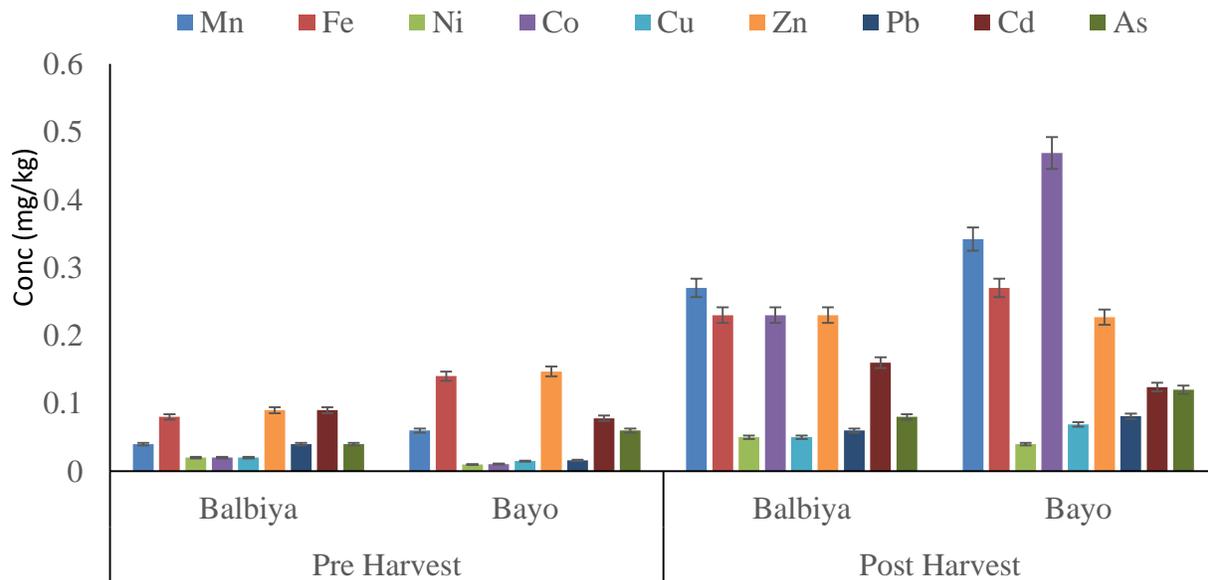


Figure 4. Mean Concentrations of Some Metals in Maize Samples from Bayo Local

Average daily dose (mg/kg day⁻¹) for heavy metals in sorghum samples from different Agricultural Locations of Hawul Local Government Area during pre-harvest and post-

harvest are as presented in Table 1. Average daily dose of Fe ranged between 3.26E+00 and 1.31E+01 mg/kg day⁻¹; 3.70E-01 and 2.01E+00 mg/kg day⁻¹Ni; 1.54E-01 and 4.61E+00 mg/kg

day⁻¹Cu; 9.53E-01 and 7.89E+00 mg/kg day⁻¹Zn; 8.82E-02 and 2.11E+00 mg/kg day⁻¹Pb; 3.88E-01 and 4.54E+00 mg/kg day⁻¹Cd and 1.76E-02 and 3.53E+00 mg/kg day⁻¹As.

Table 1: Average Daily Dose (mg/kg day⁻¹) for Heavy Metals in Sorghum Samples from Different Agricultural Locations in Hawul Local Government Area

	Locations	Fe	Ni	Cu	Zn	Pb	Cd	As
Pre-Harvest	Azare	4.01E+00	1.08E+00	1.63E-01	1.02E+00	8.82E-02	7.19E-01	1.76E-02
	Ghung	5.38E+00	5.29E-01	2.65E-01	1.41E+00	1.32E-01	5.73E-01	1.76E-01
	Thila	3.26E+00	3.70E-01	1.54E-01	9.53E-01	7.19E-01	3.88E-01	4.41E-02
	Total ADD	1.27E+01	1.98E+00	5.82E-01	3.38E+00	9.39E-01	1.68E+00	2.38E-01
Post-Harvest	Azare	1.00E+01	1.99E+00	6.04E-01	4.03E+00	2.11E+00	3.51E+00	3.53E+00
	Ghung	1.29E+01	1.89E+00	3.30E+00	7.89E+00	1.20E+00	3.89E+00	2.03E+00
	Thila	1.31E+01	2.01E+00	4.61E+00	6.50E+00	1.30E+00	4.54E+00	3.53E+00
	Total ADD	3.60E+01	5.89E+00	8.51E+00	1.84E+01	4.61E+00	1.19E+01	9.08E+00

