



## Assessment of Heavy Metals Bioaccumulation in Vegetables Grown in Three Local Government Areas of Kaduna State, Nigeria

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### ABSTRACT

Vegetables are among the major sources of proteins and vitamins in human diets. However, they have high potential for contamination by heavy metals which pose serious public health threats. A study was conducted to assess the levels of heavy metals bioaccumulation in two leafy vegetables: Spinach (*Spinacia oleracea*) and Cabbage (*Brassica oleracea*), grown in three local government areas (Giwa, Sabon-gari and Hunkuyi) of Kaduna State. The four heavy metals assessed were: Lead (Pb), Copper (Cu), Cobalt (Co) and Zinc (Zn) in the two leafy vegetables: Atomic Absorption Spectrophotometer (AAS) was used to detect and analyze heavy metals bioaccumulation in the vegetables and soil samples. The sampling locations were selected on the basis of anticipated magnitude of the extent of contamination of the water used for irrigating these vegetables in such areas. The experiment was arranged in completely randomized design with three replications. Data obtained was analyzed using Analysis of Variance with Duncan's New Multiple Range Test used to separate significant means at 5% level. The result obtained revealed significant difference ( $P \leq 0.05$ ) in the heavy metals bioaccumulation in the vegetables and the soils on which they were grown. The result showed that the concentration for Co and Cu were lower than the maximum permissible limits standards as such were non-lethal. However, the accumulation of Pb and Zn in the vegetables was above tolerable limits. This inferred that, vegetables from Sabon-gari, Giwa and Hunkuyi grown along road sides and irrigated with water containing agricultural residues accumulated higher concentration of Pb and Zn. This can be attributed to the intense use of agro-chemicals such as fertilizer and pesticides as well as domestic and industrial discharges in the area. This also suggests a high probability of lethal toxicity due to Pb and Zn in these vegetables. It is therefore recommended that, people should abstain from consuming these heavy metals contaminated vegetables due to significant health implications they posed on to the public health. More so, consumption of vegetables irrigated with waste water or close to road side should be avoided.

**Keywords:** Agrochemicals, Cabbage, Irrigation, Spinach

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## Introduction

Vegetables are common fresh edible plant matter or products. They are available in any ordinary Nigerian market both in the cities, towns and villages and are widely consumed by all (Tsor and Jombo, 2022). They are important part of human diet due to the presence of essential nutrients, as well as vitamins, minerals and trace elements (Bigdeli and Seilsepour, 2008). Vegetables contain different types of minerals essential for the normal functioning of the body and also contain dietary fibres, sugars, proteins, vitamins such as Retinol, Niacin, Folates, Ascorbic acid, Tocopherols and Phylloquinone. Vegetables perform vital functions in the body like: maintenance of healthy bones and teeth; decrease problems of coronary heart diseases and spinal cord defects in fetuses; promotion of healthy blood formation, normal and stable cell functions; development of healthy bones, teeth and gums; promotion of good eyesight and prevention of infections; and facilitates healing of wound (Balakrishna *et al.*, 2021; Li *et al.*, 2021). Chronic absence of vegetables in the diets can lead to different clinical symptoms such as: scurvy, nyctalopia, bleeding disorders, heart failure, constipation and dyspepsia, cancers, dyslipidaemias, diabetes mellitus, hypertension and depression (Hodder *et al.*, 2018). Vegetables also serve as free radical scavengers, eliminating accumulation of toxic wastes from tissues and organs hence slowing the aging process (Boeing *et al.*, 2012; Hodder *et al.*, 2018).

