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Research Article

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Determination and Risk Assessment of Heavy Metals via Intake of Allium Cepa from Wastewater Used for Irrigation in Bauchi Suburb

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Abstract This research determined heavy metal concentrations in irrigation and non-irrigation soil, wastewater used for irrigation, and irrigated and non-irrigated *Allium cepa* (spring onion) using Atomic Absorption Spectrophotometer (AAS). The research reveals that, the heavy metal (Zn, Mn, Cd, Cu, Cr and Pb) concentrations in wastewater (0.14, 1.56, 0.0, 0.06, 0.20 and 0.01 mg/dm^3 of Gwallaga, and 0.02, 0.20, 0.0, 0.06, 0.07 and 0.0 mg/dm^3 of Gombe road) were within the permissible limits of World Health Organization [WHO] (2001), except Mn and Cr of Gwallaga wastewater. The concentrations in soil (63.20, 524.5, 0.0, 15.3, 19.3 and 0.3 mg/kg for Gwallaga irrigation soil, 59.2, 538.3, 0.0, 10.0, 9.8 and 0.3 mg/kg for Gombe road irrigation soil, and 19.5, 561, 0.0, 8.0, 16.0 and 1.0 mg/kg for non-irrigation soil) were within the permissible limits of WHO (2001). The concentrations in *Allium cepa* (38.70, 28.8, 0.0, 15.2, 0.0 and 0.8 mg/kg of Gwallaga irrigation site, and 20.5, 23.3, 0.0, 8.8, 1.6 and 0.2 mg/kg for Gombe road irrigation site, and 24.0, 241, 0.0, 7.5, 0.0 and 1.0 mg/kg for non-irrigation site) were within the permissible limits of WHO (2007), except Pbin Gwallaga irrigated and non-irrigated onion. The enrichment factor (EF) shows that, Pb has the highest EF value (2.6667) and Mn has least EF value (0.1279) in *Alliumcepa* of Gwallaga irrigation site. Therefore it is suggested that *Allium cepa* (spring onion) can be used (planted) to reduce the Pb concentration from the Pb contaminated soil. The Metal Pollution Index (MPI) reveals that, the *Allium cepa* cultivated during rainy season (non-irrigation) have higher MPI, therefore will pose hazards to human health. The Health Risk Index (HRI) reveals that, Mn has index more than 1 in allium of non-irrigated site and may pose risk to human health. Thus it is recommended to be monitoring plants cultivated during rainy season (non-irrigation).

Keywords Heavy Metals, *Allium Cepa*, Wastewater

Introduction

In Nigeria there is high ratio of irrigation system in the northern part because of the short period of rainy season compare to southern part. Also most of the plants grown from irrigation system in the northern Nigeria are vegetables. Vegetables are consumed enormously by human being all over the world [1]. Production of these vegetables through irrigation and consumption of it has increased because it is one of the major components of human diets.

Vegetables are one of the major components of human diets, as it is the source of essential nutrients, antioxidants and metabolites in food items [2]. Continuous irrigation lead to heavy metals accumulation in the edible and non-edible parts of these vegetables [3]. Food safety issues and potential to health risks make this as one of the most serious environmental concerns [2]. Waste water use for irrigation leads to the accumulation of heavy metals in soil and consequently into the vegetables [4]. Heavy metals, in general are non-bio-degradable, have long biological half-lives and have the potential for accumulation in different body organs leading to chronic toxic effects. Due to non-biodegradable and persistent nature, heavy metals are accumulated in vital organs in the human body such as the kidneys, bones and livers and are associated with numerous serious health disorder [5].

Metals such as lead, mercury, cadmium and copper are cumulative poisons, which cause environmental hazards and are reported to be exceptionally toxic [6]. Metals like iron, zinc, and manganese are essential metals for humans, since they play an important role in biological systems, but the essential heavy metals can produce toxic effect when their intake is excessively elevated [7].This accumulation of heavy metals in the vital organs in the human body is through dietary intake of foodstuff [8]. Contamination of foods by heavy metals has become an inevitable challenge these days. Heavy metals enter the food through irrigation, hence there is need to investigate and assess the vegetables in some suburb area of Bauchi.

Materials and Methods

Materials

All chemicals and materials used were of analytical grade.