Average daily dose (mg/kg day⁻¹) for heavy metals in sorghum samples from different Agricultural Locations in Bayo Local Government Area during pre-harvest and post-harvest are as presented in Table 2. Average daily dose of Fe ranged between 5.85E+01 and

7.95E+01 mg/kg day⁻¹; 8.73E-01 and 2.74E+00 mg/kg day⁻¹Ni; 3.79E-01 and 3.59E+00 mg/kg day⁻¹Cu; 1.19E+00 and 9.66E+00 mg/kg day⁻¹Zn; 6.17E-02 and 2.87E+00 mg/kg day⁻¹Pb; 1.54E-01 and 1.90E+00 mg/kg day⁻¹Cd and 8.82E-02 and 3.09E+00 mg/kg day⁻¹As.

Table 2: Average Daily Dose (mg/kg day⁻¹) for Heavy Metals in Sorghum Samples from Different Agricultural Locations of Bayo Local Government Area

	Locations	Fe	Ni	Cu	Zn	Pb	Cd	As
Pre-Harvest	Balbiya	5.85E+01	8.73E-01	3.79E-01	1.19E+00	6.17E-02	2.78E-01	4.41E-01
	Bayo	6.19E+01	1.38E+00	6.53E-01	2.28E+00	6.35E-01	1.54E-01	8.82E-02
	Total ADD	1.20E+02	2.26E+00	1.03E+00	3.47E+00	6.97E-01	4.32E-01	5.29E-01
Post-Harvest	Balbiya	7.05E+01	2.74E+00	3.59E+00	9.66E+00	2.48E+00	1.24E+00	3.09E+00
	Bayo	7.95E+01	2.40E+00	2.89E+00	7.20E+00	2.87E+00	1.90E+00	1.76E+00
	Total ADD	1.50E+02	5.14E+00	6.47E+00	1.69E+01	5.35E+00	3.14E+00	4.85E+00

Average daily dose (mg/kg day⁻¹) for heavy metals in maize samples from different agricultural locations in Hawul Local

Government Area during pre-harvest and post-harvest are as presented in Table 3. Average daily dose of Fe ranged between 3.50E-02 and

8.75E+00 mg/kg day⁻¹; 1.54E-01 and 3.86E+01 mg/kg day⁻¹Ni; 3.00E+00 and 7.51E+02 mg/kg day⁻¹Cu; 1.32E+01 and 3.31E+03 mg/kg day⁻¹Zn; 5.84E+01 and 1.46E+04 mg/kg day⁻¹Pb; 2.58E+02 and 6.44E+04 mg/kg day⁻¹Cd and 1.14E+03 and 2.84E+05 mg/kg day⁻¹As
Average daily dose (mg/kg day⁻¹) for heavy metals in maize samples from different agricultural locations of Bayo Local

Government Area during pre-harvest and post-harvest are as presented in Table 4. Average daily dose of Fe ranged between 7.78E-01 and 6.65E+00 mg/kg day⁻¹; 3.43E+00 and 2.93E+01 mg/kg day⁻¹Ni; 6.67E+01 and 5.70E+02 mg/kg day⁻¹Cu; 2.94E+02 and 2.52E+03 mg/kg day⁻¹Zn; 1.30E+03 and 1.11E+04 mg/kg day⁻¹Pb; 5.72E+03 and 4.89E+04mg/kg day⁻¹Cdand 2.52E+04 and 2.16E+05 mg/kg day⁻¹As.

Table 3: Average Daily Dose (mg/kg day⁻¹) for Heavy Metals in Maize from Different Agricultural Locations in Hawul Local Government Area.