However, despite the tremendous benefits of vegetables to human health, they are amongst many food products that have high potential for contamination by heavy metals. Heavy metals are non-biodegradable metals that served as persistent environmental contaminants that can be deposited on the soil and water surfaces and later absorbed into the tissues of vegetables (Jacob and Kakulu, 2012). Plants take up these heavy metals by absorbing them from where they are deposited such as contaminated soils (Kachenko and Singh,

2006). Heavy metal pollution in the environment is one of the most pressing environmental problems of public health concern (Ratul *et al.*, 2018). Industrial, agricultural and household/ domestic wastes such as agrochemicals, urbanization and land development contributed immensely to heavy metals pollution of rivers (Manoj *et al.*, 2012) and soils. In tropical climates, automated and/or mechanical irrigation systems are widely adopted for water supply in the production of vegetables especially during the dry season due to inadequate rain supply of water. Long term use of wastewater for irrigation results in build-up of heavy metals in soil which can pollute the soil (He *et al.*, 2005; Muchuweti *et al.*, 2006; Ratul *et al.*, 2018). Heavy metals accumulation in vegetables due to pollution poses a serious threat to human health (Damek-Poprawa and Sawicka-Kapusta, 2003). Researches (Lawal and Audu, 2011; Garba *et al.*, 2019; Nimyel and Namadi, 2020) have reported heavy metals bioaccumulation in several plant species grown in Kaduna state. Consumption of heavy metals contaminated food can cause depletion in some essential nutrients in the body, poor immune performance, malnutrition related disabilities and high chances of upper gastrointestinal cancer (Arora *et al.*, 2008; Ghosh *et al.*, 2012; Ratul *et al.*, 2018). Therefore, this study aimed at determining the level of heavy metals accumulation in two major leafy vegetables grown in Giwa, Sabon-gari and Hunkuyi local government areas of Kaduna State.

## Materials and Methods

### Sample collection and preparation

The soil and vegetable samples were collected according to the modified method of Rahman *et al.* (2012). Composite samples of soils were collected from 10 farms and gardens per local government area in October, 2020 using an auger. The sampling locations were selected based on the anticipated levels of contamination of water used for irrigation by farmers in such locations. The farms and gardens

were situated 5m away from the road sides and used streams water for irrigation. The control site is a farm in Hunkuyi that was situated 92m away from the road side and which used well water for irrigation. The soil sampling spots were cleared of debris before sampling. The soil samples after quatering were air-dried for seven days to avoid microbial degradations. Prior to analysis, the soil samples were re-dried in the oven at 110°C for about 3 hours and crushed in a porcelain mortar and sieved through a 2 mm plastic sieve to obtain fine soil particles.

Freshly grown vegetable samples of spinach (*Spinacia oleracea*) and cabbage (*Brassica oleracea*) were collected in pre-cleaned zipper bags from commercial farmlands in Giwa, Sabon-gari and Hunkuyi local governments of Kaduna State. The former and the later were characteristically for intense agricultural activities all-round the year. The vegetables were irrigated mostly during dry season. Irrigation is carried out using stream water in the area. The leafy parts of the vegetables were transported to the Herbarium of the Department of Botany, Ahmadu Bello University Zaria, Nigeria for authentication. Voucher number ABU24000 and ABU3984 were assigned for spinach and Cabbage respectively. The vegetables were carried to the laboratory, thoroughly washed under running tap water and rinsed with deionized water to remove soil particles and debris attached to plant surfaces. Samples were cut into small pieces using a sterile small knife and dried in oven at 70°C for 48 h (Gupta *et al.*, 2012) till a constant weight was achieved. Samples were further ground into fine powder and sieved through 2mm mesh and kept in pre-cleaned zipper bags at ambient temperature till further analysis (Ratul *et al.*, 2018).

#### **Digestion of soil samples**

The soil samples collected were digested using the method described by Ogunfowokan *et al.* (2009). About 1.0 g of each soil sample was digested in volumetric flask with 30 ml aqua-regia (HCl:

HNO<sub>3</sub>, 3:1) on a thermostat hot-plate set at 150°C until dense white fumes appears. The volumetric flask with its content was removed from the hotplate and allowed to cool down to room temperature at 26°C and filtered. The filtrate was transferred into 50 ml sample bottle and top up to the 50 ml mark with distilled water then analysed using Atomic Absorption Spectrophotometry (Model: 932AA, GBC scientific equipment, dandenong, Australia).

