UJPICR Volume 1 Number 2 : December, 2021
UMYU Journal of Pure and Industrial Chemical Research
Volume1 No. 2 December, 2021.
ISSN: **2814 – 1628**

Assessment of heavy metal contamination and risk evaluation from selected plants in Funtua, North Western Nigeria.

*1Ikeh Divine Chinwendu,[1]Uba Sani.,[2]Nwokem Calvin., [1]Adeosun Oluwaseun Simon, [2]Nwagu Ngozi Lauretta, [1]Mikail Abdulhameed, [1]Igboecheonwu Iheanacho, [1]Abel Kayit.

[1]Department of chemistry, Ahmadu Bello University, Zaria-Nigeria.

[2]Department of Industrial Chemistry, Enugu State University of Science and Technology.

Corresponding author email; Ikehdivine081@gmail.com

Abstract

Contamination of plants (*Abelmoschus esculentus* (Okro), *Allium cepa* (onion), *Amaranthus viridis*, *Spinacia oleracea* (Spinach), *Brassica Oleracea* (Cabbage), *Digitaria horizontalis*, *Commelina diffusa*) by copper (Cu), cobalt (Co), nickel (Ni), lead (Pb) and chromium (Cr), and the subsequent human exposure risks, were determined in Funtua region, where wastewater from Funtua textile is used for irrigation. The concentrations of heavy metals (mg/kg fresh wt.) in plant samples ranged from 106.45 to 230.55 for Cu, 602.75 to 1121.50 for Cr, 70.50 to 145.10 for Ni, Below Detection Limit (BDL) to 2.15 for Pb and BDL for Co. Thus, the concentrations were found to be above the WHO (1996) permissible limit with exception to Co and Pb in all plant samples. The levels of the heavy metals analysed in the plant samples were in the following trend: *Spinacia oleracea>Allium cepa>Amaranthus viridis>Abelmoschus esculentus >commelina diffusa> Brassica Oleracea >digitaria horizontalis*. Hazard Index 1.01×10^{5} and 4.20×10^{4} were obtained for children and adults, respectively. Estimated daily intakes in mg/day ranged from 3.07×10^{-3} to 7.16×10^{-3} for Pb, 2.63×10^{-1} to 6.13×10^{-1} for Cu, 1.63×10^{-1} to 3.80×10^{-1} for Ni, 0.12×10^{1} to 0.29×10^{1} for Cr and BDL for Co in adult and children, respectively. Cu, Ni, Cr and Pb intake rates were above recommended minimum risk levels (MRLs) in both children and adult in all the plants, while Co poses no risk in all the plant samples. The result obtained from subjecting the data to statistical analysis revealed that there was no significant difference in the levels of the analysed plant samples at $p \geq 0.05$ across the sampling sites.

Key words; Ding, Hazard quotient, Hazard Index, Heavy metals, wastewater, plants, vegetable

INTRODUCTION

Pollution is a major threat to our biodiversity and it significantly contributes to the on-going mass extinction of species. Today, it is threatening the survival of more than 1 million of the planet's estimated 8 million plant and animal species, and the situation is expected to worsen, unless we change [1]. Unplanned economic development has led to pressure on cultivable land and suitable water for irrigation. To meet the food demands of exponentially growing human population, cultivation of food crops is carried out at places which are not suitable for agriculture like along wastewater drains or other polluted sites. In other to address water crisis, irrigation, using the large amount of wastewater discharged from the rapid growing industries is being carried out in many parts of the world [1].

Industrial wastewaters have been reported to contain heavy metals concentrations which are toxic to plants and, thus, affect the plant growth, seed germination, human health and lower crop yield [2]. Wastewater used for irrigation has many contaminants mainly heavy metals depending upon the source of discharge [3]. Plants grown on a land polluted with municipal, domestic or industrial wastes can absorb heavy metals in form of mobile ions present in the soil solution through their roots or through foliar absorption [4]. Studies on the uptake of heavy metals by plants have shown that heavy metals can be transported passively from roots to shoots through the xylem vessels [5, 6].These absorbed metals get bio-accumulated in the roots, stems, fruits, grains and leaves of plants [4]. The concentration of heavy metals in vegetables increases with cultivation years. A high concentration of heavy metals in end products carries risks for food safety and consumer health. Heavy metals are potentially toxic, resulting in chlorosis, weak plant growth, and low yield, and they may even be accompanied by reduced nutrient uptake, disorders in plant metabolism, and a reduced ability to fix molecular nitrogen in leguminous plants [7].

