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Bioaccumulation and Human Health Risk of Heavy Metals from Pesticides in Some Crops Grown in Plateau State, Nigeria†

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Abstract: The health risk assessment of heavy metals in food crops fumigated exclusively with pesticides as the source of metal contamination is mostly overlooked. This study determines the concentrations of heavy metals (Cd, Pb, Cr, Cu and Zn) in some food crops fumigated with pesticides and their health risk in human. The mean concentrations of heavy metals in different parts of the studied crops ranged from 0.12–2.03, 1.73–23.34, 1.60–1150.50, 0.67–19.50, 0.09–6.14-mg/kg for Zn, Pb, Cu, Cr, and Cd respectively. The concentrations of Cd, Pb, and Cr in the investigated crops were above the WHO, (2011) permissible limits and in decreasing trend of Cu > Pb > Cr > Cd > Zn. Bioaccumulation factor (BAF) >1 values for Cd, Pb and Zn and BAF value was maximum for copper (141.75) in *Oryza sativa.* Pollution indices showed all crops were contaminated with Cd, Pb and Cr and are likely to pose potential health risk to humans. The estimated daily intake from the daily intake of all the studied crops for Cd, Pb had exceeded the USEPA, (2006) oral reference dose daily limit. Hazard Quotient >1 was observed only from the consumption of *Ozyza sativa* (3.504) for Cu and could likely cause potential health risk in human. Hazard Index indicated health risk through the consumption of *Oryza sativa* (4.666), *Zea mays* (1.475), *capsicum annuum* (1.132) for all the studied metals. Therefore, there is a need for regular screening and monitoring of heavy metals in food crops from pesticides sources.

Keywords: bioaccumulation factor; hazard quotient; hazard index; heavy metals; pesticides

1. Introduction

Pesticides are extensively employed in agriculture to kill pest or unwanted organisms that may reduce crops yield and increase agricultural production (Oyeyiola et al., 2017). Famers in northern Nigeria have depend largely on pesticides for the control of pest, weeds and other diseases (Desalu et al., 2014).This has led to the proliferation in the importation of new pesticides product into Nigeria whose chemical contents are not known or mostly conceal by the manufactures (Barau et al., 2017).The use of pesticides has been on the increase and showed to contain heavy metals (Yuguda, et al., 2015; Barau et al., 2018). However, despite the banned of heavy metals in pesticides globally, recent study have revealed the presence of heavy metals in pesticides at levels above the recommended farmers dilution rate in Europe (Defarge et al., 2018). Soil-plant heavy metal transfer is the main pathway for pollutants to enter human body through food chain (Wang et al., 2004).

There is paucity if any on the study on heavy metals contamination of food crops exclusively fumigated with pesticides as the source of heavy metal contamination and their health risk to human. Therefore this study was designed with the aim of determining the concentrations of heavy metals (Cd, Pb, Cr, Cu, Zn) from pesticides in some crops, soil and their associated human health risk in Jos, Plateau State.

2. Materials and Methods

Samples of leaves, stems, roots and fruits of tomatoes, pepper, onions, cabbage, carrot, cucumber, spinach, lettuce and maize and corresponding soils, were collected from Naraguta Farm (A) in Plateau State, Nigeria (N09°58.586, E008°53.820) and Naraguta Farm B(N09°58.562, E008°53.230). Soils collected from some location outside agricultural farms that had no pesticides application were used as control . All samples were collected in a clean brown envelope, labelled and transported to ATBU Biology laboratory and analyzed for Cr, Cu, Cd, Zn, and Pb using an atomic absorption spectrophotometer. Health Risk Assessment (Zhong et al., 2017, Rattan et al., 2005, Hart et al., 2005), Hazard Quotient (USEPA, 2006), Hazard Index (USEPA, 2006), Estimated Daily Intake (Hart et al., (2005, USEPA, 2006) and Pollution Index (Chukwuma, 1994, USEPA, 2006) were determined and results statistically analyzed by SPPS version 8.1. and Two way Analysis of Variance ,