	Locations	Fe	Ni	Cu	Zn	Pb	Cd	As
Pre Harvest	Yimirshika	4.28E-01	1.89E+00	3.67E+01	1.62E+02	7.14E+02	3.15E+03	1.39E+04
	Azare	3.50E-02	1.54E-01	3.00E+00	1.32E+01	5.84E+01	2.58E+02	1.14E+03
	Pelachiroma	6.22E+00	2.74E+01	5.34E+02	2.35E+03	1.04E+04	4.58E+04	2.02E+05
	Shaffa	7.78E-01	3.43E+00	6.67E+01	2.94E+02	1.30E+03	5.72E+03	2.52E+04
	Total ADD	7.46E+00	3.29E+01	6.40E+02	2.82E+03	1.25E+04	5.49E+04	2.42E+05
Prost Harvest	Yimirshika	8.75E+00	3.86E+01	7.51E+02	3.31E+03	1.46E+04	6.44E+04	2.84E+05
	Azare	6.98E+00	3.08E+01	5.99E+02	2.64E+03	1.16E+04	5.14E+04	2.26E+05
	pelachiroma	8.34E+00	3.68E+01	7.16E+02	3.16E+03	1.39E+04	6.14E+04	2.71E+05
	Shaffa	5.25E+00	2.32E+01	4.50E+02	1.99E+03	8.76E+03	3.86E+04	1.70E+05
	Total ADD	3.76E+01	1.66E+02	3.22E+03	1.42E+04	6.27E+04	2.76E+05	1.22E+06

Table 4: Average Daily Dose (mg/kg day⁻¹) for Heavy Metals in Maize Sample from Different Agricultural Location in Bayo Local Government Area

	Locations	Fe	Ni	Cu	Zn	Pb	Cd	As
Pre Harvest	Balbiya	7.78E-01	3.43E+00	6.67E+01	2.94E+02	1.30E+03	5.72E+03	2.52E+04
	Bayo	1.17E+00	5.15E+00	1.00E+02	4.41E+02	1.95E+03	8.58E+03	3.79E+04
	Total ADD	1.94E+00	8.58E+00	1.67E+02	7.36E+02	3.24E+03	1.43E+04	6.31E+04
Post Harvest	Balbiya	5.25E+00	2.32E+01	4.50E+02	1.99E+03	8.76E+03	3.86E+04	1.70E+05
	Bayo	6.65E+00	2.93E+01	5.70E+02	2.52E+03	1.11E+04	4.89E+04	2.16E+05
	Total ADD	1.19E+01	5.25E+01	1.02E+03	4.50E+03	1.99E+04	8.76E+04	3.86E+05

Table 5: Hazard Quotient and Hazard Index (mg/kg day⁻¹) of Non-Carcinogenic Heavy Metals Via Consumption of Sorghum from Hawul Local Government agricultural locations.

	Locations	Fe	Ni	Cu	Zn	Pb	Cd	As
Pre-Harvest	Azare	5.73E+00	5.42E+01	4.08E+00	3.40E+00	2.21E+01	7.19E+02	5.88E+01
	Ghung	7.69E+00	2.65E+01	6.62E+00	4.70E+00	3.31E+01	5.73E+02	5.88E+02
	Thila	4.66E+00	1.85E+01	3.86E+00	3.18E+00	1.80E+02	3.88E+02	1.47E+02
	HI	1.81E+01	9.92E+01	1.46E+01	1.13E+01	2.35E+02	1.68E+03	7.94E+02
Post-Harvest	Azare	1.43E+01	9.94E+01	1.51E+01	1.34E+01	5.28E+02	3.51E+03	1.18E+04
	Ghung	1.84E+01	9.46E+01	8.25E+01	2.63E+01	3.00E+02	3.89E+03	6.76E+03
	Thila	1.87E+01	1.00E+02	1.15E+02	2.17E+01	3.25E+02	4.54E+03	1.18E+04
	HI	5.14E+01	2.94E+02	2.13E+02	6.14E+01	1.15E+03	1.19E+04	3.03E+04

Table 6: Hazard Quotient and Hazard Index (mg/kg day⁻¹) of Non-Carcinogenic Heavy Metals via Consumption of Sorghum from Bayo Local Government agricultural locations

	Locations	Fe	Ni	Cu	Zn	Pb	Cd	As
Pre-Harvest	Balbiya	8.36E+01	4.37E+01	9.48E+00	3.97E+00	1.54E+01	2.78E+02	1.47E+03
	Bayo	8.85E+01	6.92E+01	1.63E+01	7.59E+00	1.59E+02	1.54E+02	2.94E+02
	HI	1.72E+02	1.13E+02	2.58E+01	1.16E+01	1.74E+02	4.32E+02	1.76E+03
Post-Harvest	Balbiya	1.01E+02	1.37E+02	8.96E+01	3.22E+01	6.21E+02	1.24E+03	1.03E+04
	Bayo	1.14E+02	1.20E+02	7.22E+01	2.40E+01	7.17E+02	1.90E+03	5.88E+03
	HI	2.14E+02	2.57E+02	1.62E+02	5.62E+01	1.34E+03	3.14E+03	1.62E+04

