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Research Article

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Health risk assessment and heavy metal bioaccumulation in vegetables irrigated with waste water in Kano State, Nigeria

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Abstract

Intake of vegetables grown in heavy metals contaminated soils is one of the most common food chain routes for exposure of human. For this purpose, this research aimed at evaluating the concentration of heavy metals (cadmium-Cd, lead-Pb and zinc-Zn) in vegetables such as spinach (S), lettuce (L), and onion (O), irrigated with two different wastewater sources in Kano State Nigeria. Atomic Absorption Spectrophotometric analysis (AAS) was used in this research to determine the metal levels. Zn (0.17-0.12 mg/l) was detected in the wastewater, as well as in the irrigated soil (8.36-33.64 mg/kg), while Cd and Pb were not detected in both the wastewater and irrigated soils. Furthermore, between (1.50-27.05 mg/kg) of Zn was detected in the assayed vegetables (S, L and O). However, there was no significant difference ($p<0.05$) between the Zn content of the two wastewater sites. *Lactuca sativa* was observed to have the highest Zn concentration (27.5 mg/kg) in site A, while *Spinacia oleracea* had the lowest Zn concentration (1.5 mg/kg). Zn levels in all the samples analysed in this study were below the permissible limit of 100 mg/kg in vegetables, 50 mg/kg in soil and 5mg/l in wastewater set by FAO/WHO. However, Pb and Cd were not detected in all the samples. Bioaccumulation factor was found ranging from 0.32-41.17 mg/kg and the pollution index ranged from (0.46-1.80 $\mu g\ g^{-1}$). This indicated potential health risk from Zn in people who are consuming these vegetables for long period of time due to biomagnification. This research suggested that frequent test should be carried out to monitor the accumulation and, farmers should be sensitized on the importance of treating irrigation water before agricultural usage.

Keywords: bioaccumulation; health risk assessment; vegetables; wastewater

Introduction

Shortage of irrigation water, especially in the tropical savannah regions of Nigeria have affected crop production. This problem became serious because of the increasing urbanization and industrialization in this region. In order to improve crop productivity through improved irrigation, local farmers resulted to utilizing immense amount of wastewaters released from industries for watering vegetables, most especially in industrial regions, due to water scarcity issues (Mashiatullah *et al.*, 2005; Hamid *et al.*, 2016). Wastewater have been documented to contain heavy metals such as zinc (Zn), iron (Fe), lead (Pb), copper (Cu), cadmium (Cd) and

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nickel (Ni) among other chemicals. The concentration of these chemicals found in wastewater depends on the nature of the industry discharging the wastewater. Long term use of wastewater for irrigation have resulted in heavy metal build up in farming soils and vegetables (Chen *et al.*, 2005; Sharma *et al.*, 2007; Fatoba *et al.*, 2012; Saini *et al.*, 2014; Ugya *et al.*, 2017) in different parts of the world.

In Kano state for example, wastewater is most times used for continuous irrigation of crops, especially vegetables such as lettuce, spinach, and onions. Aside water scarcity, easy accessibility, disposal problems and low rainfall are some of the reasons why local farmers opt for wastewater in growing vegetables in this area (Najam *et al.*, 2015). Although there exist various clean-up strategies for treating wastewater, only few cares to treat the wastewater before usage. Growing soils usually serves as a substrate for plants therefore, presence of heavy metals in growing soils can easily be absorbed by the plants, leading to bioaccumulation and biomagnification in vegetables. Health complications in human and animals can occur by the intake of crops and vegetables grown with heavy metals containing water or substrate because leafy vegetables have high capacity to uptake and bioaccumulate heavy metals in their different parts (Alam *et al.*, 2003).

Human health complications such as intrauterine growth retardation and upper gastrointestinal cancer and among others have been linked to heavy metals toxicity. Heavy metals such as copper, arsenic and zinc have also been known to cause diseases such as diarrhea, stomatitis, tremor, vomiting and poisoning (McCluggage, 1991; Cempel and Nikel, 2006; Oves *et al.*, 2016). Based on the possible health risk owing to heavy metals intake and accumulation strength of vegetables, this study was therefore conducted to evaluate heavy metals levels in wastewater, soil, and commonly consumed vegetables after irrigation with wastewater of Fagge and Zawaciki wastewater sources. This is because these wastewater sources are the largest and first receivers of industrial and household's effluent in Fagge Local Government and Kumbotso Local Government Areas of Kano State, Nigeria. Bioaccumulation factor and pollution index were also determined to predict the associated health risk.