Methodology

Study sites

The samples were collected from two sites Gwallaga and Gombe road which areBauchi suburb area. The samples that were collected include Wastewater used for irrigation, irrigated and non-irrigated soils, and irrigated and non-irrigated spring onion (*Allium cepa)*.

Collection of Sample

Water Sampling

Water used for irrigation were collected monthly(January, February and March 2015) using a pre-acid washed polypropylene bottles. The samples were collected in place where the water was stagnant. 500ml of water was collected and 5ml of concentrated HNO_3 was added in the water sample to prevent microbial activity. The samples were then kept in refrigerator before digestion.

Soil Sampling

Soil samples of the irrigated water site were collected monthly (January February, and March, 2015) using a polyethylene bags. It was collected by digging out 5x5x10 cm size, from 5 areas randomly. That of non-irrigated site were collected once (September, 2014). The samples were air dried, crushed, sieved and stored at ambient temperature before digestion.

Vegetable Sampling

The spring onion (*Allium cepa*) at the irrigated water site were collected monthly (January, February and March, 2015) and that of the non-irrigated site were collected (September, 2014). Five areas were randomly marked at the experimental site and the *Allium cepa*vegetables were collected. The samples were taken to the laboratory and washed with distilled water to remove the soil particles adhered to the sample of the vegetable. The samples were cut into pieces, and placed in an oven at a temperature of 40-60°C until a constant weight was achieved. The samples were then ground and sieved and stored before digestion.

Digestion of Samples

Water

The irrigation water samples (50ml) were digested with 10ml of concentrated HNO_3 at 80°C until the solution becomes transparent [9]. The solution was filtered through what man No 1 filter paper and the total volume was maintained to 50ml with distilled water.

Soil and Vegetable

Soil and plant (1g) were digested with 15ml of tri acid mixture (HNO_3, H_2SO_4 and $HClO_4$ in 5:1:1ratio) at 80°C until transparent solution were obtained [10]. The solutions were then cooled and filtered using what man No. 1 filter paper and the filtrate were maintained to 50ml with distilled water.

Heavy Metal Analysis

Concentration of Mn, Cu, Cd, Pb, Zn, and Cr in the filtrate of digested water, soil and vegetable (*Allium cepa*) samples were estimated by using atomic absorption spectrophotometer (210VGB-ASS). The instrument was calibrated using manually prepared standard solution of respective heavy metals and the blank.

Data Analysis

Enrichment Factor

To examine the translocation of heavy metal from the soil to the edible portion of test plants, and to show the difference in metal concentration in the plants, the enrichment factor (EF) was calculated by using the formula given by [4].

$$EF = \frac{\text{Conc of metal in edible part at irrigated water site / conc of metal in soil at irrigated water site}}{\text{Conc of metal in edible part at the control site/conc of metal in soil at the control site.}}$$

Metal Pollution Index (MPI)

To examine overall heavy metal concentrations of all the metals in the vegetable to be analyzed in the irrigated site, metal pollution index (MPI) was calculated. This was done by calculating the geometrical mean of concentrations of all the metals in vegetable [4]

MPI of vegetable (mg/kg) =$(CF, \text{ x } CF2 \text{ x } \text{-----------------} XCFn)^{1/n}$

MPI of milk (mg/L) =$(CF, \text{ x } CF2 \text{ x } \text{-----------------} XCFn)^{1/n}$

Health Risk Index (HRI)

The daily intake metal were determined by conducting a survey where the people having average body weight of 59kg at Gwallaga site and 60kg at Gombe road site were asked for their daily intake of *allium cepa* from the experimental area in each month of sampling [4]. The average daily intake of vegetables was calculated to be 0.215kg/person/day at Gwallaga site and that of Gombe road was 0.22kg/person/day.

The health risk index was calculated at ratio of estimated exposure of test vegetable and oral reference dose [11]. The oral reference dose were 0.30 for Zn, 0.001 for Cd, 0.04 for Cu, 0.004 for Pb and 1.5 for Cr, 0.033(mk/kg/day) for Mn [4]. The estimated exposure were obtained by dividing daily intake of heavy metals by their safe limits. An index more than 1 is considered as not safe for human health [12].

$$HRI = \frac{\text{Daily intake metal}}{\text{Reference Dose}}$$

Where $\text{Daily intake metal (DIM)} = \frac{C_{metal} \text{ X } D_{foodintake} \text{ X } C_{factor}}{B_{averageweight}}$

C_{metal} = represent the heavy metal concentration in plant (mg/kg)

$D_{foodintake}$ = represent daily intake of vegetables

$B_{averageweight}$ = represent average body weight

C_{factor} is used to convert fresh vegetable weight into dry weight and is given as 0.085 [8].

