



Heavy Metals Contamination of Agricultural Land and Their Impact on Food Safety

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MM and IYH designed the study and conducted the laboratory experiments, authors IH and AAB collect the samples and wrote the protocol and conducted statistical analysis and all wrote the first draft of the manuscript. Authors AY and TAM managed the analyses of the study. All author managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI:10.9734/EJNFS/2021/v13i130354

Editor(s):

(1) Dr. Rasha Mousa Ahmed Mousa, University of Jeddah, Saudi Arabia.

Reviewers:

(1) José Franciraldo de Lima, The Federal University of Campina Grande, Brazil.

(2) Victor Pablo Pardo Arquero, Spain.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/63702>

Original Research Article

Received 01 November 2020

Accepted 02 January 2021

Published 03 March 2021

ABSTRACT

Aims: The aim of this study is to investigate the heavy metals pollution status and health risks assessment of the vegetables grown at Danbatta irrigation lands.

Study Design: The research involved the collection of soil, water and cultivated vegetable from irrigation lands as well as analyzing their heavy metals pollution status.

Place and Duration of Study: Samples were collected from Danbatta irrigation lands of Kano state, Nigeria. The research study covered a period of one year.

Methodology: This study investigates the prevalence of heavy metals pollution and related health risks associated with the vegetables grown at Danbatta local government of Kano state. This was achieved by collecting irrigation soil, water and vegetables (onion, spinach and lettuce) from the irrigation sites, which were subsequently assayed for several heavy metals such as; Pb, Mn, Cu, Fe, Zn and Co using atomic absorption spectrophotometry (AAS).

Results: The results obtained show that the concentrations of Pb, Cu and Zn in water samples to be 0.033, 0.8, and 0.89 mg/ml, respectively, while Mn and Co were not detected. Even though concentrations of these metals in water are within FAO/WHO limits, the soil was found to be contaminated with Cu (12.17 mg/kg), Fe (152.29 mg/kg) and Zn (55.75 mg/kg). Furthermore, both spinach, lettuce and onion were contaminated with Pb, and Mn. However, only lettuce and spinach were contaminated with Cu, Fe and Zn. Health risk assessment of both adults and children show that Pb, Mn, Co and Cu, posed a significant health risk to the population as their health risk index (HRI) is greater than one. The result shows that poor agricultural practices could be responsible for contaminating the soil with heavy metals, which eventually gets accumulated in the edible parts of the plants and posed a great risk to its consumers. Impacts of heavy metals pollution is on the rise across the globe. As such, it becomes necessary to monitor our environment to checkmate the threat of these contaminants and implement a reliable strategy and stable treatment of the pollution to ensure food safety.

Keywords: Heavy metals; environmental pollution; vegetables; food safety.

1. INTRODUCTION

Environmental pollution remains one of the major challenges facing humanity today. The impact of heavy metals on food security is a worldwide public health issue due to their toxicity, non-biodegradability and persistently spent a lengthy time in the soil [1,2]. They are released to the soil through the application of chemicals, polluted water and direct waste disposal on farmlands. The presence of heavy metals in soil is a serious issue for the entire ecosystem. They can pass into the food chain when taken up by plants and to humans by ingestion, inhalation, or drinking of polluted water [3]. The toxicity of heavy metals depends on the age of an organism, the biological role of the metal, amount and the duration of the exposure [4]. Heavy metals become toxic when they are metabolized by the body and accumulated into the soft tissues. High consumption of contaminated food can pose a serious risk to the human body as such food security is the prerequisite for human health and survival [5]. For instance, excessive amounts of Pb can damage the brain and central nervous system to cause coma, convulsion and even death [6]. Manganese toxicity can cause permanent neurological disorder and adverse cognitive effects [7], while, Copper toxicity induces iron deficiency, lipid peroxidation, destruction of membranes, coma and death [8]. Within this context, monitoring heavy metals pollution and health risk assessment are very vital steps for putting the right policies on environmental protection and proper public health measures. In this study, the concentrations of Pb, Cu, Co, Fe, Zn and Mn in soil, water, *Spinacia oleracea* (spinach), *Lactuca sativa* (lettuce) and *Allium cepa* (onion) were determined from irrigation farmlands located at

Danbatta Local Government Area of Kano State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The sampling site is located along the Bank of River Danbatta (Thomas dam) at Danbatta Local Government Area of Kano State, Nigeria. Large scale vegetable production is conducted in these areas, essentially to sustain markets in the city.

