

Accumulation of Heavy Metals in Vegetables Grown on Wastewater Irrigation Farms in Bauchi L.G. A.

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ABSTRACT

Vegetables provide minerals and nutrients essential for both humans and animal well-being. The continuous application of waste water for irrigation of these vegetables may likely increase their heavy metal load and contamination. The aim of this study is to investigate the concentration of heavy metal (Pb, Ni, Cd, Fe, Cr, Cu and Zn) accumulated in three different kinds of vegetables (onion, tomatoes, spinach) grown in some commercial wastewater irrigated farms in Bauchi L.G.A., and their possible pollution index. All the collected samples were analyzed for Cd, Cu, Pb, Ni, Fe, and Zn using the Atomic Absorption Spectrophotometer; and the measured parameters were compared to the WHO/FAO permissible limits. Results of analysis indicated that the accumulation of the metals in the study vegetables varied considerably. The ranges of the concentration (mg/kg) of Ni, Fe, Pb, Cu, Zn and Cd in the onions in all the study sites are 0.27 – 1.44, 1.00 – 2.25, 0.61 – 1.96, 2.14 – 3.25, 1.65 – 3.96 and 1.99 – 6.51 respectively. For tomatoes, the concentrations (mg/kg) are 1.22 – 2.29, 0.69 – 1.23, 0.44 – 1.38, 2.71 – 10.61, 1.65 – 6.32 and 2.32 – 11.67, while in spinach, the levels in mg/kg were 0.71 – 1.32, 1.07 – 2.01, 1.00 – 1.56, 1.34 – 7.22, 0.90 – 5.79, 2.84 – 4.60. In all the sites, the level of Cd and Pb exceeded the WHO/FAO permissible limits of 0.30mg/kg and 0.21mg/kg respectively. The level of Ni in tomatoes in Bayara (1.93 ± 0.02 mg/kg) and Kofar Idi (2.29 ± 0.01 mg/kg) also exceeded the WHO/FAO permissible limits of 1.50mg/kg. MPI values obtained were greater than 1. Onions and tomatoes grown in Kofar Idi had the highest MPI levels (2.228, 2.201) while Spinach in Bayara had the highest MPI (2.517). The observed levels of metal, above the safe limits, and the MPI of the sampled vegetables indicate that these vegetables may not be suitable for human consumption.

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INTRODUCTION

Vegetables are an integral part of human diet due to their nutritional contents, which are essential for human existence. They contain essential micronutrients like Fe, Zn, Ca, K, I, and other essential metabolites (Mawari et al. 2022). Unfortunately, most edible vegetables grown in urban cities and their suburbs are contaminated because they are either grown in heavy metal polluted areas or in nearby sources of heavy metal pollution. Heavy metals are released into the environment via a variety of practises, which include irrigation with polluted

water, inorganic fertilisers, herbicides, discharge of wastes into water bodies. Prolonged used of wastewater polluted with heavy metal has been reported to raise heavy metal concentrations in both soil and plants over the allowable limit (Christou et al., 2014). Soil in most cases is the reservoir for these metal contaminants, from which they are transmitted into the food chain. When soils are polluted by heavy metals, its health implications especially with regards to vegetables and other food crops grown on the soil is enormous. Although some of these heavy metals such as Fe, Zn, Cu, Ni,

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Co and Mn are necessary for the growth and normal function of living things at trace amounts, they can cause acute or chronic toxicity when consumed in large amount (Reuben et al., 2017; Liang et al., 2019; Mawari et al., 2022). According to Orisakwe et al., (2012), the entry of these metals into the food chain would result in the increased susceptibility and exposure of humans to the metals, resulting in poisoning of the local population. Consuming heavy metal contaminated foods could lead to deficiency of some essential minerals in the body. This would likely result in decreased immune defenses, intrauterine growth retardation, impaired psycho-social behaviors, and disabilities associated with malnutrition. The accumulation of these metals in human tissue beyond permissible limits would adversely affect vital organs and systems. Excessive intake of cadmium, lead, copper and chromium can adversely affect the bone; cause neurological and cardiovascular disorders, renal impairment and gastrointestinal disturbances (Najmi et al., 2023).