Materials and Methods

Water sampling, handling, and analysis

Water samples were obtained randomly from Fagge wastewater source at Fagge Local Government Area of Kano State and Zawaciki wastewater source at Kumbotso Local Government Area of Kano State. The sample were collected from three zones and care was taken to ensure that the wastewater collected is within the water source and soils that the local farmers used in growing the sample vegetables. The test vegetables and soils were collected around Fagge and Kumbotso Local Government Area of Kano State. Thirty samples (15 from each source) were taken in high density polyethylene bottles HDPE of 250ml and sterilized with HNO_3 as reported by Siddique *et al.*, 2014). The sample bottles were introduced into the water at 10cm and allow to fill. The HNO_3 acid was added so that the water samples would be preserved following (Khan *et al.*, 2013). The samples obtained were filtered by using a Whatman 42 paper and then stored in storage flasks as reported by (Rehman *et al.*, 2014; Siddique *et al.,* 2014). The metallic levels (Zn, Pb and Cd) of the water were evaluated using atomic absorption spectrophotometer (AAS). Standards were prepared with distilled water as matrix for every metal (Saini *et al.*, 2014).

Soil sampling and analysis

Soil samples (5 g) at the rhizosphere of vegetables (0-15 cm) were collected separately from 3 zones on the farmland at each irrigation sites (A and B) by using a spiral auger of 2.5 cm diameter, following Khan *et al.* (2013). The soil samples were cleared by removing unrequired particles and air dried in a clean room to avoid contamination. The soils were then crushed and sieved through a 600 μm. The sieved samples were then stored in plastic jars following (Hamid *et al.*, 2016). About 2.5 g of the soil sample was taken and added 50 ml of

DTPA solution. The mixture was constantly shacked for 2 hours using a shaker and filtered using Whatman 42 paper following (Al-Jaboobi *et al.*, 2014).

A blank test was run using a sample that contains all substances excluding soil. The levels of Zn, Pb and Cd were analyzed using AAS (Shimadzhu-7000, Japan) with respective hollow cathode lamp.

Plant sampling and analysis

Matured leaves of vegetables (*Allium cepa*, *Lactuca sativa*, and *Spinacia oleracea*) were obtained at harvesting stage in three different zones each from the two sites (A and B). The samples were cleared off impurities and bacterial using distilled water and then air dried. The sample were crushed to increase the surface area as seen in Hamid *et al.* (2016). A dry matter sample of 1g was weighed into 250 ml beaker, a 10 ml analytical grade acids mixture containing HNO_3: $HClO_4$ in the ratio 5:1 was added to the sample. Samples were then digested at a temperature of 190 °C for 1.5 hour and allowed to cool. Digested samples were filtered using Whatman No. 1 filter paper and solution was made up to final volume in a volumetric flask with distilled water. Heavy metals (Zn, Pb and Cd) levels were detected by AAS. Guidelines for heavy metals acceptable limits in vegetables were adopted from FAO- WHO (2007).

Metal pollution index (MPI)

Metal Pollution Index (MPI) was computed to analyse the heavy metal concentrations in the wastewater irrigated vegetables. This index obtained using the geometrical mean of concentrations of all the metals in the vegetables as described by (Ureso *et al.*, 1997; Musa *et al.*, 2019) following:

$$MPI = (\mu g\, g - 1) = (Cf \times Cf \times \ldots\ldots\ldots.. \times Cf\, n)1/n$$

Where Cf^{n}= concentration of metal 'n' in the sample.

Statistical analysis

Statistical analysis was observed using SPSS VERSION 16, measuring the mean and standard deviations. Concentrations of heavy metals were expressed as mean ± SDM (Standard Deviation of the Mean) of five replicates. Data obtained were then subjected to analysis of variance (ANOVA) with values for $p \leq 0.05$ considered significantly different. Results were presented in Tables.

Results and Discussion

Heavy metal concentration in wastewater

Table 1 showed the heavy metals levels (Zn, Pb, Cd) in wastewater samples from the two sites (A and B) in the three sample zones. The concentration of zinc taken from the two different wastewater locations of Kano State ranged from 0.12-0.17 mg/l. The maximum mean zinc concentration (0.17 mg/l) was observed in Zone 1 of site A, while minimum zinc concentration (0.11 mg/l) was in sample taken from Zone 3 in site A. The order of zinc contents in all location was Zone 1 A>Zone 3 B>Zone 1 B>Zone 2 A and B>Zone 3 A. Zinc concentration in all wastewater samples was below the permissible limits of both WHO and FAO. This is consistent with a study by Mustaq and Khan (2010) who investigated water samples from two factories areas and found Zn and other metals below the WHO permissible level. However, Cd and Pb were not detected in all the wastewater samples from all the assayed zones. Since heavy metals contents of wastewaters depend on production company and type of its by-products, the presence of Zn in the wastewater indicated that the company might have likely make use of Zn oxides in their production. Constant release of these untreated wastewater may increase the Zn content to toxic levels. Although, Cd and Pb were detected in wastewater from other sources in Lagos, this may be as a result of the nature of the wastewater source or pollution sources. (Jagtap *et al.*, 2010).