Food safety is a major public concern worldwide. During the last decades, the increasing demand for food safety has stimulated research regarding the risk associated with consumption of foodstuffs contaminated by pesticides, heavy metals and/or toxins.

Contaminated food is one of the main sources of exposure to heavy metals, and research points these toxicants to come from their raw material which are basically crops [7]. Contamination of the human food chains by heavy metals is not directly affected by the plants' total uptake, but rather by the concentration in those parts that are directly consumed [8]. Thus, in assessing exposure risks, heavy metal contents in roots and stems are of less importance than those in the edible leaves. According to [9] and [10], sensitivity of organisms to heavy metal toxicity depends on heavy metal accumulation rate in plants, intake rate (in animals) and age of the consuming organism amongst other factors.

The present study aims to check for metal content (copper, nikel, lead, chromium and cobalt) in plants irrigated with wastewater from Funtua textile industry, Nigeria. Furthermore comparison of hazard index associated with intake of these metals in adults and children is also assessed.

MATERIALS AND METHODS

Study Area

The study area of this research is the Funtua textile industry and its neighboring sites where irrigation farming and other commercial agricultural activities are carried out. The study area lies between latitude 11°34'N and longitude 7°14'E. The Irrigation sites are located along the waterway of waste water coming out from Funtua textile limited which is used for farming.

Sampling and Analysis

Plants leaf samples were collected from the farm sites irrigated with wastewater from Funtua textile industry, the plants samples were collected by randomly picking up two or three mature bottom leaves from the plants. The samples were washed once with distilled water by running the water through the leaves to mimic the general practice of unsuspecting consumers. Each bundle was sub-divided in the laboratory to give duplicate samples weighing approximately 6g (fresh wt.). The fresh vegetable samples were digested at the fresh state because the consumers eat them in that state and then further analysis was carried out.

2.0 g of the sample was weighed out into a Kjeldahl flask mixed with 20 cm^3 of concentrated H_2SO_4, concentrated $HClO_4$ and concentrated HNO_3 in the ratio 1: 4: 40 by volume respectively and left to stand overnight. Thereafter, the flask was heated at 70°C for about 40 min and then, the heat was increased to 120°C. The mixture turned black after a while. The digestion was complete when the solution became clear and white fumes appeared. The digest was diluted with 20 cm^3 of distilled water and boiled for 15 min. This was then allowed to cool, transferred into 100 cm^3 volumetric flasks and diluted to the mark with distilled water. The sample solution was then filtered through a 0.5 µm Teflon filter paper and transferred into a volumetric flask.

Analytical procedures: Determination of heavy metals

Determination of different heavy metals viz. Cu, Ni, Co, Cr and Pb in digested plant samples was done using Atomic Absorption Spectrophotometer (AAS) (280 FS AA) at the Multi-user Science Laboratory, Faculty of Physical Sciences, ABU - Zaria.

Risk Assessment Calculation

- Hazardous Index (HI) were used to estimate the risk to human health through the hazard index (THI). The hazard index is the sum of the hazard quotients which was calculated as follows:

$THI = \Sigma HQ$, ------------------------------- (1), and

$\Sigma HQ = (HQPb + HQCo + HQCu + HQCr + HQNi.)$ --------------------------------- (2)

Where: THI = Total Hazardous Index and HQ = Hazard Quotient for the metals

The following equation was used to represent daily exposure route:

CDI = C X DI/BW --------- (3)

Where: CDI = Is the Chronic Daily Intake (mg/kg/d),

C = Concentration of the water contaminant (mg/L),

DI = Is the Average Daily Intake rate of the water (l/d), and

BW = Is the Body Weight in (kg).

The hazard quotient, (HQ) was calculated using the following equation:

level of the toxicants manifesting long term health hazard effects increasing [11, 12].