Several plants are non-selective in absorption and uptake of heavy metals. Their plant roots absorb these metals from the contaminated/polluted soils and environmental wastes, and accumulate them in large concentration in the aerial or edible parts of plant tissues (Tang et al., 2021; Mohammad et al., 2022). Najmi et al., (2023) studied the levels of Fe, Mn, Zn, Cu, Cr, Pb, Co, Cd, and Mg in lettuce, radish, mint, parsley and jarjir grown in the Jazan region of Saudi Arabia using an ICP-MS. Their results revealed that jarjir had the highest contamination level while radish was the least contaminated, though the concentrations of all the analysed heavy metals were lower than their corresponding maximum permissible limits set by the FAO/WHO and European Committee. Hang et al., (2016) noted that the concentrations of Pb, Cd, Cu, Zn and As in the edible parts of the vegetables planted in contaminated farmland were highest in leafy vegetables compared to the other types of vegetables. They observed that leafy vegetables have the ability for heavy metal uptake. A study in Hong Kong revealed that 16%, 26%, and 0.56% of market vegetables were contaminated by Pb, Cd and Cr, respectively (Hu et al., 2013). High levels of Cd, exceeding the Australian allowable limit (0.1

mg/kg) have been reported in vegetables obtained from Australia and Bangladeshi (Hang, 2016). Mohammed et al., (2022) reported that the levels of Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn in the vegetable grown and sold in different areas of Aligarh city in India were above the international standard (WHO/FAO). They therefore concluded that accumulation of the metals in vegetables may be due to the utilization of effluent containing water in irrigation, changes in the agricultural practices, and exposure of vegetables to multiple levels of air pollutants release from various sources of Aligarh city and abundant deposition of these pollutants in peri-urban areas of Aligarh.

Considering the adverse effect of these heavy metals on humans as a result of excessive and continuous consumption of the vegetable harvested from wastewater irrigated farms, it has become very important to investigate the level of heavy metal in commonly consumed vegetables grown on these farms so as to create public awareness on environmental pollution and provide adequate information to environmental agencies to create policies that will enhance food safety and quality.

Metal Pollution Index (MPI)

MPI is used to estimate the overall load heavy metals concentration determined in vegetable samples (Sharma et al., 2016). The MPI (in mg/kg) = $[C_{Ni} \times C_{Fe} \times C_{Pb} \times C_{Cu} \times C_{Zn} \times C_{Cd}]^{1/n}$

Where C = Average concentration of a particular metal in the vegetable and n = number of heavy metals determined in the assessment (n = 6).

RESULTS AND DISCUSSION

Heavy Metal Accumulation in the studied Vegetables

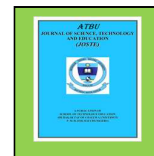
The concentrations of the heavy metals in the vegetables studied are shown in Tables 1 – 3. The ranges of the concentration (mg/kg) of Ni, Fe, Pb, Cu, Zn and Cd in the onions in all the study sites are 0.27 – 1.44, 1.00 – 2.25, 0.61 – 1.96, 2.14 – 3.25, 1.65 – 3.96 and 1.99 – 6.51 respectively. Hussaini et al., (2021) reported Ni, Pb and Cd levels of 1.72 – 2.12mg/kg, 2.37 – 5.47mg/kg and 1.33 – 1.73 mg/kg respectively in wastewater

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irrigated farms in Kano metropolis compared to the present work.

Table 1: Heavy metals concentration (mg/kg) in Edible vegetables grown in Bayara wastewater Irrigated farm

Metals (mg/kg)	Ni	Fe	Pb	Cu	Zn	Cd
Onion	1.44±0.00	1.00±0.00	1.10±0.01	3.25±0.01	3.96±0.01	1.99±0.03
Tomatoes	1.93±0.02	1.23±0.01	0.72±0.01	3.47±0.02	6.32±0.01	2.32±0.03
Spinach	1.32±0.01	1.07±0.019	1.56±0.01	7.22±0.02	4.49±0.00	3.56±0.03
Range	1.32 – 1.93	1.00 – 1.23	0.72 – 1.56	3.25 – 7.22	3.96 – 6.32	1.99 – 3.56
WHO/FOA (2001)	1.50	-	0.30	9.4	60	0.21

For tomatoes, the concentrations (mg/kg) are 1.22 – 2.29, 0.69 – 1.23, 0.44 – 1.38, 2.71 – 10.61, 1.65 – 6.32 and 2.32 – 11.67, while in spinach, the levels in mg/kg were 0.71 – 1.32, 1.07 – 2.01, 1.00 – 1.56, 1.34 – 7.22, 0.90 – 5.79, 2.84 – 4.60.