Table 1. Mean concentration of heavy metals (mg/l) in wastewater used in irrigation obtained from different zones in site A and B

Samples	Site A			Site B		
	Zn	Cd	Pb	Zn	Cd	Pb
Zone 1	0.17±0.0029[a]	ND	ND	0.14±0.0019[a]	ND	ND
Zone 2	0.12±0.0028[a]	ND	ND	0.12±0.0042[a]	ND	ND
Zone 3	0.11±0.00097[a]	ND	ND	0.15±0.0023[a]	ND	ND
WHO standard	5 mg/l			5 mg/l		

NB: Mean±SD (in the same column) with same letters in superscripts were significantly same ($P \leq 0.05$). ND implies not detectable.

Heavy metal concentration in wastewater irrigated soils

Current experiment used the soil samples collected from the same spot where the test water was used to irrigate plants. This result was presented in Table 2. The Zn content in the soils irrigated with wastewater from two different sites ranged between 11.145-33.64 mg/kg. The concentration of Zn in soil (33.64 mg/kg) was obtained in site B where lettuce was planted, while the lowest zinc concentration was obtained from site A soil where onion was planted. This showed that heavy metals present in irrigation water can leach into the lower soil layers and may influence plant physiology. Other heavy metals such as Cd and Pb that were not detected in the wastewater were also not found in all the growing soils. The zinc concentration in all the growing soil were below the WHO standard for heavy metals in growing soils. This study contradicts the findings of Mahallapa *et al.* (2010) who investigated soil samples from wastewater irrigated areas around Solapur city, India and they found that the contents of zinc extracted was above WHO permissible values. This difference may be because of the contamination frequency or the physicochemical properties of the soil. Plant species growing in the farmland may also influence the level of pollutant present (Musa and Ikhajiagbe, 2020). This study also showed that irrigation water plays a role in influencing physico-chemical properties and structures of arable soils.

Table 2. Heavy metal concentration (mg/kg) of soils receiving wastewater

Samples	Site A			Site B		
	Zn	Cd	Pb	Zn	Cd	Pb
Spinach soil	8.36±0.27[a]	ND	ND	23.90±2.26[a]	ND	ND
Lettuce soil	31.70±0.12[b]	ND	ND	33.64±0.76[b]	ND	ND
Onion soil	11.145±0.15[c]	ND	ND	32.36±0.27[b]	ND	ND
WHO standard	50 mg/kg			50 mg/kg		

NB: Mean±SD (in the same column) with different letters in superscripts differ significantly ($p<0.005$). ND implies not detectable.

Heavy metal concentration in wastewater irrigated vegetables

The levels of heavy metals (Zn, Pb and Cd) detected in the edible parts of the vegetables were shown in Table 3. The main sources of heavy metals to vegetables are the substrates used in growing them. In the present study, the concentration of Zn in different vegetables ranged from 27.5-1.5 mg/kg. Among all vegetables assayed, *Lactuca sativa* (Lettuce) contained the maximum concentration of Zn (16.82 mg/kg) from the two experimental sites (A and B) with the site A lettuce having the maximum Zn (27.5 mg/kg) content. However, lowest Zn levels (2.63 mg/kg) was detected in *Spinacia oleracea* (spinach) obtained from the two experimental sites (A and B), with the spinach from site A recording the lowest Zn content. The morphology and physiology of vegetables for heavy metal usage is different. This may be the reason for variations in heavy metal concentration in different vegetables (Kumar *et al.*, 2009). Variations among vegetables in terms of Zn concentration may also be due to the difference in Zn content of the wastewater and the Zn composition of the soil along with plants' capability to uptake and accumulate the heavy metal. There was significant difference ($P \leq 0.05$) between the Zn content in all vegetables irrigated with A and B wastewater sources. The order of vegetables regarding Zn concentration was lettuce>onion>spinach. However, Zn content in all the vegetables were below the safe limits of 100mg/kg set by WHO and FAO. Cd and Pb were not found in the vegetables, this is possible as owing to the results that showed Cd and Pb were not observed in the wastewater and the irrigated soil (Table 1 and 2).

Table 3. Mean concentration of heavy metals (mg/kg) in vegetables

Common name	Scientific name	Site A			Site B		
		Zn	Cd	Pb	Zn	Cd	Pb
Spinach	*Spinacia oleracea*	1.5±0.32[a]	ND	ND	3.77±0.12[a]	ND	ND
*Lettuce	*Lactuca sativa*	27.5±0.82[b]	ND	ND	6.15±1.72[c]	ND	ND
Onion	*Allium cepa*	7.15±0.47[c]	ND	ND	8.01±0.92[c]	ND	ND
WHO/FAO (2001)		100mg/kg			100mg/kg		

NB: Mean±SD (in the same column) with different letters in superscripts differ significantly (P≤0.05)* shows highest accumulation.