#### **Plant sample digestion**

Using the methods of Ratul *et al.* (2018), one (1) g of plant samples powder were weighed into beakers (100 ml) and digested following the protocol of Cao *et al.* (2010) with 10 ml 65% concentrated HNO<sub>3</sub> and 4 ml 20% H<sub>2</sub>O<sub>2</sub>. Beakers were covered with watch glass. The suspensions were boiled on a hot plate at 200°C for 4 hours and thereafter allowed to cool at room temperature before dilution with deionized water (50 ml) in a volumetric flask. The solution was then filtered using Whatman No. 1 filter paper with 0.45 µm pore size into plastic bottle and kept the solution in the refrigerator until analysis. Blanks were prepared to check for background contamination by the reagents used. The samples were arranged in Completely Randomized Design with three replications.

#### **Sample analysis**

To assess the concentration of heavy metals (Copper [Cu], Cobalt [Co], Lead [Pb] and Zinc [Zn]), the digested vegetable samples were analyzed by Flame Atomic Absorption Spectrophotometer (Model: 932AA, GBC scientific equipment, dandenong, Australia). Reference standards 1, 2 and 3 ppm for these metals were prepared from their stock solution and standards prepared by pipetting 0.1, 0.2 and 0.3ml respectively of the metal reference standards and made up to 100 ml for standard calibration curve measurement (Ratul *et al.*, 2018). All chemicals used were of analytical grade.

**Statistical analysis**

Mean concentrations of heavy metals in the soils and vegetables were subjected to one-way Analysis of Variance (ANOVA) with Duncan’s New Multiple Range Test (DNMRT) used to separate significant means at 5%. The transfer factor (TF) of heavy metals from soils to crops was calculated according to the formula described by Cui *et al.* (2005) as follows:

$$TF = \frac{\text{Heavy metal concentration in plant}}{\text{Heavy metal concentration in soil}}$$

**Results**

The result for the heavy metals accumulation in the soils used for growing spinach and cabbage in three local government areas of Kaduna state is presented in Table 1. The result showed significant difference ( $P \leq 0.05$ ) in the levels of heavy metals in different high concentration of Co, Pb and Zn (8.27, 316.21 and 210.37 mg/kg respectively) from Sabon-gari soils. However Hunkuyi had the least values (5.06, 17.55, 291.33 and 185.26 mg/kg) for Co, Cu, Pb and Zn respectively of the heavy metals accumulation among the different soil samples (except the control).

**Table 1:** Heavy Metals Accumulation in soils from three local government areas, Kaduna

Location	Co (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Giwa	5.06 <sup>b</sup> ±0.02	17.55 <sup>b</sup> ±0.11	29.33 <sup>b</sup> ±0.02	185.26 <sup>b</sup> ±0.14
Sabon-gari	8.27 <sup>a</sup> ±0.01	23.41 <sup>a</sup> ±0.01	31.21 <sup>a</sup> ±0.10	210.37 <sup>a</sup> ±0.02
Hunkuyi	2.21 <sup>bc</sup> ±0.01	13.37 <sup>c</sup> ±0.12	27.34 <sup>c</sup> ±0.14	143.27 <sup>c</sup> ±0.12
Control	1.03 <sup>c</sup> ±0.01	2.56 <sup>d</sup> ±0.03	0.12 <sup>d</sup> ±0.02	10.30 <sup>d</sup> ±0.01
Means	4.14	14.22	22.00	137.30
WHO/FAO (2007)	50.00	36.00	85.00	50.00

**NB:** Means with the same superscript(s) down a column are not significantly different ( $P=0.05$ )

**Key:** Co= Cobalt Cu= Cupper Pb= Lead Zn= Zinc

The result for the heavy metals accumulation in spinach grown in the study areas is shown in Table

2. The result indicated significant difference ( $P \leq 0.05$ ) in the heavy metals accumulation in spinach obtained from different locations. The values of Cu, Pb and Zn were higher in spinach grown in Sabon-gari followed by that in Giwa. The value of Co in Giwa (0.29 mg/kg) is higher than the ones from the remaining locations. More so, the trend in heavy metals accumulation in spinach follows the following order: Zn>Cu>Pb>Co. Similarly, the soil-vegetable metals transfer factor (TF) in spinach is higher for Zn (0.42 mg/kg) and least in Co (0.04 mg/kg). The values for the TF in spinach followed similar trend: Zn>Cu>Pb>Co.