The hazard quotient and hazard index of non-carcinogenic heavy metals via consumption of Sorghum from Hawul Local Government Area agricultural locations, Borno State, Nigeria during the pre-harvest and post-harvest are as presented in Table 5. Hazard quotient and hazard index of Fe ranged between 4.66E+00 and 1.87E+01 mg/kg day⁻¹; 1.85E+01 and 1.00E+02 mg/kg day⁻¹Ni; 3.86E+00 and 1.15E+02 mg/kg day⁻¹Cu; 3.18E+00 and 2.63E+01 mg/kg day⁻¹Zn; 2.21E+01 and 5.28E+02 mg/kg day⁻¹Pb; 3.88E+02 and 4.54E+03 mg/kg day⁻¹Cd and 5.88E+01 and 1.18E+04 mg/kg day⁻¹As.

The hazard quotient and hazard index of non-carcinogenic heavy metals via consumption of Sorghum from Bayo Local Government Area agricultural locations, Borno State, Nigeria during the pre-harvest and post-harvest are as presented in Table 6. Hazard quotient and hazard Index of Fe ranged between 8.36E+01 and 1.14E+02 mg/kg day⁻¹; 4.37E+01 and 1.37E+02 mg/kg day⁻¹Ni; 9.48E+00 and 8.96E+01 mg/kg day⁻¹Cu; 3.97E+00 and 3.22E+01 mg/kg day⁻¹Zn; 1.54E+01 and 7.17E+02 mg/kg day⁻¹Pb; 1.54E+02 and 1.90E+03 mg/kg day⁻¹Cd and 2.94E+02 and 1.03E+04 mg/kg day⁻¹As.

Table 7: Hazard Quotient and Hazard Index (mg/kg day⁻¹) of Non-Carcinogenic Heavy Metals via Consumption of Maize from Hawul Local Government agricultural location

	Locations	Fe	Ni	Cu	Zn	Pb	Cd	As
Pre-Harvest	Balbiya	1.11E+00	1.72E+02	1.67E+03	9.81E+02	3.24E+05	5.72E+06	8.41E+07
	Bayo	1.67E+00	2.57E+02	2.50E+03	1.47E+03	4.87E+05	8.58E+06	1.26E+08
	Total DD	2.78E+00	4.29E+02	4.17E+03	2.45E+03	8.11E+05	1.43E+07	2.10E+08
	HI	5.56E+00	8.58E+02	8.34E+03	4.90E+03	1.62E+06	2.86E+07	4.21E+08
Post-Harvest	Balbiya	7.50E+00	1.16E+03	1.13E+04	6.62E+03	2.19E+06	3.86E+07	5.68E+08
	Bayo	9.50E+00	1.47E+03	1.43E+04	8.39E+03	2.77E+06	4.89E+07	7.19E+08
	Total DD	1.70E+01	2.62E+03	2.55E+04	1.50E+04	4.96E+06	8.76E+07	1.29E+09
	HI	3.40E+01	5.25E+03	5.10E+04	3.00E+04	9.93E+06	1.75E+08	2.57E+09

Table 9: Carcinogenic Risk Assessment (mg/kg day^{-1}) of Some Heavy Metals in Sorghum from Hawul Local Government Area.

	Locations	Pb	Cd	As
Pre-Harvest	Azare	7.50E-04	4.53E+00	2.65E-02
	Ghung	1.12E-03	3.61E+00	2.65E-01
	Thila	6.11E-03	2.44E+00	6.62E-02
	ΣIICR	7.98E-03	1.06E+01	3.57E-01
Post-Harvest	Azare	1.80E-02	2.21E+01	5.29E+00
	Ghung	1.02E-02	2.45E+01	3.04E+00
	Thila	1.11E-02	2.86E+01	5.29E+00
	ΣIICR	3.92E-02	7.52E+01	1.36E+01