HQ = CDI/R*f*D ------------------------- (4)

Where: HQ = Hazard Quotient and R*f* D = Is the Reference Dose (mg/kg).

The R*f* D values employed in this study were obtained from [11]. When the values are less than 1 (i.e if HQ or THI < 1) it means there is no risk and generally, the greater the values, the greater is the risk.

Statistical Treatment of the Data

All experiments was performed in duplicate. One-way analysis of variance (ANOVA) was utilized to test whether there is a significant difference in the levels of the metals (Cu, Cr, Ni, Pb and Co) analysed across the sampling points at 95 % confidence limit.

Microsoft spreadsheet was also used to calculate the mean and standard deviation of the parameters determined.

Results and Discussions

Table 1: Heavy metals parameter of plant

Samples	Pb	Co	Cu	Ni	Cr
A	BDL	BDL	222.60±0.01	145.10±0.10	812.50±0.03
B	2.00±0.04	BDL	229.00±0.01	128.95±0.20	1031.64±0.03
C	BDL	BDL	193.05±0.02	110.05±0.13	1010.25±0.02
D	BDL	BDL	230.55±0.01	141.25±0.03	1121.50±0.02
E	BDL	BDL	147.72±0.00	102.90±0.02	736.25±0.03
F	BDL	BDL	106.45±0.01	70.50±0.14	602.75±0.01
G	BDL	BDL	158.93±0.01	101.75±0.12	730.00±0.02
WHO 1996	2	0.07	10	10	1.30

Where A: okro, B: Onion, C: *Amaranthus viridis*, D: Spinach, E: Cabbage, F:*Digitaria horizontalis* , G: *Commelina diffusa*

Table 2 Daily ingestion, Hazard quotients and hazard indexes for plants sample

Metals	Plant samples				
	Ding-children	**Ding-adults**	**HQchildren**	**HQadult**	**Rf**
Pb	7.16×10^{-3}	3.07×10^{-3}	0.18×10^{1}	7.50×10^{-1}	4.00×10^{-3}
Co	NA	NA	NA	NA	5.71×10^{-6}
Cu	6.13×10^{-1}	2.63×10^{-1}	1.53×10^{1}	0.68×10^{1}	4.71×10^{-2}
Ni	3.80×10^{-1}	1.63×10^{-1}	1.46×10^{1}	0.63×10^{1}	2.06×10^{-2}
Cr	0.29×10^{1}	0.12×10^{1}	1.01×10^{5}	4.20×10^{4}	3.01×10^{-1}
Σ (HI)			1.01×10^{5}	4.20×10^{4}	

Ding; Daily ingestion rate, HQ; Hazard quotient, HI; Hazard index, Rf; Reference oral dose of metal (mg/kg of body weight/day).

Table 3 Analysis of variance for plant samples

Multiple Comparisons

Dependent Variable: Concentration

Tukey HSD

(I) Sample	(J) Sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	-.84400	1.034292	.981	-4.16531	2.47731
	C	-.53260	1.034292	.998	-3.85391	2.78871
	D	-1.25240	1.034292	.883	-4.57371	2.06891
	E	.77540	1.034292	.988	-2.54591	4.09671
	F	1.60210	1.034292	.714	-1.71921	4.92341
	G	.76570	1.034292	.988	-2.55561	4.08701
B	A	.84400	1.034292	.981	-2.47731	4.16531
	C	.31140	1.034292	1.000	-3.00991	3.63271
	D	-.40840	1.034292	1.000	-3.72971	2.91291
	E	1.61940	1.034292	.704	-1.70191	4.94071
	F	2.44610	1.034292	.256	-.87521	5.76741
	G	1.60970	1.034292	.710	-1.71161	4.93101
C	A	.53260	1.034292	.998	-2.78871	3.85391
	B	-.31140	1.034292	1.000	-3.63271	3.00991
	D	-.71980	1.034292	.992	-4.04111	2.60151
	E	1.30800	1.034292	.861	-2.01331	4.62931
	F	2.13470	1.034292	.404	-1.18661	5.45601