2.2 Sampling

Surface soil samples were randomly collected from 10 plots and 100 ml of the irrigation water were collected in triplicate from different sites. On the other hand, matured leaves of spinach, lettuce, and onion bulbs were collected from 10 farms, packaged into labeled paper bags and transported to the lab.

2.3 Sample Preparation

Soil samples were dried in the lab to remove the moisture content, crushed and passed through 2 mm mesh size sieve. All the collected vegetable samples were washed with distilled water to remove airborne pollutants. The edible parts of the vegetable samples were weighted and air-dried for a day, followed by oven-drying at 70 - 80°C for 24 h. Dried samples were finely powdered and sieved.

2.4 Digestion of Sample

Samples were digested as described by Allen et al. [9]. Accurately 2.0 g of soil samples were weighed and wet with one to two drops of water

and then 2 cm³ of sulphuric acid and 4 cm³ of nitric acid were added to the samples. The mixtures were digested slowly in a digestion block for one hour and finally diluted and filtered. Similarly, 10 cm³ of Conc. HNO₃ was added to a 100 cm³ of water sample and boiled slowly on a hot plate till it evaporated to about 50 cm³, after cooling, another 5 cm³ of nitric acid was added. Continuous heat was supplied with further addition of nitric acid until when a slight colored solution was observed. Similarly, 1.0 g (Dry weight) of finely grounded vegetable is added into the crucible and put into a muffle furnace for 4 hours at 500°C, then transferred to the desiccator for 30 minutes to cool down. To the leftover ash, 5 ml of 1 molar nitric acid solution was added and heated at 400°C for about 10 to 12 min when perfectly grayish-white ash was obtained.

2.5 Determination of Heavy Metals Concentration in the Samples

Analysis of the concentrations of Pb, Cu, Co, Fe, Zn and Mn were carried out using Atomic Absorption Spectrophotometer according to the standard protocol [10]. The samples were analyzed in triplicates.

2.6 Estimation of Heavy Metals Accumulation Factor

Heavy metals have the capability of translocations from soil to the edible parts of food crops. This translocation can be determined by the accumulation factor (AF) according to the equation [11].

Accumulation factor =

$$\frac{\text{heavy metals concentration in vegetables}}{\text{Heavy metals concentration in Soil}} \quad (1)$$

2.7 Estimation of Heavy Metals Daily Intake Rate

The daily intake rate of heavy metals (DIR) was calculated as described previously with the assumptions of considering the average body weights of adults and children to be 55.9 kg and 32.7 kg, respectively, while average daily vegetable intakes for adults and children to be 0.345 and 0.232 kg/person/day respectively [11]. DIR was calculated according to equation (2).

Daily intake rate =

$$\frac{\text{Conc of metal in plant (mg/kg)} \times \text{daily Food intake}}{\text{Average body weight (kg/person)}} \quad (2)$$

2.8 Estimation of Heavy Metals Health Risk Index

Health risk index (HRI) is the ratio of the metals daily intake in the food divided by the oral reference dose according to equation (3), an HRI >1 for the toxic metal in food crops means that the consumer population faces a health risk[7]:

$$\text{Health risk index} = \frac{\text{Daily metal intake}}{\text{Oral reference dose}} \quad (3)$$

2.9 Statistical Analysis

Statistical analysis was performed using SPSS version 20. Data were presented in mean and standard deviation. Student's t-test at 5% level of significance was employed for data analysis.

3. RESULTS

3.1 Heavy Metals Concentration in Farmland and Water

The concentration of heavy metals in soil and water were presented in Table 1, the mean concentration of Pb, Cu and Zn in water samples were 0.033 mg/ml, 0.8 mg/ml, and 0.89 mg/ml, respectively, while Mn, Fe and Co were not detected. According to these findings, the concentration of these metals in irrigation water were within the safe limit of FAO/WHO (Table 1). Similarly, Pb, Mn, Cu, Fe, Zn and Co were all present in the soil with mean concentrations of 1.99, 11.29, 12.17, 152.29, 55.75 and 8.13 mg/kg respectively, among these metals, Cu, Fe and Zn were present above the safe limits of FAO and WHO standards [12], while Mn and Co were not (Table 1).