The carcinogenic risk assessment of some heavy metals in sorghum from Hawul Local Government Area of Borno State, Nigeria during the pre-harvest and post-harvest are as presented in Table 9. Carcinogenic risk assessment of Pb ranged between $7.50\text{E-}04$ and $1.80\text{E-}02$ mg/kg day^{-1} ; $2.44\text{E+}00$ and $2.86\text{E+}01$ mg/kgday^{-1} Cd and $2.65\text{E-}02$ and $5.29\text{E+}00$ mg/kg day^{-1} As. Carcinogenic Risk Assessment (mg/kg day^{-1}) of heavy metals in Hawul Local Government agricultural locations are in the following order $\text{Cd} > \text{As} > \text{Pb}$

The carcinogenic risk assessment of some heavy metals in sorghum from Bayo Local Government Area of Borno State, Nigeria during the pre-harvest and post-harvest are as presented in Table 10. Carcinogenic risk assessment of Pb ranged between $5.25\text{E-}04$ and $2.44\text{E-}02$ mg/kg day^{-1} ; $9.72\text{E-}01$ and $1.19\text{E+}01$ mg/k day^{-1} Cd and $1.32\text{E-}01$ and $4.63\text{E+}00$ mg/kg day^{-1} As. Carcinogenic Risk Assessment (mg/kg day^{-1}) of heavy metals in Bayo Local Government agricultural locations are in the following order $\text{Cd} > \text{As} > \text{Pb}$

Table 10: Carcinogenic Risk Assessment (mg/kg day^{-1}) of Some Heavy Metals in Sorghum from Bayo Local Government Area.

	Locations	Pb	Cd	As
Pre-Harvest	Balbiya	5.25E-04	1.75E+00	6.62E-01
	Bayo	5.40E-03	9.72E-01	1.32E-01
	ΣIICR	5.92E-03	2.72E+00	7.94E-01
Post-Harvest	Balbiya	2.11E-02	7.81E+00	4.63E+00
	Bayo	2.44E-02	1.19E+01	2.65E+00
	ΣIICR	4.55E-02	1.98E+01	7.28E+00

The carcinogenic risk assessment of some heavy metals in maize from Hawul Local Government Area of Borno State, Nigeria during the pre-harvest and post-harvest are as presented in Table 11. Carcinogenic risk assessment of Pb ranged between $4.96\text{E-}01$ and $1.24\text{E+}02$ mg/kg day^{-1} ; $1.62\text{E+}03$ and $4.06\text{E+}05$ mg/kgday^{-1} Cd and $1.70\text{E+}03$ and $4.26\text{E+}05$ mg/kg day^{-1} As. Carcinogenic risk assessment of heavy metals in

Hawul Local Government agricultural locations are in the following order $\text{As} > \text{Cd} > \text{Pb}$.

Table 11: Carcinogenic Risk Assessment (mg/kg day⁻¹) of Some Heavy Metals in Maize from Hawul Local Government Area.

	Locations	Pb	Cd	As
Pre Harvest	Yimirshika	6.07E+00	1.98E+04	2.08E+04
	Azare	4.96E-01	1.62E+03	1.70E+03
	Pelachiroma	8.82E+01	2.88E+05	3.03E+05
	Shaffa	1.10E+01	3.61E+04	3.79E+04
	∑ILCR	1.06E+02	3.46E+05	3.63E+05
Post Harvest	Yimirshika	1.24E+02	4.06E+05	4.26E+05
	Azare	9.90E+01	3.24E+05	3.40E+05
	Pelachiroma	1.18E+02	3.87E+05	4.06E+05
	Shaffa	7.44E+01	2.43E+05	2.56E+05
	∑ILCR	4.16E+02	1.36E+06	1.43E+06

The carcinogenic risk assessment of some heavy metals in maize from Bayo Local Government Area of Borno State, Nigeria during the pre-harvest and post-harvest are as presented in Table 12. Carcinogenic risk assessment of Pb ranged between 1.10E+01 and 9.43E+01 mg/kg

day⁻¹; 3.61E+04 and 3.08E+05 mg/kgday⁻¹Cd and 3.79E+04 and 3.24E+05 mg/kg day⁻¹As. Carcinogenic risk assessment of heavy metals in Bayo Local Government agricultural locations are in the following order As > Cd > Pb.

Table 12: Carcinogenic Risk Assessment (mg/kg day⁻¹) of Some Heavy Metals in Maize from Bayo Local Government Area.