3. Results

3.1. Heavy Metals in the plants, soil and their factors

There was significant variation ($p < 0.05$) in the concentration of heavy metals in different parts of most the studied crops (Tables1 and 2). The trend of heavy metals in the studied crops was in the decreasing trend of Cu > Pb > Cr > Cd > Zn (Tables 1 and 2). Cadmium, chromium, lead concentration in the all the studied crops were above the permissible limits except in *Allium cepa* (root, leaf, bulb) and *Daucas carota* (root, stem), *Cucumis sativus* (fruit), *Lactuca sativa* (root, leaf) (Table 3.1a and 3.1b). The concentration of zinc in all the investigated crops were below the permissible limit. Copper was also below the permissible limit except in *Cucumis sativus* (stem, leaf, fruit,), *Zea mays* (root, leaf, fruit) and *Orzy sativa* (root, stem, fruit) (Tables 1 and 2).

Table 1. Mean concentration of heavy metals in crops grown in Plateau state (2018).

Sampling Site	Name of Sample	Botanical Name	Hausa Name	Heavy Metals mg/kg				
				Cd	Pb	Cr	Cu	Zn
Jos	Tomato	*Solanum lycopersicum*	Tomatur					
	Root			4.47 [a]	2.32 [a]	10.17 [ab]	28.37 [b]	1.02 [c]
	Stem			5.66 [b]	4.48 [a]	7.58 [a]	18.94 [a]	0.15 [a]
	Leaf			5.14 [ab]	3.26 [a]	9.83 [ab]	39.25 [c]	0.47 [b]
	Fruit			5.08 [ab]	1.73 [a]	10.92 [b]	35.26 [bc]	1.40 [d]
	Pepper	*Capsicum annuum*	Attarugu					
	Root			3.11 [a]	14.88 [b]	2.67 [a]	12.28 [a]	1.72 [a]
	Stem			3.25 [a]	15.97 [b]	5.58 [b]	18.44 [ab]	0.12 [a]
	Leaf			3.76 [a]	9.51 [a]	4.25 [b]	20.71 [ab]	1.01 [a]
	Fruit			3.33 [a]	21.25 [b]	5.00 [b]	25.55 [c]	0.97 [a]
	Onion	*Allium cepa*	Albasa					
	Root			2.58 [a]	14.98 [a]	1.67 [a]	6.30 [a]	1.90 [b]
	Stem			ND	ND	ND	ND	ND
	Leaf			3.95 [c]	18.60 [a]	1.83 [a]	12.42 [b]	1.42 [ab]
	Bulb			2.72 [a]	17.25 [a]	2.00 [a]	6.67 [a]	0.58 [a]
	Carrot	*Daucus carota*	Karas					
	Root			ND	ND	ND	ND	ND
	Stem			4.87 [a]	18.33 [b]	0.67 [a]	12.08 [b]	2.03 [b]
	Leaf			4.55 [a]	19.78 [b]	1.17 [a]	23.43 [c]	0.72 [a]
	Fruit			4.63 [a]	3.77 [a]	3.00 [b]	1.60 [a]	ND
	Spinach	*Spinacia oleracea*	Alayyaho					
	Root			3.57 [a]	14.91 [a]	3.58 [a]	12.21 [b]	ND
	Stem			3.91 [a]	14.20 [a]	3.75 [ab]	10.68 [a]	0.84
	Leaf			3.21 [a]	16.12 [a]	4.17 [c]	15.68 [c]	ND
Safe limits [a]				0.2	0.3	2.3	40	60

[a] Source:FAO/WHO(2001). Mean followed with same letter across the column are not significantly different p >0.05.

Table 2. Mean concentration of heavy metals in crops grown in Plateau State (2018).