Heavy metal bioaccumulation factor in wastewater irrigated vegetables

Since Zn was the only metal detected in the wastewater, soil and vegetables, a possible bioaccumulation factor was predicted and presented in Table 4. The result showed Zn bioaccumulation factor in all the assayed vegetables irrigated with wastewater from the two experimental sites (A and B) in Kano State. Bioaccumulation factor is the ratio of heavy metal concentration in an organism to its surrounding concentration. Those samples with BAF >1 mg/kg are heavy metals accumulators. From the results, lettuce, spinach, and onion all proved to be accumulators of Zn. Onion proved to be the highest Zn accumulator in the both experimental sites, while spinach was the lowest accumulator in the both experimental sites. This high bioaccumulation factor in onion may be influenced by soil parameters such as pH, organic matter, redox potential, CEC (Wang *et al.*, 2013; Wilson *et al.*, 2014; Ikhajiagbe *et al.*, 2019). Zn show a significantly negative correlation with pH (García *et al.*, 2009; Wang *et al.*, 2013). The BAF in lettuce from the site A experimental site was below 1mg/kg therefore its not proven as a bio accumulator. Aging factor and other soil properties may also affect heavy metals bioavailability in plants (Smolders *et al.*, 2009; Ahmad and Goni, 2010). It may be predicted that if these plants were continuously irrigated with wastewaters, there is higher percentage of heavy metal pollution. Zinc toxicity causes neurological, gastrointestinal, and other physiological disorders (ATSDR, 2007).

Table 4. Estimated bioaccumulation factor mg/kg

Samples	Site A	Site B
	Zn	Zn
Spinacia oleracea	1.37	0.32
Lactuca sativa	0.86	1.37
Allium cepa	41.17	2.47

NB: BAF >1 indicate higher accumulation of metal.

Vegetables contamination and the implication for human health

Due to the increasing consumption of vegetables irrigated with waste water especially in urban areas where waste water practices are still unchecked and the likely health impacts, there is a serious need for quantification of human risk assessment of consuming waste water irrigated vegetables. Pollution index (Table 5) is considered to be effective and precise method for monitoring heavy metal adverse effect of wastewater irrigated vegetables (Ureso *et al.*, 1997).

Table 5. Estimated pollution index (µg g^{-1})

Samples	Pollution index	
	Zn	
	Site A	Site B
Spinacia oleracea	0.81	0.80
Lactuca sativa	0.82	0.46
Allium cepa	1.80	1.47

NB: Pollution index >1 indicate higher level of contamination.

The highest metal pollution index was obtained from onion in site A. This may be due to the high BAF observed. This study is in line with a previous work by Khan *et al.* (2008) who researched on the health risk index of Zn in vegetable samples. They discovered *Allium cepa* and *Lactuca sativa* to be of higher Zn pollution index. All the vegetables have low, but growing pollution index of zinc. This suggested that if not minimized, these vegetables may lead to human health risk as a result of increasing build-up of heavy metals in their edible sections. Therefore, heavy metal contamination and accumulation in vegetables could be a matter of great concern for residents.

Conclusions

The presence of high concentration of heavy metals (Zn, Cd and Pb) irrigation water may lead to contamination of growing soil and can easily be uptake and accumulated by growing vegetables in their various body sections. Different vegetables showed different ability to absorb and accumulate heavy metals. In the present study, heavy metals concentration in irrigation water, soil and vegetables were all observed to be below permissible level of WHO/FAO for water, soil, and vegetable. Zn was the only heavy metal detected in the wastewater, irrigated soils, and vegetables. The zinc levels were obtained to be below permissible level of WHO/FAO for water, soils, and vegetables. However, the high bioaccumulation factor observed in onion could lead to health hazard. The pollution index for onion from the two wastewater sites analysed exceeded 1 which may pose future cancer or neuro-intestinal health risk. Lettuce and spinach though indicated low level of contamination, continuous irrigation with wastewater may pose serious health challenge. Based on the current findings; it is recommended that irrigating vegetables with wastewater should be immediately discouraged and there should be a frequent assays of vegetable farms before being released for consumption. Farmers should be sensitizing on the importance of treating irrigation water before usage.

Authors' Contributions

HMA and UB designed the study, HMA carried out the research under the supervision of UB and MSI. MSI carried out the statistical analysis and interpretation of data. HMA and UB wrote the first draft. UB and MSI edited the final draft of the manuscripts. All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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