As	Locations	Pb	Cd	As
Pre Harvest	Balbiya	1.10E+01	3.61E+04	3.79E+04
	Bayo	1.65E+01	5.41E+04	5.68E+04
	∑ILCR	2.76E+01	9.01E+04	9.46E+04
Post Harvest	Balbiya	7.44E+01	2.43E+05	2.56E+05
	Bayo	9.43E+01	3.08E+05	3.24E+05
	∑ILCR	1.69E+02	5.52E+05	5.79E+05

Table 13: Average Daily Dose of Some Heavy Metals

Heavy Metal Integrated Risk Information System (US EPA, 2013)	
Fe	45E-01
Zn	40E-01
Cu	10E-01
Pb	2.40E-01
Cd	6.40E-02
Mn	11E-01
Cr	1.05E-02

Table 14: Reference Dose of Some Heavy Metals

Heavy Metal	RfDo (mg kg ⁻¹ day ⁻¹)	
	Integrated Risk Information System (US EPA, 2013)	FAO/WHO (Codex, 2013)
Fe	-	7.00E-01
Zn	-	3.00E-01
Cu	-	4.00E-02
Pb	1.00E-03	4.00E-03
Cd	-	1.00E-03
Mn	-	1.40E-02
Cr	1.50E+00	1.50E+00

DISCUSSION

Variation of heavy metals in sorghum and maize samples

From the two Local Government agricultural locations the highest concentration of Cd (1.03E+00 mg/kg) in the sorghum was observed at Thlila agricultural location from Hawul local government area, while the lowest concentration (4.00E-02 mg/kg) was detected at Balbaya agricultural location in Bayo local government area. For maize samples from the two Local Government agricultural locations the highest concentration of Cd (2.40E-01 mg/kg) in the maize was observed at Shaffa agricultural location, while the lowest concentration (4.00E-

02 mg/kg) was detected at Azare agricultural location, all in Hawul local government area. Cadmium is a highly mobile metal, as reported by Itanna (2002) and Muhammad *et al.* (2008). There a direct relationship between the levels of cadmium present in the root zone and its absorption by plant. The concentrations of cadmium in some studied agricultural locations were observed to be higher than the 0.02 mg/kg WHO/FAO safe limit.

From the two Local Government agricultural locations the highest concentration of Fe (1.80E+01 mg/kg) in the sorghum was observed at Bayo agricultural location from Bayo local government area, while the lowest concentration

(7.40E-01 mg/kg) was detected at Thila agricultural location from Hawul local government area. The highest concentration of Fe (3.23E+00 mg/kg) in the maize was detected at Yimirshika agricultural location from Hawul local government area, while the lowest concentration (8.00E+02 mg/kg) was detected at Balbiya agricultural location from Bayo local government area. Iron is essential to several cofactors like hemoglobin and the cytochromes. Iron is a potentially toxic heavy metal Chang *et al.*, 1984, reported that excess iron causes several illnesses among which are cancer, heart disease, kidney disease and liver disease. In this study the levels of Fe in some agricultural locations were found to higher than the 0.3 mg/kg WHO/FAO safe limit.

The highest level of Cu (1.05E+00 mg/kg) in the sorghum sample was detected at Thila agricultural location from Hawul local government area and the lowest concentration (1.00E-02 mg/kg) was also observed at Ghung agricultural location from the same local government area. The highest concentration of Cu (2.40E-01mg/kg) in the maize sample was detected at Balbaya agricultural location from Bayo local government area and the lowest concentration (1.00E-02 mg/kg) was detected at Yimirshika agricultural location from Hawul local government area. In some agricultural locations the levels of Cu in the sorghum and were observed to be higher than 0.1mg/kg WHO/FAO joint safe limit.

The highest concentration of 2.19E+00 mg/kg in the sorghum for Zn was observed at Balbiya agricultural location from Bayo local government area, while the lowest concentration (2.20E-01mg/kg) was detected at Thila agricultural location from the same local government area. For maize, the highest concentration of Zn (3.300E-01 mg/kg) was detected at Balbiya agricultural location from Bayo local government area, while the lowest concentration (9.00E-02mg/kg) was observed at

Azare agricultural location from Hawul local government area. Zinc enhances the immune system of the body and is required at permissible level. The recommended dietary allowable concentration for zinc is 15mg/day for men and 12mg/day for Women Ogunlesi *et al.* (2010) as cited by Adu *et al.* (2012). In some agricultural locations the zinc content in this study was lower than the WHO/FAO (2001) joint safe limit of 3.00 mg/kg.