Sampling Site	Name of Sample	Botanical Name	Hausa Name	Heavy Metals mg/kg				
				Cd	Pb	Cr	Cu	Zn
Jos	Lettuce	*Lactuca sativa*	Salad					
	Root			0.66 [b]	17.03 [c]	1.25 [a]	8.34 [a]	ND
	Stem			0.09 [a]	15.13 [a]	2.25 [c]	6.75 [a]	ND
	Leaf			1.43 [c]	17.21 [c]	1.92 [ab]	14.61 [b]	ND
	Cabbage	*Brassica oleracea*	Kabeji					
	Root			2.87 [b]	22.52 [c]	1.83 [a]	11.45 [b]	0.27
	Stem			0.55 [a]	15.38 [b]	3.17 [a]	3.07 [a]	ND
	Leaf			5.03 [c]	5.50 [a]	2.67 [a]	0.38 [a]	ND
	Cucumber	*Cucumis sativus*	Kwawamba					
	Root			ND	ND	ND	ND	ND
	Stem			1.43 [a]	15.75 [ab]	3.67 [c]	214.48 [c]	ND
	Leaf			1.92 [a]	16.13 c	2.83 [b]	16.52 [a]	ND
	Fruit			1.38 [a]	12.78 [a]	1.83 [a]	26.08 [b]	ND
	Maize	*Zea mays*	Masara					
	Root			3.53 [a]	12.42 [a]	18.92 [b]	111.80 [b]	ND
	Stem			5.53 [b]	15.68 [a]	9.00 [a]	1.78 [a]	ND
	Leaf			6.14 [b]	15.37 [a]	9.08 [a]	30.78 [a]	ND
	Fruit			5.53 [b]	15.68 [a]	8.08 [a]	105.80 [b]	ND
	Rice	*Oryza sativa*	Shinkafa					
	Root			3.68 [a]	13.55 [a]	12.42 [a]	92.55 [a]	1.00 [a]
	Stem			3.92 [a]	18.70 [ab]	6.17 [a]	37.13 [a]	0.97 [a]
	leaf			ND	ND	ND	ND	ND
	Fruit			3.68 [a]	23.34 [c]	19.50 [a]	1150.50 [b]	0.93 [a]
Safe limits[a]				0.2	0.3	2.3	40	60

[a]Source:FAO/WHO(2001). Mean followed with same letter across the column are not significantly different $p > 0.05$.

Bioaccumulation Factor (BAF) of heavy metals showed BAF > 1 for Cd, Pb and Zn and and BAF was in the decreasing order of Cu > Zn > Pb > Cd > Cr (Table 3). Pollution Indices (PI) lead compared to other metals and all crops had PI values > 1 for Cd and Pb and in most crops for Cr (Table Figure 4). Estimated Daily Intake of Metal (EDI) for adult exceeded the USEPA, (2006) oral reference dose daily limit in all the crops for Cd, Pb. (Table 3). The EDI for Cr, Zn and Cu were below the USEPA, (2006) except in *Solanum lycopersicum*, *Brassica oleracea,* and *Oryza sativa* for Cu. (Table 3). EDI values was in decreasing order of risk Cu > Pb > Cr > Cd > Zn. Hazard quotient (HQ) values were not detected for Zn and > 1 for *Oryza sativa*. (Table 4.4). The HI values for all crops were > 1 (4.666) in *Oryza sativa*, (1.475) in *Zea mays*, (1.132) in *capsicum annuum.*

Table 3. Estimated daily intake of metals (EDI) (mg/kg/bw/day) through consumption of crops grown in Plateau state (2018).

Name of Sample	Botanical Name	Hausa Name	Estimated Daily Intake				
			Cd	Pb	Cr	Cu	Zn
Tomato	*Solanum lycopersicum*	Tomatur	0.007	0.053	0.016	0.051	0.002
Pepper	*Capsicum annuum*	Attarugu	0.005	0.647	0.007	0.037	0.001
Onion	*Allium cepa*	Albasa	0.004	0.525	0.003	0.010	0.001
Carrot	*Daucus carota*	Karas	0.007	0.115	0.004	0.002	0.000
Spinach	*Spinacia oleracea*	Alayyaho	0.005	0.491	0.006	0.022	0.000
Lettuce	*Lactuca sativa*	Salad	0.002	0.524	0.003	0.021	0.000
Cabbage	*Brassica oleracea*	Kabeji	0.007	0.168	0.004	0.001	0.000
Cucumber	*Cucumis sativus*	Kokwamba	0.002	0.389	0.003	0.037	0.000
Maize	*Zea mays*	Masara	0.008	0.478	0.012	0.152	0.000
Rice	*Oryza sativa*	Shinkafa	0.005	0.711	0.028	1.649	0.001
	RfD[a]		0.001	0.004	1.5	0.04	0.30

[a]Source:USEPA, (2006).