Statistical Analyses

The concentrations of heavy metals analyzed in irrigated and non-irrigated soil, irrigated and non-irrigated spring onion were subjected to one-way analysis of variance (ANOVA) test for assessing the significant difference at 95% confidence level. The statistical analysis were carried out using SPSS version 23.

Results and Discussion

Table 1: Concentration of Heavy Metals (mg/dm^3) in Wastewater Used for Irrigation and Comparison with Some Similar Work

Heavy Metals	G Wtr (present study)	R Wtr (present study)	Lente *et al.* (2014)	FAO (2001)	WHO (2001)
Zn	0.14	0.02	0.14	2.00	2.00
Mn	1.56	0.20	0.78	0.20	0.20
Cd	0.0	0.0	ND	0.01	0.01
Cu	0.06	0.06	0.06	0.20	0.20
Cr	0.20	0.07	ND	0.10	0.10
Pb	0.01	0.0	0.08	0.3	0.5

ND = Not Detected, GWtr = Wastewater Sample of Gwallaga Irrigation Site (Present study) and
RWtr = Wastewater Sample of Gombe Road Irrigation Site (Present study)

The table 1 above shows the overall mean concentrations of the heavy metals in the wastewater samples analyzed. The table also shows the comparison of heavy metal concentrations with published research of Lente *et al.* (2014), Accra Ghana and FAO/WHO (2001) standard.

Also the overall mean concentrations of the heavy metals in the wastewater samples analyzed shows that, the concentration of heavy metals in mg/dm^3 of Zn, Mn, Cu, Cr, and Pb in irrigated water of Gombe road were lower than that of Gwallaga, although the concentrations of the heavy metals at both sites were below the safe limits of FAO/WHO (2001) [3] except for Cr & Mn of Gwallaga which are above the safe limit. Cd is not detected in both sites of the present study.

Table 2: Concentration of Heavy Metals (mg/kg) in Soil and Comparison with Some Similar Work

Heavy Metals	G Soil (Present Study)	R Soil (Present Study)	N Soil (Present Study	Tsafe *et al.* (2012)	USA Standard	WHO (2001)
Zn	63.20	59.20	19.5	68.9	200-300	300
Mn	524.50	538.30	561.00	142.9	NA	2000
Cd	0.00	0.00	0.0	0.97	3	3
Cu	15.30	10.00	8.0	1.13	80-200	100
Cr	19.30	9.80	16.0	16.73	400	50
Pb	0.30	0.20	1.0	29.66	300	100

NA = Not Analysed, G Soil = Soil samples of Gwallaga irrigation site, R Soil = Soil Samples of Gombe Road irrigation site and N Soil = Soil Sample of the Non irrigation site.

Table 2 shows the overall mean of heavy metal concentrations in the irrigated soil samples. Also the table shows the comparison of heavy metal concentration of in Soil sample of present study with published research of Tsafe*et al.* (2012) , USA standard and WHO Standard 2001.

However, the heavy metal concentrations in soil are very high compare to the concentration in the irrigation water. This is because heavy metals tend to accumulate in the soil through continuous irrigation [13]. The concentrations of Mn in the soil are very high compare to the concentrations of Zn, Cu, Cr and Pb, whereas Cd is not detected. The heavy metal concentrations of this research are within the maximum permissible limits of USA and WHO.

Table 3: Concentration of Heavy Metals (mg/kg) in *Allium cepa* (Spring Onion) and Comparison with Some Similar Work

Heavy metals	G Alm (Present study)	R Alm (present study)	N Alm (present Study)	Tsafe *et al.* (2012)	FAO/WHO Standard (2007)
Zn	38.70	20.50	24.00	5.9237	60.0
Mn	28.80	23.30	241.00	7.5450	500.0
Cd	0.00	0.00	0.00	3.0825	0.2
Cu	15.20	8.80	7.50	26.3350	40.0
Cr	1.80	1.60	0.00	22.5800	2.3
Pb	0.80	0.20	1.00	44.5875	0.3

G Alm = *Allium cepa* of Gwallaga irrigation site, R Alm = *Allium cepa* of Gombe road irrigation siteandN Alm = *Alliumcepa* of non-irrigation site.