For Pb the highest concentration (6.50E-01 mg/kg) in the sorghum was detected at Bayo agricultural location from Bayo local government area, while the lowest concentration (1.00E-02 mg/kg) was observed at Balbiya agricultural location from the same local government area. For maize the highest concentration of Pb (3.20E-01 mg/kg) was observed at Pelachroma agricultural location from Hawul local government area, while the lowest concentration (1.00E-02 mg/kg) was detected at Azare agricultural location from the same local government area. Pathways of lead to the environment and its effect were reported by Tanna *et al.*, 2002, as cited by Lawan *et al.*, 2020. Level of Pb studied in all sorghum and maize in some agricultural locations were higher when compared to 0.01 mg/kg WHO/FAO joint safe limit.

The highest concentration of Co (3.60E-01 mg/kg) in the sorghum was observed at Balbiya agricultural location from Bayo local government area, while the lowest concentration (1.60E-02 mg/kg) was detected at Azare agricultural location from Hawul local government area. The highest concentration of Co (5.50E-01 mg/kg) in the maize was detected at Bayoa gricultural location from Bayo local government area while the lowest concentration (1.00E-02 mg/kg) was also observed at Azare agricultural location from Hawul local government area.

The highest concentration of As (8.00E-01 mg/kg) in the sorghum was detected at Thila

agricultural location in Hawul local government area, while the lowest concentration ($1.00\text{E}-02$ mg/kg) was detected at Azare agricultural location in the same local government area. The highest concentration of As ($1.50\text{E}-01$ mg/kg) in the maize was observed at Yimirshika agricultural location in Hawul local government area, while the lowest concentration ($1.00\text{E}-02$ mg/kg) was observed at agricultural location in Bayo local government area.

The highest level of Mn ($7.98\text{E}+00$ mg/kg) in the sorghum from the two agricultural locations was detected at Balbiya agricultural location from Bayo local government area, while the lowest level ($1.00\text{E}-02$ mg/kg) was detected at Azare agricultural location from Hawul local government area. The highest concentration of Mn ($4.50\text{E}-01$ mg/kg) in the maize from the two Local Government agricultural locations was detected at Pelachiroma agricultural location from Hawul local government area, while the lowest concentration ($1.00\text{E}-02$ mg/kg) was observed at Yimirshika agricultural location from the same local government area. High level of manganese triggers production of free radicals in the body which can cause several ailments. The values of Mn are high in some agricultural location when compared to 0.3 mg/kg WHO/FAO joint safe limit.

The highest level of Ni ($6.20\text{E}-01$ mg/kg) in the sorghum from the two local government agricultural locations was detected at Balbiya agricultural location from Bayo local government area, while the lowest level ($8.00\text{E}-02$ mg/kg) was detected at Thlila agricultural location from Hawul local government area. The highest concentration of Ni ($3.20\text{E}-01$ mg/kg) in the maize from the two Local Government agricultural locations was detected at Yimirshika agricultural location from Hawul local government area, while the lowest concentration ($1.00\text{E}-02$ mg/kg) was observed at Azare agricultural location from the same local government area. The levels of Ni in some

agricultural location were high when compared to the WHO/FAO joint safe limit of 0.1 mg/kg.

The concentrations of the heavy metals studied are higher in the post-harvest compared to the Pre-harvest; this could be as a result of intense use of agrochemicals by the farmers to increase agricultural yield.

Average Daily Dose (ADD)

Singh *et al.* (2010) reported that the degree of toxicity of heavy metal to human being depends upon their daily intake; hence, the daily cereal consumption was obtained through estimation of average consumption of cereals (sorghum and maize) per person per day for human. The ADD estimated for all the study area is presented in Tables 1 to 3. The highest ADD value for Fe in sorghum was $3.26\text{E}+00$ mg/kg per day in Hawul and $7.95\text{E}+02$ mg/kg per day in Bayo local government areas. The highest daily dose of Cd was estimated as $6.44\text{E}+04$ mg/kg per day in maize samples from Hawul, while the lowest daily dose of Cd was estimated as $1.54\text{E}-01$ mg/kg per day in sorghum sample from Bayo. The lowest ADD for As was estimated as $1.76\text{E}-02$ mg/kg per day in sorghum samples from Hawul, while the highest value of $2.84\text{E}+05$ mg/kg per day in maize samples from the same local government. The highest daily dose of Pb was estimated as $1.11\text{E}+04$ mg/kg per day in maize samples from Bayo local government area, while the lowest daily dose of Pb was estimated as $1.546.17\text{E}-07$ mg/kg per day in sorghum sample also from Bayo. When compared to other studies, lower and higher ADD values were observed as reported by Lawan *et al.* (2020). In all the study area, the estimated average daily intakes of most of the heavy metals through the consumption of cereals were higher than the tolerable daily intake limit set by USEPA (2013) (Table 15). There is risk upon the consumption of the studied cereals as shown by the observed results.