3.2 Assessment of Heavy Metals Contamination of Vegetables

The concentrations of heavy metals were further determined in *S. oleracea* (spinach), *L. sativa* (lettuce) and *A. cepa* (onion) that were cultivated at the study site. As shown in Table 2, the mean concentration of Pb in spinach is 5.46 mg/kg, in lettuce is 7.65 mg/kg and in onion is 8.74 mg/kg respectively, while Mn, Cu, Fe, Zn and Co were respectively, 5.46, 5.97, 27.63, 16.75, 41.05 and 78.86 mg/kg in spinach, In the lettuce are 7.65, 6.82, 48.36, 82.08, 57.39 and 50.41 mg/kg, while in the onion are at the concentrations of 8.74, 4.26, 63.90, 55.78, 51.24 and 42.28 mg/kg respectively. This indicates that all the three vegetables cultivated at the study site were

contaminated with Pb (FAO/WHO limit, 0.3 mg/kg) and Mn (FAO/WHO limit; 2 mg/kg), while lettuce and spinach were contaminated with Cu (FAO/WHO limit; 40 mg/kg), Zn (FAO/WHO limit; 47.4 mg/kg) and Fe (FAO/WHO limit; 20 mg/kg).

compared to Mn, Fe and Zn. Pb has a transfer coefficient of 2.7, 3.8 and 4.3 in spinach, lettuce and onion, respectively. Mn has the least transfer coefficient of 0.5, 0.6 and 0.38 in Spinach, lettuce and onion, respectively.

3.3 Bioaccumulation of Heavy Metals

Bioaccumulation is the pathway by which the heavy metals from the soil enters into the food chain. As shown in Fig. 1, Cu, Co and Pb, have a higher transfer coefficient in all the vegetables

3.4 Heavy Metals Intake

The health risk impact of heavy metals exposure through food consumption depends on the amount of exposure and accumulation of these heavy metals [4]. In this study, we estimated the

Table 1. Mean concentration of heavy metals in soil (mg/kg) and water (mg/ml)

	Pb	Mn	Cu	Fe	Zn	Co
Water						
Observed	0.033	ND	0.80±0.183	ND	0.89±0.07	ND
Standard	0.1	-	20	3	50	-
Soil						
Observed	1.99±0.47	11.29±1.14	12.17±3.0	152.29±4.43	55.75±2.18	8.13±1
Standard	10	437	6	150	50	-

Standards are by FAO/WHO 2001, and Codex Alimentarius commission 1994, Values are expressed as Mean SD of Triplicate (n=3)

Table 2. Mean concentration (mg/kg) of heavy metals in the edible parts of vegetables

Heavy metals	<i>S. oleracea</i> (Spinach)	<i>L. sativa</i> (Lettuce)	<i>A. cepa</i> (Onion)	WHO/FAO Limits ^a
Pb	5.46 ± 1.89	7.65 ± 1.89	8.74 ± 1.89	0.3
Mn	5.97 ± 1.48	6.82 ± 1.47	4.26 ± 1.48	2.0
Cu	27.63 ± 5.9	48.36 ± 7.92	63.90 ± 7.91	40
Fe	16.75 ± 2.90	82.08 ± 31.9	55.78 ± 5.03	20
Zn	41.05 ± 2.84	57.39 ± 8.53	51.24 ± 4.93	47.4
Co	78.86 ± 18.62	50.41 ± 25.39	42.28 ± 18.63	-

^aWHO limits (FAO/WHO 2001, and Codex Alimentarius commission 1994, Values are expressed as Mean SD of Triplicate (n=3)

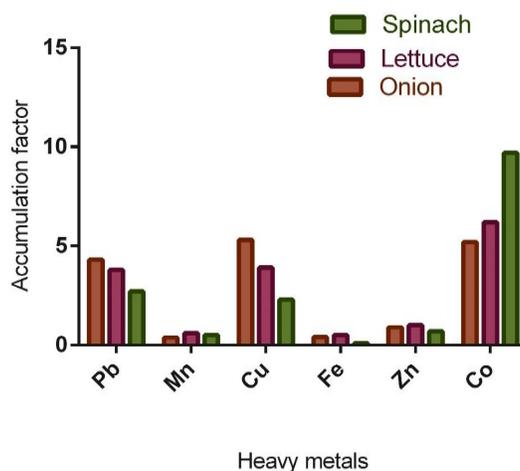


Fig. 1. Bioaccumulation of heavy metals in different vegetables

average daily intake of heavy metals by both adults and children through the consumption of vegetables (Fig. 2). Co, Fe, Zn and Cu have the highest percentage of the heavy metals consumed via vegetables under study. Onion has a higher capacity of absorbing and accumulating most of the metals than spinach and lettuce.