The result for heavy metals accumulation in cabbage grown in the study areas is presented in Table 3. The result showed significant difference ( $P \leq 0.05$ ) in the heavy metals accumulation in the plant under study. The result indicated that, the values of Zn, Pb and Co concentrations in cabbage obtained from Sabon-gari are higher than those from Giwa, Hunkuyi and the control. Zinc had the highest value with a total mean of 73.26 mg/kg followed by Pb (67.01 mg/kg). However, the highest value for Cu (7.14 mg/kg) was observed in cabbage obtained from Giwa. Furthermore, the transfer factor value is higher for Zn (0.41 mg/kg) followed by that of Cu (0.34) and least for Co (0.04).

**Table 2:** Mean value of heavy metals concentration in spinach

Location	Co (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Giwa	0.29 <sup>a</sup>	6.55 <sup>b</sup>	6.57 <sup>b</sup>	66.89 <sup>b</sup>
Sabon-gari	0.17 <sup>b</sup>	8.94 <sup>a</sup>	8.63 <sup>a</sup>	79.45 <sup>a</sup>
Hunkuyi	0.11 <sup>c</sup>	5.67 <sup>b</sup>	5.47 <sup>c</sup>	61.66 <sup>c</sup>
Control	0.08 <sup>d</sup>	1.28 <sup>c</sup>	1.24 <sup>d</sup>	23.39
Means	0.16	5.61	5.48	57.85
TF	0.04	0.39	0.25	0.42
WHO/FAO (2007)	0.10	40.00	0.30	60.00

**NB:** Means with the same superscript(s) down a column are not significantly different ( $P=0.05$ )

**Key:** Co= Cobalt Cu= Cupper Pb= Lead Zn= Zinc

**Table 3:** Mean value of heavy metals concentration in Cabbage.

Location	Co (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Giwa	0.14 <sup>b</sup>	7.14 <sup>a</sup>	60.12 <sup>b</sup>	62.76 <sup>b</sup>
Sabon-Gari	0.19 <sup>a</sup>	4.42 <sup>b</sup>	67.01 <sup>a</sup>	73.26 <sup>a</sup>
Hunkuyi	0.13 <sup>b</sup>	6.56 <sup>ab</sup>	38.49 <sup>c</sup>	60.65 <sup>b</sup>
Control	0.09 <sup>c</sup>	1.26 <sup>c</sup>	1.26 <sup>d</sup>	27.18 <sup>c</sup>
Means	0.14	4.85	41.72	55.96
TF	0.04	0.34	1.89	0.41
WHO/FAO (2007)	0.10	40.00	0.30	60.00

**NB:** Means with the same superscript(s) down a column are not significantly different (P=0.05)

**Key:** Co= Cobalt Cu= Copper Pb= Lead Zn= Zinc

### Discussion

The high accumulation of heavy metals in Sabon-gari and Giwa soils can be attributed to the intense agricultural activities including pesticides and fertilizer applications as well as high vehicular density as the areas possessed major roads that link several states in the North West region. This finding agrees with that of Garba *et al.* (2019) who reported high values of heavy metals in Giwa due to intense agricultural activities. The values obtained are above tolerable standards of FAO/WHO (2007). Heavy metals such as Cobalt (Co) and Copper (Cu) were all present at non-lethal amount in both spinach and cabbage grown in the study areas. The concentrations of Zn in the two vegetables obtained from the study areas (Sabon-gari, Giwa and Hunkuyi) were higher than the permissible standards of FAO/WHO (2007). This finding contradicts that of Ametepey *et al.* (2018) who reported high concentrations of heavy metals in various vegetables below the World Health Organisation (WHO) standard obtained from Tamale, Ghana. This can be attributed probably to the rate of agricultural activities of fertilizer and pesticides application as well as types of domestic

and industrial discharges. The trend in heavy metals bioaccumulation in plant species reported by the present study was in the order of *Spinacia oleracea*>*Brassica oleracea*. The studied data showed that the heavy metals contents varied among the two vegetables at the different sites.