	G	1.29830	1.034292	.865	-2.02301	4.61961
D	A	1.25240	1.034292	.883	-2.06891	4.57371
	B	.40840	1.034292	1.000	-2.91291	3.72971
	C	.71980	1.034292	.992	-2.60151	4.04111
	E	2.02780	1.034292	.463	-1.29351	5.34911
	F	2.85450	1.034292	.126	-.46681	6.17581
	G	2.01810	1.034292	.469	-1.30321	5.33941
E	A	-.77540	1.034292	.988	-4.09671	2.54591
	B	-1.61940	1.034292	.704	-4.94071	1.70191
	C	-1.30800	1.034292	.861	-4.62931	2.01331
	D	-2.02780	1.034292	.463	-5.34911	1.29351
	F	.82670	1.034292	.983	-2.49461	4.14801
	G	-.00970	1.034292	1.000	-3.33101	3.31161
F	A	-1.60210	1.034292	.714	-4.92341	1.71921
	B	-2.44610	1.034292	.256	-5.76741	.87521
	C	-2.13470	1.034292	.404	-5.45601	1.18661
	D	-2.85450	1.034292	.126	-6.17581	.46681
	E	-.82670	1.034292	.983	-4.14801	2.49461
	G	-.83640	1.034292	.982	-4.15771	2.48491
G	A	-.76570	1.034292	.988	-4.08701	2.55561
	B	-1.60970	1.034292	.710	-4.93101	1.71161
	C	-1.29830	1.034292	.865	-4.61961	2.02301
	D	-2.01810	1.034292	.469	-5.33941	1.30321
	E	.00970	1.034292	1.000	-3.31161	3.33101
	F	.83640	1.034292	.982	-2.48491	4.15771

Based on observed means.

The error term is Mean Square(Error) = 2.674.

Table 4 Correlation Matrix for metals in plant samples

Sample	PbB	CuA	CuB	CuC	CuD	CuE	CuF	CuG	NiA	NiB	NiC	NiD
PbB	1											
CuA	1.000**	1										
CuB	1.000**	1.000**	1									
CuC	-1.000**	-1.000**	-1.000**	1								
CuD	-1.000**	-1.000**	-1.000**	1.000**	1							
CuE	1.000**	1.000**	1.000**	-1.000**	-1.000**	1						
CuF	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1					
CuG	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1				
NiA	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1			
NiB	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1		
NiC	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1	
NiD	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	-1.000**	1
NiE	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	-1.000**	1.000**
NiF	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1.000**	-1.000**
NiG	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1.000**	-1.000**
CrA	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1.000**	-1.000**
CrB	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1.000**	-1.000**
CrC	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1.000**	-1.000**
CrD	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	-1.000**	1.000**
CrE	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1.000**	-1.000**
CrF	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	1.000**	-1.000**

DISCUSSION

Table 1 shows the mean concentration of metals in each plant sample and maximum value reported among replicates. The concentrations of Cu, Ni and Cr were in the ranges of 106.45±0.006 (F) to 230.55±0.004 (D), 70.5±0.142 (F) to 145.1±0.1 (A), and 602.75±0.005 (F) to 1121.5±0.02 (D) mg/L. Similarly, the ranges of Pb and Co were BDL (A,C,D,E,F) to 2.15±0.037 (B) and BDL(A,B,C,D,E,F,G), respectively.

Mean concentration of Cr, Ni, and Cu in all the analysed samples across the sampling sites were higher than the WHO permissible limits of 1.3, 10 and 10 mg/kg, respectively. The concentration of Co was below detection limit in all the analysed plant samples while Pb was only found in sample B and appeared above 2 mg/ kg WHO permissible limit. The following trend was generally observed for the heavy metals in the analyzed plant samples in which the highest contamination was observed at sample D while sample F was least contaminated. The order of contamination across the sampling points was; D>B>C>A>G>E>F. This might be attributed to the different retention capacity for essential metals by the plants.