3.5 Health Risk Index Assessments of Consuming the Contaminated Vegetables

Health risk index (HRI) was estimated by taking the ratio of the daily heavy metals intake in vegetables to the oral reference dose, an HRI of <1 for any metal in food crops means that the consumer population faces a health risk [7]. Based on that, as shown in Table 3, only Fe, and Zn were within the safe limit in both adult and children population, whereas Pb, Mn, Co and Cu, poses a greater health risk to the population as their HRI is greater than 1 (Table 3).

4. DISCUSSION

Heavy metals contamination of the environment is one of the major threats to our collective wellbeing. Industrial effluents, mining activities, bad agricultural practices and air pollutants emitted by vehicles and other machinery are the major contributors to ecological pollution. Vegetables are the major constituent of the human diet. Unfortunately, their safety is under a menace of heavy metals contamination, a phenomenon that has become an alarming issue across the globe [12].

Heavy metals concentrations in soil, water and vegetables were analyzed in this study in order to determine the health risk and pollution index of the agricultural lands. As shown in Table 1, irrigation water was found to be safe for agricultural purposes as the concentration of Pb, Cu, Fe and Zn were both below the limit set by FAO/WHO [13]. In contrast, Minhaz Ahmad et al. have reported irrigation water contaminated with heavy metals in farmland near an industrial area in Bangladesh [14]. And in Tanzania, the

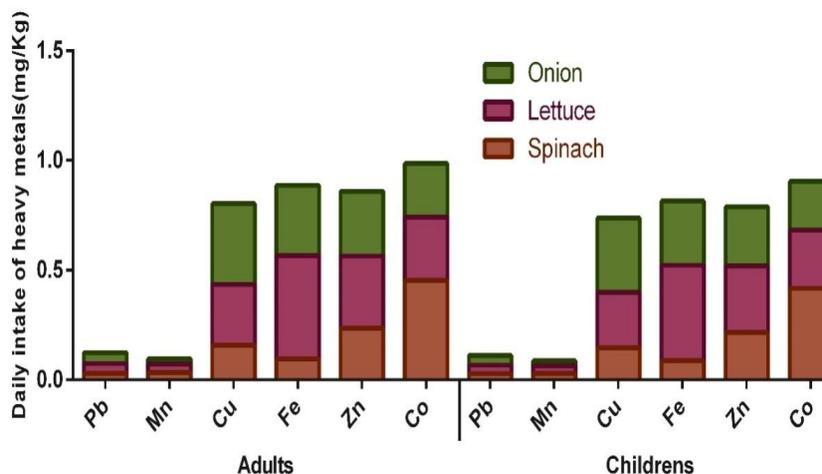


Fig. 2. Estimated daily heavy metals intake for adults and children

Table 3. Health risk index of adults and children population

Heavy metals	Adults			Children		
	Spinach	Lettuce	Onion	Spinach	Lettuce	Onion
Pb	7.75	10.75	12.5	7.0	10	11.5
Mn	2.27	2.6	1.6	2.06	2.4	1.47
Cu	3.95	6.95	9.17	3.65	6.37	8.45
Fe	0.137	0.67	0.46	0.126	0.62	0.42
Zn	0.79	1.09	0.98	0.723	1.01	0.90
Co	22.65	14.45	12.15	20.85	13.3	11.15

irrigation water is chiefly polluted with Pb and Fe but not with Zn [15]. This indicated that the source of the irrigation water body is the determinant of its pollution status as such, most of the irrigation lands that have effluents from the industrial area have a mild to a high concentration of these metals.

Analysis of soil samples has a different story as the soil is contaminated with Cu (12.17 mg/kg), Fe (152.29 mg/kg), and Zn (55.75 mg/kg), which all revealed higher concentration values than the limits set by FAO/WHO [12]. While Pb, Co, and Mn have moderate concentrations in the soil. Similarly, Mashi and Alhassan reported Zn contamination of 30 irrigation sites in Kano [16]. While at Kwara State, Nigeria, roadsides soil were found with a high concentration of Pb, Cu and Zn [1]. Heavy metals such as Pb, Mn and Cu pollution of agricultural land can be as a result of poor agricultural practices of dumping refuse as organic manure that may contain batteries and other electrical appliances. Fe and Zn could be from phosphorous fertilizer or agrochemical [17].