The findings of this research agrees with the reports of Singh *et al.* (2010) and Ratul *et al.* (2018) who individually reported that variations in heavy metals concentrations in vegetables may be due to the differences in their morphology and physiology for heavy metals uptake, exclusion, accumulation and retention. Plant architecture, when taken into consideration may also be a factor capable of influencing the level of heavy metal accumulation in plants. From the observed data in the present study, the higher concentration of selected heavy metals in spinach can probably be due to the nature of its extensive vascular architecture compared to that in cabbage with dense-leaved heads and shallow roots.

The accumulation of Co in the soils and vegetables reported by the present study indicated a potential health risk in continuous consumption of these vegetables. This finding conformed to the report by Sheikh (2016) who stressed more on Cobalt poisoning. More so, the normal range for Cu concentration in plant is 3-15 mg/kg and toxic level is 20 mg/kg (Pivic *et al.*, 2013; Ratul *et al.*, 2018). Cu is an essential trace element required for normal biological activities of aminoxide and tryosinase enzymes (Ratul *et al.*, 2018). However, excessive intake of Cu may have severe health implications ranging from haemolysis, hepatotoxic, nephrotoxicity (Hasmi *et al.*, 2005). Similarly, the toxicity effects due to Pb in the food chain can result in nausea, vomiting, abdominal pains, anorexia, constipation, insomnia, anemia, irritability, mood disturbances, coordination loss and neurological effect (Ansari *et al.*, 2004; Bigdeli and Seilsepour, 2008). More so, Zn is an essential nutrient in plants but in concentrations higher than 60.0mg/kg can be toxic which results in plant

growth inhibition as reported by Chao *et al.* (2007). Acute toxicity from Zn in humans may include: tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhea and damage to pancreatic and hepatic tissues (Ratul *et al.*, 2018). Similarly, the values of Pb accumulation in spinach and cabbage reported by the present study were higher than that reported by Lente *et al.* (2012) in cabbage, lettuce, green pepper, jute and hot pepper irrigated with waste water in Accra, Ghana. The disparity could probably be due to the differences in the nature of the vegetables and their absorption rates.

The high concentration of Zn in spinach and cabbage when compared to other metals in Giwa is an indication of long-term health implications for consumers. This observation is in line with the findings of Agrawal and Verma (2021) which stated that despite the biological importance of zinc in human body, acute as well as chronic exposure may occur in human body by consumption of vegetables highly contaminated with Zinc metal. The presence of Pb in the vegetables may exert toxicity on organs that include kidneys, liver, lung and spleen that cause different biochemical defects. It exhibits neuropathology when adults are exposed occupationally or accidentally to excessive levels. There is a relationship between Pb in the human body and the increase of blood pressure of adults (Maihara and Fávoro, 2006).

The presence of other metals such as Co, Cu and Pb can pose significant health challenges to consumers which depend on these vegetables for different purposes. However, the mean concentrations of Co, Pb and Zn in vegetables from Hunkuyi and Sabongari in the present study were all below the safe limits of FAO/WHO (2007). Toxicity levels of heavy metals in leafy vegetables are dependent on irrigation-water source, synthetic pesticide usage, industrial and domestic effluents and vehicular exhaust emissions (Agrawal and Verma, 2021). The soil-plant transfer factor (TF) reported by the present study agrees with the work of Jacob and

Kakulu (2012) who reported that Pb is the least in the uptake of heavy metals by vegetables.