The concentrations of chromium obtained in this study were above the concentration range of 0.35-4.50 mg/kg reported by [14] in Bangladash, 26.0 - 50.0 mg/kg by [15] and 0.38 -3.37 mg/kg reported by [13] in Delta state Nigeria. The main sources of Cr in plants are due to the repeated use of untreated or poorly treated waste water from industrial establishments and the application of chemical fertilizers and pesticides [16, 14]. Cr a possible carcinogen and dietary intake of Cr have been associated with slow healing ulcers. It has also been reported that chromate compounds can destroy DNA in cells [17]. These increased levels of metals is due to bio-accumulation in the roots, stems, fruits, grains and leaves of plants [4].

Similarly the highest concentration of Cu was recorded in sample D (230.55±0.35 mg/kg) while the lowest concentration was recorded at sample F (106.45±0.65 mg/kg), the concentration obtained from this study were mostly below 21.76 - 102.95 mg/kg reported in a similar studies by [13] and higher than 0.7- 561.64 mg/kg reported by [18], 8.50 - 15.50 mg/kg by [19] in leafy and non-leafy vegetables, and 20.5-71.2 mg/kg reported by [20] in a similar study. Generally, the highest concentration of Cu in the analysed samples could be attributed to metallic salts ($CuCl_2$; $CuSO_4$) used during the dyeing process in the textile industries as well as metals present as scraps in the sampling sites which are present in water used to grow these plants. The concentrations of Cu in the plant samples were generally above the WHO tolerable limit of 10 mg/kg. Although Cu is an essential trace element, its excessive concentration can threaten human health [21]. Cu can bio-accumulate in human bodies and have important health implications. Its toxicity may induce diarrhea, vomiting, and sporadic fever.

The concentration of Nickel (Ni) in the plant samples were found to be within the range of 70.50−145.10 mg/kg. The highest mean value of Ni was found in sample A (145.10±0.55) while the lowest value was detected in F (70.50±0.14), the mean concentration of Ni was higher than the WHO tolerable limit of 10 mg/kg. The concentrations obtained in this study were below those reported in a similar study by [22] in Greece and higher than the range of 0.4-6.3 $mgkg^{-1}$ reported by [18] and 0.92 – 5.1 $mgkg^{-1}$ reported by [14] in a similar study. Nickel pollution on a local scale is caused by emission from machines and generator engines that use Ni gasoline in the textile factory and by the abrasion and corrosion of Ni in machine parts. Upon exposure to Nickel, an individual may show increased levels of Ni in his or her tissues and urine [17]. Ni plays a crucial role in the biological activities of microorganisms and plants [23]. However, at high levels, Ni is toxic.

The concentrations of Pb obtained in this study were below the concentration range of 0.6-5.4 $mgkg^{-1}$ reported by [18] and 0.19-11.2 $mgkg^{-1}$ reported by [24] for cabbage and spinach in Zhejiang, China. [20] reported lower values between 0.88- 1.56 $mgkg^{-1}$ in a similar study conducted in India. However, the concentration of Pb recorded in this study was above the WHO tolerable limit for sample B while the others were below detection limit. Residents could be prone to lead poisoning due to bioaccumulation. The concentrations of Pb recorded in the plant sample could be attributed to the use of leaded fossil fuel for powering plants in the textile factory, which consequently settles on the soil and water. This could have a devastating effect on the plants due to bioaccumulation over time. Pb is considered a potential carcinogen and is associated with etiology of many diseases especially cardiovascular, liver, kidney, bladder, nervous system, blood and bone diseases [25].

Uptake pattern of heavy metals by plants was found to be similar in all the plants. In all the seven plants, the uptake of metals exhibited the following trend: *Cr > Cu > Ni > Pb> Co*. The concentration of all metals was found to be very high in the leafy plants (C; *Amaranthus viridis,* G; *commelina diffusa* and D;spinach). This trend was found to be in accordance with previous studies estimating heavy metals in plants [26, 27]. The high concentration of heavy metals found in Sample A, okro, may be due to its high retention capacity of metals as reported by [21] and [7], while other reports also showed that cabbage is generally low accumulator of trace metals even if there might be high concentration in the soils [28]. This low level of metal accumulation could be originated from the genetic behavior of the plant [29].