Accumulation of Cd, Pb and Ni in this study compares favourably to those reported in Hussaini et al., (2021) (1.53 – 2.14mg/kg Cd, 4.37 – 6.19mg/kg Pb and 1.39 – 2.21mg/kg Ni).

Table 2: Heavy metals concentration (mg/kg) in Edible vegetables grown in wastewater Irrigated farm at FGCC

Metals (mg/kg)	Ni	Fe	Pb	Cu	Zn	Cd
Onion	0.27±0.01	1.95±0.01	0.61±0.01	2.14±0.02	1.65±0.01	6.51±0.04
Tomatoes	1.22±0.01	0.72±0.01	0.44±0.01	10.61±0.01	2.06±0.01	7.19±0.05
Spinach	0.71±0.01	2.01±0.01	1.00±0.01	1.34±0.01	5.79±0.02	4.60±0.04
Range	0.27 – 1.22	0.72 – 1.95	0.44 – 1.00	1.34 – 10.61	1.65 – 5.79	4.60 – 7.19
WHO/FOA (2001)	1.50	-	0.30	9.4	60	0.21

Table 3: Heavy metals concentration (mg/kg) in Edible vegetables grown in Kofar Idi wastewater Irrigated farm

Metals (mg/kg)	Ni	Fe	Pb	Cu	Zn	Cd
Onion	1.18±0.01	2.25±0.01	1.96±0.01	3.07±0.01	2.61±0.00	2.93±0.05
Tomatoes	2.29±0.01	0.69±0.00	1.38±0.01	2.71±0.03	1.65±0.01	11.67±0.06
Spinach	0.84±0.01	1.83±0.01	1.08±0.00	3.61±0.01	0.90±0.01	2.84±0.03
Range	0.84 – 2.29	0.69 – 1.83	1.08 – 1.96	2.71 – 3.61	0.90 – 2.61	2.84 – 11.67
WHO/FOA (2001)	1.50	-	0.30	9.4	60	0.21

Patterns of accumulation of heavy metals in vegetables based on the locations of the wastewater Irrigated farm

The patterns of accumulation of heavy metals in vegetables based on the locations of

the wastewater Irrigated farm are shown in Figures 1-3. Results of analysis indicated that the accumulation of the study metals in onions in Bayara followed the pattern Fe<Pb<Ni<Cd<Cu<Zn; in FGCC:

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Ni<Pb<Zn<Cu<Fe<Cd while in Kofar Idi, it was Ni<Pb<Fe<Cd<Zn<Cu (Figure 1). Heavy metal accumulation pattern in tomatoes in Bayara was

Pb<Fe<Ni<Cd<Cu<Zn, in FGCC: Pb<Fe<Ni<Zn<Cd<Cu; the pattern in kofar Idi is Fe<Pb<Zn<Ni<Cu<Cd (Figure 2).

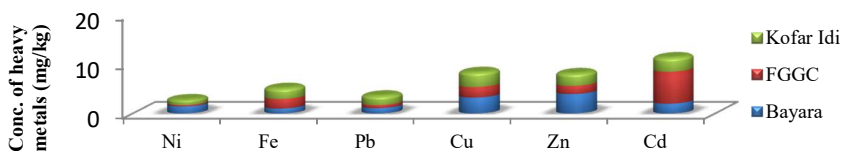


Figure 1: Pattern of accumulation of heavy metals (mg/kg) in Onion based on the locations of the wastewater Irrigated farm

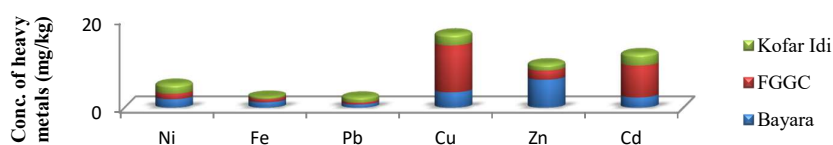


Figure 2: Pattern of accumulation of heavy metals (mg/kg) in Tomatoes based on the locations of the wastewater Irrigated farm