## Conclusion

It was concluded that, heavy metals in form of Co and Cu were present in spinach and cabbage grown in Giwa, Sabon-Gari and Hunkuyi local government areas at non-lethal concentrations. However, Zn and Pb accumulated at levels above tolerable limits. The presence of heavy metal contamination in vegetables depends on the source of irrigation-water, agrochemicals, industrial and domestic effluents. Therefore, vegetables grown close to road sides and/or which were irrigated with waste water should be avoided.

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## Competing Interest

There is no conflict of interest

## References

- Agrawal, N. and Verma, A. (2021). Assessment of copper and zinc contamination through vehicular emission on vegetables grown near road side. *International Journal of Environment and Pollution Research*, 9(1): 45-51.
- Ametepey, S.T., Cobbina, S.J., Akpabey, F.J., Duwiejuah, A.B. and Abuntori, Z.N. (2018).
- Health risk assessment and heavy metal contamination levels in vegetables from Tamale Metropolis, Ghana. *International Journal of Food Contamination*, 5:1-8.
- Ansari, T.M., Marr, I.L. and Tariq, N. (2004). Heavy Metals in Marine Pollution Perspective- A Mini Review. *Journal of Applied Science*, 4(1): 1-20.

- Arora, M., Kiran, B., Rani, S., Rani, A., Kaur, B. and Mittal, N. (2008). Heavy metal accumulation in vegetables irrigated with water from different sources. *Food Chemistry*, 111: 811-815.
- Balakrishna, Y., Manda, S., Mwambi, H. and van Graan, A. (2021). Identifying Nutrient Patterns in South African Foods to Support National Nutrition Guidelines and Policies. *Nutrients*. 13(9):3194.
- Boeing, H., Bechthold, A., Bub, A., Ellinger, S., Haller, D., Kroke, A. *et al.* (2012). Critical review: vegetables and fruit in the prevention of chronic diseases. *Eur J Nutr.*, 51(6):637-663.
- Bigdeli, M. and Seilsepour, M. (2008). Investigation of metals accumulation in some vegetables irrigated with waste water in Shahre Rey-Iran and toxicological implications. *American-Eurasian Journal of Agricultural and Environmental Sciences* 4(1): 86-92.
- Cao, H., Chen, J., Zhang, J., Zhang, H., Qiao, L. and Men, Y. (2010). Heavy metals in rice and garden vegetables and their potential health risks to inhabitants in the vicinity of an industrial zone in Jiangsu, China. *Journal of Environmental Science* 22 (11): 1792-1799.
- Chao, W., Xiao-chen, L., Li-min, Z., Pei-fang, W. and Zhiyong, G. (2007). Pb, Cu, Zn and Ni Concentrations in Vegetables in Relation to Their Extractable Fractions in Soils in Suburban Areas of Nanjing, China. *Polish Journal of Environmental Studies* 16: 199-200.
- Cui Y, Zhu YG, Zhai R, Huang V, Qiu Y, Liang J (2005) Exposure to metal mixtures and human health impacts in a contaminated area in Nanning, China. *Environ Int* 31:784-790
- Damek-Poprawa, M. and Sawicka-Kapusta, K. (2003). Damage to liver, kidney and tests with reference to burden of heavy metals in yellow-necked mice from areas around steelworks and zinc smelters in Poland. *Toxicology*, 186(1-2): 147-158.
- FAO/WHO (Food and Agriculture Organization/World Health Organization). (2007). Joint
- FAO/WHO Food Standard Programme Codex Alimentarius Commission (ALINORM 07/30/13). Report of the 38th Session of the Codex Committee on Food Hygiene. Houston, USA: Codex Alimentarius Commission
- Garba, M. D., Usman, M., Mazumder, M. A. J., and Al-Ahmed, A. (2019). Complexing agents for metal removal using ultrafiltration membranes: a review. *Environmental Chemistry Letters*, 1-14.
- Ghosh, A.K., Bhatt, M. and Agrawal, H. (2012). Effect of long-term application of treated sewage water on heavy metal accumulation in vegetables grown in Northern India. *Environmental Monitoring and Assessment*, 184:1025-1036.
- Gupta, N., Khan, D.K. and Santra, S.C. (2012). Heavy metal accumulation in vegetables grown in a longterm wastewater-irrigated agricultural land of tropical India. *Environmental Monitoring and Assessment*, 184: 6673-6682.
- Hasmi, D.R., Khan, F.H., Shaikh, G.H. and Usmani, T.H. (2005). Determination of Trace Metals in the Vegetables Procured from Local Markets of Karachi City by Atomic Absorption Spectrophotometry. *Journal of Chemical Society of Pakistan* 27(4): 353-357.