Allowable safe limits of heavy metals in food samples are associated with low health risks in humans [30]. The concentration of heavy metals in plants increases with cultivation years. Heavy metal accumulation depends on plant species, while the efficiency of plants in absorbing metals is determined by either plant uptake or soil-to-plant transfer factors of the metals [7]. Leafy plants are more likely to accumulate heavy metals than root crops [31].

Hazard Quotient for Plants `

Health risk associated with any pollutant is dependent upon the level of exposure and amount of absorption by human body. Thus, hazard quotient is a valid tool to assess the level of risk associated with particular pollutant. If level of Hazard quotient is less than 1, the risk associated with exposure of metal is negligible. However if level of hazard quotient is higher than 1, the metal may pose serious health hazards. Hazard quotient of Cr and Pb was found to be higher for children than for adult. Daily ingestion of Pb was above permissible limits for all samples and the hazard quotient associated with Pb for children was above 1 in all samples. Toxicity of Pb is associated with etiology of many diseases, especially cardiovascular, liver, kidney, and bladder, nervous system, blood and bone diseases [25].

Cu was found to be above the safe limits in all the analysed samples of all leafy plants. Cu, though a vital element for human life can cause severe toxicity symptoms when in excess. The plant samples all exhibited high level of hazard quotient. Hazard quotient was found more than one both for children and adult, however, children showed higher hazard quotient than adult.

Hazard quotient of cobalt was not calculated both for children and adult as the Co was below detection limit in all the plant samples. Sample A, D, E and B had highest hazard index for Cu, Ni, Cr . These implies that these plants are highly hazardous for consumption by both children and adults. Hazard quotient was calculated using the minimum dietary requirement of plants in balanced diet for adult 325 g and 162 g for children and exposure duration (6 years for children (EDchild), 24 years for adults (EDadult), respectively); BW is average body weight (15 kg for children (BWchild), 70 kg for adults (BWadult).

The hazard quotient and metal concentration in food crops in sites irrigated with wastewater was in accordance with previous studies [32, 33, 34, 35, and 36]. In the present study, we observed that plants growing in vicinity of wastewater coming from the Funtua textile pose a significant threat to human health.

Statistical Treatment of Data

Results of ANOVA revealed that the variation in metal concentration is not significant with type of plants as reflected in Table 3. Summary of post hoc Tukey HSD test as revealed that there was no significant difference between concentrations of metals in all the plants irrigated with wastewater at 95% confidence level. The result of Pearson correlation as reflected in Table 4 showed strong positive correlation between Cu in sample A with Pb and Cu in sample B and with Cu in sample D and C. Strong positive correlation shows a common pollution source and also depicts a direct relationship between metals in the sample. However, there are also strong negative correlation between some of the parameters as reflected in Table 4. Ni in sample G was strongly negatively correlated with Pb in sample B, Cu in samples A and B, strong negative correlation shows that the metals in the plant sample comes from different sources, thus resulting to an inverse relationship.

Conclusion

The healthy and balanced diet is very essential, plants serve as part of this on a daily basis. However, this study reveals that plants grown in the study area is highly contaminated due to poor agricultural practice by some farmers. Results obtained showed that leaves and fleshy vegetable are good accumulator of heavy metals, hence it is advisable not to grow vegetables in farms and fields irrigated with wastewater or water rich in heavy metals. The regular consumption of plants grown in polluted sites can cause detrimental effects to the human.

Acknowledgement

The authors would like to thank the Ahmadu Bello University Multi User Science Lab for their assistance in analyzing the plant samples and also to Mrs. Christiana Obiageri Mmadu, the secretary to HOD, Department of Chemistry, Ahmadu Bello University, Zaria for her support and assistance in typesetting the manuscript.