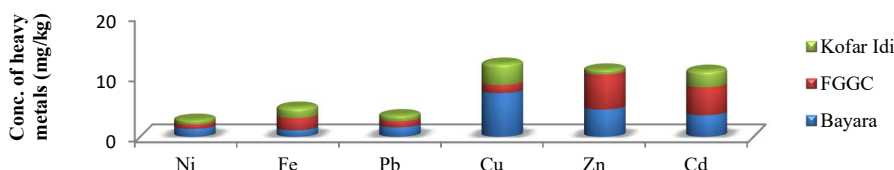


Figure 3: Pattern of accumulation of heavy metals (mg/kg) in Spinach based on the locations of the wastewater Irrigated farm

For the accumulation of the heavy metals in spinach based on the studied locations, the following patterns were observed. Bayara: Fe<Pb<Ni<Cd<Zn<Cu, FGCC: Fe<Pb<Cu<Fe<Ni<Cd<Zn and Kofar Idi: Ni<Zn<Pb<Fe<Cd<Cu (Figure 3). Studies have shown that heavy metals easily accumulate in the edible parts of leafy vegetables compared to other forms of vegetables (Garg et al. 2014).

Metal Pollution Index (MPI)(mg/kg) for vegetables

In Figure 4, the pollution index calculated for the vegetables in Bayara was in the order: Onion (1.854) <tomatoes (2.105) < spinach (2.517). In FGCC, the order is onion (1.395) < Spinach (1.925) < tomatoes (1.983).

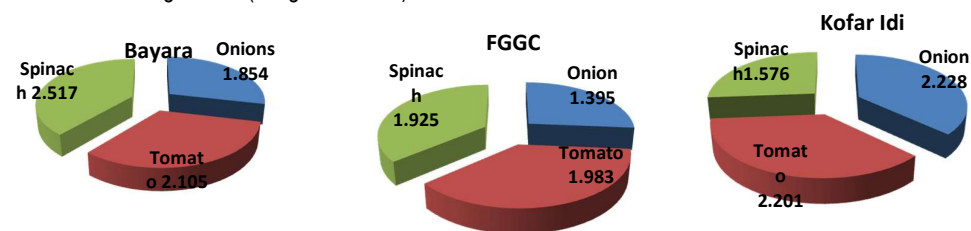


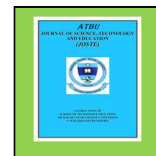
Figure 4: Metal Pollution Index (mg/kg) for vegetables grown in Wastewater Irrigated Farmlands

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For Kofar Idi, the MPI followed the ascending order Onion (2.228) > tomatoes (2.201) > spinach (1.576). The estimated MPI levels for the various studied vegetables are very high and therefore calls for serious action. Onions and tomatoes grown in Kofar Idi had the highest MPI levels while Spinach in Bayara had the highest MPI. The MPI values for all the three vegetables were observed to be different for the investigated locations. It is an indication that the level of heavy metals in the vegetables is influenced by the source of the wastewater used in the farms and other environmental conditions. The levels of Pb, Ni and Cd contributed to a larger extent to the estimated MPI values reported in this study. Hu et al. (2013) reported that 16% and 26% vegetables bought from markets in Hong Kong were contaminated by Pb and Cd respectively. These metals have been classified as carcinogens. Their presence in vegetables beyond the recommended limits will result in serious health issues within these studies localities.

CONCLUSION

The result of the heavy metal analysis of vegetables in the study shows elevated levels of Cd, Pb and Nickel in vegetables studied. The high metal pollution indices for vegetables are an indication that the continual application of the contaminated wastewater to the farm may have contributed to the observed accumulated metals and this poses serious environment problems. Residents, within these study area and customers, who patronize these farms, may face serious health risks due to the regular consumption of these vegetables from these wastewater irrigated farms.

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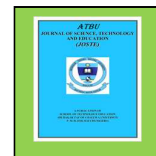
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