Hazard Quotient (HQ)

Oral reference doses (RfDo) for heavy metals is presented in Table 14 WHO/FAO 2013, which was the basis for estimation of hazard quotient (HQ) values. The result is presented in tables 5 to 8. From the result obtained, in all the sample locations, the HQ values of all heavy metals, in all cereal samples were all above one (1) except for Fe (5.00 mg/kg) in maize from Hawul local government area. When HQ exceed one (1), there is concern for health effect Huang *et al.*, 2008. The lowest HQ value of 4.66E+00 Ni and the highest HQ of 1.59E+04 As in sorghum samples was higher than the HQ values of one (1), while for maize samples, the lowest and highest HQ value of 1.10E+00 Cu from shani. Sridhara *et al.* (2008) also found HQ in Spinach as high as 5.3 E-00. Higher HQ for Pb were also reported by Zheng *et al.* (2007) in vegetables collected from a Huludao Zinc Plant in Huludao city, China; and in vegetables from Pb and Sb smelter in Nanning, China reported by Cui *et al.* (2004). In this study level of metals show HQ value greater than one (1), hence the population could be at health risk as a result of continuous intake of the studied cereals.

Hazard Index (HI)

Hazard index (HI) for residents ingestion of heavy metals through consumption of cereals grown in the study areas were evaluated by summation of HQ of all heavy metals for each cereal (Table 5 to 8). Highest HI of heavy metals was found in maize samples from Bayo local government area with a value of 3.17E+09 As, whereas the lowest HI was also found in maize from Hawul local government area with a value of 5.56E+00 Pb. HI values of heavy metals for all the cereals were between 5.56E+00 and 3.17E+09. These values were more than one (1), indicating that there is health risk for resident in the studied areas from the intake of these cereals.

Cancer Risk Assessment

Cancer risk computed for sorghum and maize were presented in tables 9 to 12, the highest concentration is 4.26E+05 and the lowest is 5.25E-04. These risk values indicate that consumption of cereals from Yimirshika would result in an excess of 4 cancer cases per 100,000 people, while consumption of cereals would result into an excess of 5 cancer cases per 10,000 people Molina, 2011. The risk of developing cancer as a result of consuming Sorghum and maize showed significant difference ($p > 0.05$). Cd and As were predominant contaminant contributing more of the ILCR in maize and Sorghum respectively compared to other heavy metals. Excess cancer risks below 1 chance in 1,000,000 (1.00E-06) negligible, and risks above 1 in 10,000 (1×10^{-4}) sufficient to sort desirable remediation. An ILCR greater than one in ten thousand ($ILCR > 10^{-4}$) is benchmark for gathering additional information whereas 1/1000 or greater ($ILCR > 10^{-3}$) is moderate increased risk and should be given high priority as a public health concern USEPA (2005a).

CONCLUSION

The concentrations of the heavy metals studied are higher in the post-harvest compared to the Pre-harvest; this could be as a result of intense use of agrochemicals by the farmers to increase agricultural yield.

When compared with joint safety limit of WHO/FAO, the levels of heavy metals were higher in most of the agricultural locations. The average daily dose (ADD) of the heavy metals computed for cereal samples were above the tolerable daily intake. The levels of heavy metals exposure due to consumption of cereals were above the acceptable risk levels ($ILCR > 10^{-4}$), suggesting an individual developing cancer over a lifetime is of high probability. There is potential health risk for humans through the consumption of the study cereals as revealed by high values of hazard quotient (HQ).

Moreover, hazard indices (HI) of all the metals due combined non-cancer effects in the study were greater than one (1), suggesting potential health risk. As, Cd and Pb show consistency

through consumption of the study cereals and should be given priority to public health concern because of health risk associated with these heavy metals

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