References

1. IPBES. Summary for policymakers. *European Environment Agency*. 2019, B.10-B.14: pp. 17-19. The European environment – state and outlook 2019.
2. S. Ali, T. Akhtar, M. Alam. The effect of industrial wastewater on crop plants: A review. *Int J Res Eng Soc Sci*. 2015, 5(4):28–39.
3. F. Pedrero, I. Kalavrouziotis, J. J. Alarcón, P. Koukoulakis & T. Asano, .Use of treated municipal wastewater in irrigated agriculture—Review of some practices in Spain and Greece. *Agricultural Water Management.* 2010, *97*(9): 1233-1241.
4. A. O. Hammed, A. Lukuman, K. A. Gbola, & O. A Mohammed. Heavy metal contents in soil and plants at dumpsites. A case study of Awotan and Ajakanga dumpsite Ibadan, Oyo State, Nigeria. *J Environ Earth Sci*, 2017, *7*(4): 11-24.
5. M.B. Kirkham. Trace elements in sludge on land: effects on plants, soil and groundwater. In: Loehr, C.R. (Ed.), Land as a Waste Management Alternative. *Ann Arbor Science Publishers*, New York, 1977, pp. 209–247.
6. G.C. Krijger, P.M. Vliet, H.T. Wolterbeek. Metal speciation in xylem exudate of Lycopersicon esculentum. *Plant Soil*. 1999, 212: 165–173.
7. M. M. Onakpa, A. A. Njan, & O. C. Kalu. A review of heavy metal contamination of food crops in Nigeria. *Annals of global health,* 2018, *84*(3): 488.
8. R. L. Bieleski, & A. Lauchli. Inorganic plant nutrition, synthesis

and outlook. *Encyclopedia of plant physiology*, 1983, 745-755.

9. B. J. Alloway, & D. C. Ayres. Chemical principles of environmental pollution. Blackie Academic and Professional. *An imprint of Chapman and Hall*. 1993.
10. S. Lee, E.H. Allens, C.P. Huang, D.L. Sparks, P.F. Sanders, W.J.G. Peijnenburg. Predicting soil-water partition coefficients for Cd. *Environ. Sci. Technol*. 1996, 30: 3418–3424.
11. US Environmental Protection Agency (US EPA). Human health risk assessment: risk-based concentration table, 2012. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.html
12. B. B. Potter, & J. C. Wimsatt, USEPA method 415.3: Quantifying TOC, DOC, and SUVA. *Journal of American Water Works Association*. 2012, *104*(6): E358-E369.
13. M. A. Balogun, & M. O. Money-Irubor, Concentration, Soil-To-Plant Transfer Factor Determination of Heavy Metals in Udu Area of Delta State, Nigeria. *Journal of Chemical Society of Nigeria*. 2021, *46*(2).
14. M. S. Islam, M. K. Ahmed, M. Habibullah-Al-Mamun, & M. Raknuzzaman. The concentration, source and potential human health risk of heavy metals in the commonly consumed foods in Bangladesh. *Ecotoxicology and environmental safety*. 2015, *122*: 462-469.
15. E. S. El-Sayed, Z. Khater, M. El-Ayyat, & E. S.Nasr. Assessment of heavy metals in water, sediment and fish tissues, from, Sharkia province, Egypt. *Egyptian Journal of Aquatic Biology and Fisheries*. 2011, *15*(2): 125-144.
16. M. A. H. Bhuiyan, N. I. Suruvi, S. B. Dampare, M. A. Islam, S. B. Quraishi, S. Ganyaglo, & S. Suzuki. Investigation of the possible sources of heavy metal contamination in lagoon and canal water in the tannery industrial area in Dhaka, Bangladesh. *Environmental monitoring and assessment*. 2011, *175*(1): 633-649.
17. G. K. Kinuthia, V. Ngure, D. Beti, R. Lugalia, A. Wangila, & L. Kamau. Levels of heavy metals in

wastewater and soil samples from open drainage channels in Nairobi, Kenya: Community health implication. *Scientific Reports*, 2020, *10*(1): 1-13.