Table 4. Hazard quotient and Hazard index for adult population through the consumption of crops grown in Plateau (2018).

Name of Sample	Botanical Name	Hausa Name	Hazard Quotient(HQ)					Hazard Index(HI)
			Cd	Pb	Cr	Cu	Zn	
Tomato	*Solanum lycopersicum*	Tomatur	0.619	0.053	0.001	0.107	ND	0.780
Pepper	*Capsicum annuum*	Attarugu	0.406	0.647	ND	0.078	ND	1.132
Onion	*Allium cepa*	Albasa	0.331	0.525	ND	0.020	ND	0.877
Carrot	*Daucus carota*	Karas	0.564	0.115	ND	0.005	ND	0.684
Spinach	*Spinacia oleracea*	Alayyaho	0.391	0.491	ND	0.048	ND	0.930
Lettuce	*Lactuca sativa*	Salad	0.174	0.524	ND	0.044	ND	0.742
Cabbage	*Brassica oleracea*	Kabeji	0.613	0.168	ND	0.001	ND	0.782
Cucumber	*Cucumis sativus*	Kokwamba	0.169	0.389	ND	0.079	ND	0.637
Maize	*Zea mays*	Masara	0.674	0.478	0.001	0.322	ND	1.475
Rice	*Oryza sativa*	Shinkafa	0.449	0.711	0.002	3.504	ND	4.666

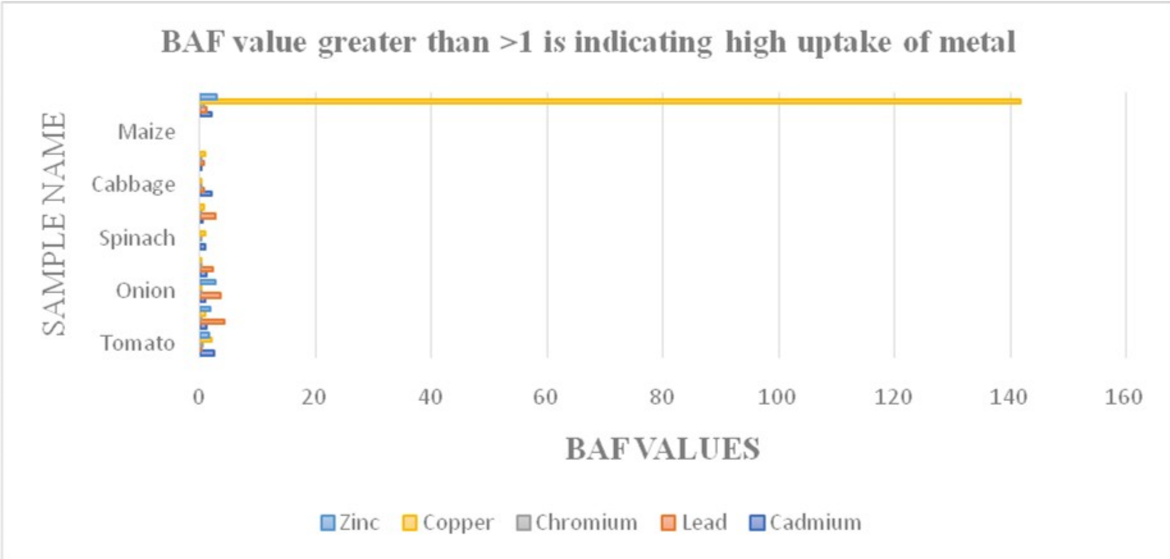

Figure 2. Bioaccumulation factor (BAF) of heavy metals in the edible parts of crops grown in Plateau (2018).