Table 3 shows the overall mean of heavy metal concentrations in vegetable samples of the irrigation sites and non-irrigation site. It also shows the comparison of these heavy metals with similar work of Tsafe et al., 2012. The table shows the presence of Zn, Mn, Cu, in all the vegetable samples, while Cr &Pb are present in some vegetables and absent in some. Cd is not detected in all the vegetable. The concentration of heavy metals in vegetable were less compared to the concentration in the soil. The concentration of Mn in vegetable of the Non-irrigation site are higher than the concentration in the vegetable of the irrigation sites. Beside that there is absence of Cr in the vegetable of Non-irrigation site whereas Cr is present in some of the vegetables of the irrigation site. However Cd is not detected in the vegetables of both (irrigation and non-irrigation) sites. Although the values obtained were within the safe limits of WHO (2007) [8], except Pb in allium of Gwallaga irrigation site and non-irrigation site.

Table 4: Enrichment Factor of Heavy Metals in Vegetable

Gwallaga Vegetables						
Vegetables	**Zn**	**Mn**	**Cd**	**Cu**	**Cr**	**Pb**
G Alm	0.4975	0.1279	0.0	1.0597	0.0	2.6667
R Alm	0.2814	0.1008	0.0	0.9387	0.0	1.0000

Enrichment factor shows the translocation of heavy metals from the soil to the edible portion of the test plants. Higher enrichment factor (EF) suggest poor retention of metal in the soil and more translocation in the plants [4]. In the vegetables of both Gwallaga and Gombe road suburb Pb have the highest translocation factor, this shows that there is much translocation ofPb in spring onion.

Table 5: Metal Pollution Index

Samples	MPI(mg/kg)
G Alm	7.542
R Alm	4.224
N Alm	14.431

Table 5 shows metal pollution index (MPI) which is the geometrical mean of heavy metal concentration of spring onion in the samples. The geometrical mean of heavy metal concentration of *Allium cepa* were calculated and found to be (7.542) in Gwallaga irrigation site, (4.224) in Gombe road irrigation site and (14.431) in non-irrigation site. In general this study reveals that, the MPI of vegetables from non-irrigation site may pose more hazardous risk to human health because they have higher MPI.

Table 6: Health Risk Index

	Zn	Mn	Cd	Cu	Cr	Pb
N Alm	0.02476	2.26060	0.0	0.24875	0.00000	0.07725
G Alm	0.03966	0.26969	0.0	0.11750	0.00033	0.05000
R Alm	0.02100	0.21818	0.0	0.06750	0.000266	0.01558

Table 6 above present the health risk index calculated for this research. The Gwallaga irrigated *Allium cepa* samples were in the order, Mn>Cu >Pb>Zn >Cr, Gombe road irrigated *Allium cepa* were Mn>Cu >Zn >Pb>Cr, and Non-irrigated *Allium cepa* were Mn>Cu >Pb>Zn>Cr. The health risk index for each metal of this research were found to be less than 1 except for Mn in *Allium cepa* of non-irrigation site. Thus *Allium cepa* of non-irrigation site were contaminated with Mn and may pose risk to human health.

Conclusion

The concentration of all the heavy metals in wastewater samples, soil samples and Vegetable samples were within the safe limits of FAO/WHO, except Manganese& Chromium in wastewater, Lead in *Allium cepa* vegetable of Gwallaga irrigation site and non-irrigation site. Since Manganese& Chromium in wastewater have concentrations higher than the safe limits, continuous irrigation with wastewater will cause more accumulation of these heavy metals in the soil and into the vegetables, then to human body which will lead to serious health problem. The high EF value in allium suggest that *Allium cepa* can be used (planted) to reduced Lead (Pb) concentration from the Lead contaminated soils. MPI showed that vegetables cultivated during rainy season will pose more hazards to human health than those from the irrigation. Also the health risk index indicated that non-irrigated *Allium cepa* will pose risk to human health.

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