Heavy metals in soils could be readily absorbed by the roots of leafy vegetables by transpiration and translocation, at different rates. Upon analysis of the vegetables, we found that they were able to absorb and accumulate significant concentrations of the metals in their edible parts. The result shows that Pb, Cu and Zn (Table 2) were present in onion spinach and lettuce at the concentrations above the limits set by FAO/WHO [12]. Their concentrations varied in these vegetables; the variation could be as a result of differences in absorption capacity and their translocation within the plants. Furthermore, evidence of heavy metals contamination of vegetables has been reported by numerous researchers in Nigeria; Babandi et al. reported Pb concentration of up to 28 mg/kg in roadside plants [18], Olajire and Ayodele described a much higher concentration of heavy metal near the roadside at Ibadan; Pb 205 mg/kg, Cu (80 mg/kg), and Mn (86.2 mg/kg) [19]. Similarly, contamination of vegetables with heavy metals was reported in other parts of the world; for instance, Pb and Zn were found at higher concentrations in soybean of Argentina [20], Pb (3.96 mg/kg) in spinach of Pakistan, [21] while in India, Zn and Pb contaminated Amaranthus at a concentration of 10 mg/kg and 3.1 mg/kg respectively [22]. On the other hand, Unaegbu et al. from Nigeria, M. A. Elbagermi et al. from the Misurata area of Libya and May M. Amer et al. from Egypt both reported plant samples that

were not contaminated with the heavy metals and are safe for consumption [23-25]. Our results shows that Cu and Pb, has higher transfer coefficient in both lettuce, spinach and onion compared to Mn, Fe and Zn. Transfer of heavy metals from soil to vegetables depends on many factors, which include bioavailability of the metals, their concentration in the soil, chemical form, plant uptake capability and growth rate. Pb poorly translocate from soil to vegetables while Cu and Zn are easily absorbed by vegetables because of their functions as plant micronutrients [23]. Several studies have revealed contamination of aquatic animals in the water body, high concentration of heavy metals were found in the tissue of tilapia zilli [26].

Health risk assessment of contaminated vegetables suggested that only Fe and Zn were within the safe limit in both adult and children population, whereas Pb, Mn and Cu, have HRI values greater than one. As such, ingesting a higher amount of contaminated vegetables may accumulate in the body and causes serious complications in the long run. For instance, Lead can affect almost every organ in the body, among which the nervous system is the most affected. Long-time exposure to lead has been reported to cause anemia, increase in blood pressure, severe damage to the brain and kidneys, reduce fertility in males, and miscarriage in pregnant women [27]. Mn is essential to human health, acting as a co-factor of various enzymes, and is required for maintenance of nerve and immune cell functions, and regulation of blood sugar and vitamins. The earliest symptoms of overexposure to Mn include anorexia, apathy, hypersomnolence, and headaches. Neurobehavioral changes include irritability, emotional lability, and, after continued exposure, psychosis and speech abnormalities that sometimes lead to autism. Other signs and symptoms include masklike facies, bradykinesia, micrographia, retropulsion and propulsion, fine or coarse tremor of the hands, and gross rhythmical movements of the trunk and head [28]. Similarly, copper is required as an important catalytic cofactor in redox chemistry for many proteins, when present in excess, free copper ions can cause damage to cellular components. Excess copper induces not only oxidative stress but also DNA damage and reduced cell proliferation [29].

Heavy metals contamination of food is a global problem and there are strong needs for it to be addressed collectively [30]. Regulations and bioremediation techniques should be employed

to protect the environment against heavy metals pollution and avoid the consequences of complications associated with their toxicity.

5. CONCLUSION

Heavy metals pollution is a widespread threat to food safety worldwide. Though most of the investigators focused on the impact of heavy metals emanating from industrial waste rather than other potential causes such as poor agricultural practices as reported in this study. At Danbatta irrigation lands, we found that the water is free from heavy metals contamination, but due to poor agricultural practices, the soil is contaminated with Pb, Zn, Mn and Cu, which eventually get accumulated in the edible parts of the plants. Eating high amount of these vegetables exposes their consumers to a high risk of Pb, Mn and Cu. The effect of heavy metals pollution is on the rise across the globe. Contamination of agricultural soil, irrigation water or transpiration serves as an entry point of these heavy metals into the food chain. As such, it becomes necessary to monitor our environment to checkmate the threat of these contaminants and implement a reliable strategy and stable treatment of the pollution to ensure food safety.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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