18. F. Mapanda, E. N. Mangwayana, J. Nyamangara, & K. E. Giller. Uptake of heavy metals by vegetables irrigated using wastewater and the subsequent risks in Harare, Zimbabwe. *Physics and chemistry of the earth, parts A/B/C*, 2007, *32*(15-18): 1399-1405.
19. M.G.M. Alam, E.T. Snow, & A. Tanaka.Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh", *Sci. Total Environ*. 2003, **308**(1): 83-96.
20. R.K. Sharma, M. Agrawal & F.M. Marshall. Heavy metals contamination of soil and vegetables in suburban areas of Varanasi, India", *Ecotoxicol*. *Environ. Safe*. 2007, **66**(2): 258-266.
21. J. Zhou, J. Liang, Y. Hu, W. Zhang, H. Liu, L. You, & J. Zhou. Exposure risk of local residents to copper near the largest flash copper smelter in China. *Science of the Total Environment*. 2018, *630*: 453-461.
22. K. Fytianos, G. Katsianis, P. Triantafyllou, G. Zachariadis. Accumulation of heavy metals in vegetables grown in an industrial area in relation to soil. *Bulletin of environmental contamination and toxicology*. 2001;67(3):0423-30.
23. N. K. Asare-Donkor, T. A. Boadu, & A. A. Adimado. Evaluation of groundwater and surface water quality and human risk assessment for trace metals in human settlements around the Bosomtwe Crater Lake in Ghana. *SpringerPlus*. 2020, *5*(1): 1-1
24. Z. Huang, X. D. Pan, P. G. Wu, J. L. Han, & Q. Chen. Heavy metals in vegetables and the health risk to population in Zhejiang, China. *Food Control*. 2014, *36*(1), 248-252.
25. L. M. Cai, Z. C. Xu, J. Y. Qi, Z. Z. Feng, & T. S. Xiang. Assessment of exposure to heavy metals and health risks among residents near Tonglushan mine in Hubei, China. *Chemosphere*. 2015, *127*: 127-135.
26. A. Arora. Sensing by the people, for the people & of the people. 2008 *Apr*, *21*, 48.

27. A. Singh, M. Agrawal, & F. M. Marshall. The role of organic vs. inorganic fertilizers in reducing phytoavailability of heavy metals in a wastewater-irrigated area. *Ecological Engineering*. 2010, *36*(12): 1733-1740.
28. E. E. Santos, D. C. Lauria, & C. P. Da Silveira. Assessment of daily intake of trace elements due to consumption of foodstuffs by adult inhabitants of Rio de Janeiro city. *Science of the total environment*, 2004, *327*(1-3): 69-79.
29. M. M Lasat. Phytoextraction of toxic metals: a review of biological mechanisms. *Journal of environmental quality*, 2002, *31*(1): 109-120.
30. S. Sobhanardakani, L. Tayebi, & S. V. Hosseini. Health risk assessment of arsenic and heavy metals (Cd, Cu, Co, Pb, and Sn) through consumption of caviar of Acipenser persicus from Southern Caspian Sea. *Environmental Science and Pollution Research*, 2018, *25*(3): 2664-2671.
31. A. S. Qureshi, M. I. Hussain, S. Ismail, & Q. M. Khan. Evaluating heavy metal accumulation and potential health risks in vegetables irrigated with treated wastewater. *Chemosphere*, 2016, *163*: 54-61.
32. S. Gupta, S. Satpati, S. Nayek, & D. Garai. Effect of wastewater irrigation on vegetables in relation to bioaccumulation of heavy metals and biochemical changes. *Environmental monitoring and assessment*. 2010, *165*(1): 169-177.
33. C. Masona, L. Mapfaire, S. Mapurazi, & R. Makanda. Assessment of heavy metal accumulation in wastewater irrigated soil and uptake by maize plants (Zea mays L) at Firle Farm in Harare. *Journal of Sustainable Development*, 2011, *4*(6): 132.
34. O. E. Orisakwe, N. J. Kanayochukwu, A. C. Nwadiuto, D. Daniel, & O. Onyinyechi. Evaluation of potential dietary toxicity of heavy metals of vegetables. *Journal of Environmental & Analytical Toxicology*, 2012, *2*(3): 136-139.
35. F. Pedrero, I. Kalavrouziotis, J. J. Alarcón., P. Koukoulakis, & T. Asano. Use of treated municipal wastewater in irrigated agriculture—

Review of some practices in Spain and Greece. *Agricultural Water Management*, 2010, *97*(9): 1233-1241.

36. A. Singh, & M. Agrawal. Effects of municipal waste water irrigation on availability of heavy metals and morpho-physiological characteristics of Beta vulgaris L. *Journal of Environmental Biology*, 2010 *31*(5): 727.