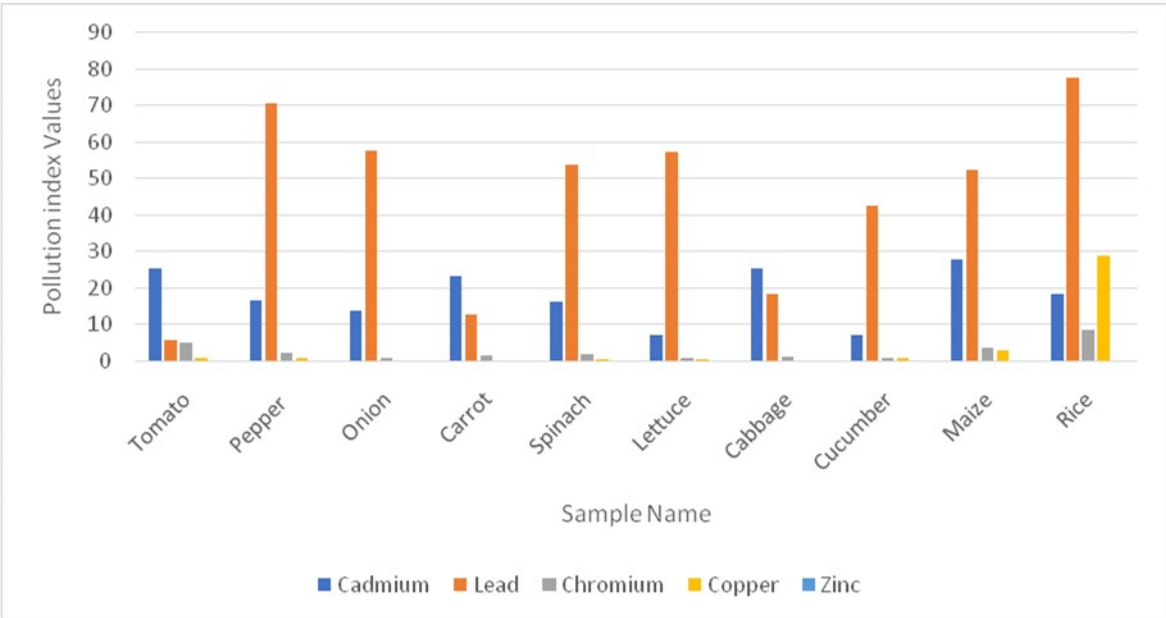

Figure 3. Pollution indices of heavy metals in the edible parts of crops grown in Plateau state (2018).

4. Discussion and Conclusions

The contamination of food crops by heavy metals from pesticides sources are a major concern of food quality safety. The concentrations of Cd, Pb, and Cr in all the studied crops fumigated with pesticides as the only source of contamination have exceeded the WHO, (2011) permissible limits. While the concentration of heavy metals in the corresponding soils of all the studied crops were below the UNEP, (2013) limits for agricultural soils. Most of the studied crops showed BAF > 1 for Cd, Pb, and Zn and BAF was in decreasing order of Cu > Zn > Pb > Cd > Cr. Pollution index indicated that most of the studied crops were contaminated for Pb, Cd, and Cr. The estimated daily intake of metals showed that all the studied crops have exceeded the daily oral reference dose limit and could cause risk to human. Hazard quotient showed all the studied crops were safe for human consumption except *Oryza sativa* for Cu which may cause risk to human. However, the inhabitants may be experiencing severe adverse health risk (HI) from the consumption of *Oryza sativa, Zea mays* and *Capsicum annuum* for all the studied metals. Similar reports relating to this work include but not limited to Liang et al., (2019), Njuguna et al., (2019), Peters et al., (2018), Eliku and Leta, (2017). Proshadet al., (2019). Thus, there is need for regular screening of heavy metals in pesticides. The predominant use of metal based pesticides with high Cd, Pb and Zn in the study areas could be responsible for BAF > 1 values observed (Yuguda et AL., 2015)

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