- He, M., Tian, G., Liang, X., Yu, Y., Wu, J. and Zhou, J. (2005). Effect of two sludge application on fractionation and phytotoxicity of zinc and copper in soil. *Journal of Environmental Science*, 19: 1482-1490.
- Hodder RK, Stacey FG, Wyse RJ, O'Brien KM, Clinton-McHarg T, Tzelepis F, *et al.* (2018). Interventions for increasing fruit and vegetable consumption in children aged five years and under. *Cochrane Database Syst Rev.*, 5(5): CD008552.
- Jacob JO, Kakulu SE. (2012). Assessment of heavy metal bioaccumulation in spinach, jute mallow and tomato in farms within Kaduna Metropolis, Nigeria. *American Journal of Chemistry*. 2(1):13-6.
- Kachenko, A. G. and Singh, B. (2006). Heavy metals contamination in vegetables grown in urban and metal smelter contaminated sites in Australia, *Water, Air and Soil Pollution*, 169: 101–123.
- Lawal, A. O., and Audu, A. A. (2011). Analysis of heavy metals found in vegetables from some cultivated irrigated gardens in the Kano metropolis, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, 3(6), 142-148.
- Lente I, Keraita B, Drechsel P, Ofori-Anim J, Brima AK. (2012). Risk assessment of heavy metal contamination on vegetables grown in long-term wastewater irrigated urban farming sites in Accra, Ghana. *Water Qual Expo Health*; 4:179–86.
- Li, Y., Bahadur, R., Ahuja, J., Pehrsson, P. and Hamly, J. (2021). Macro-and micronutrients in raw plant foods: The similarities of foods and implication for dietary diversification. *Journal of Food Composition and Analysis*. 102: 103993e.
- Maihara, V.A. and Fávoro, D.I.T. (2006). Toxic Elements. p. 629–660. In: Cozzolino SMF, editor. Bioavailability of nutrients. Barueri: Manole; 2006. (in Portuguese).
- Manoj, K., Kumar, B. and Padhy, P. K. (2012). Characterization of Metals in Water and Sediments of Subarnarekha River along the Projects' Sites in Lower Basin, India. *Universal Journal of Environmental Research and Technology* 2(5): 402-410.
- Muchuweti, M., Birkett, J.W., Chinyanga, E., Zvauya, R., Scrimshaw, M.D. and Lister, J.N. (2006). Heavy metal content of vegetables irrigated with mixtures of wastewater and sewage sludge in Zimbabwe: implication for human health. *Agriculture, Ecosystems and Environment*, 112: 41-48.
- Nimyel, S. H., and Namadi, M. M. (2020). Assessment of the level of heavy metal concentration in the street dust in some selected locations in zaria metropolis, kaduna state, nigeria. *Fudma Journal of Sciences*, 4(3): 93-98.
- Ogunfowokan, A. O., Oyekunle, J. A. O., Durosinmi, L. M., Akinjokun, A. I., and Gabriel, O. D. (2009). Speciation study of lead and manganese in roadside dusts from major roads in Ile-Ife, South Western Nigeria. *Chemistry and Ecology*, 25(6), 405-415.
- Pivić, R.N., Sebić, A.B.S. and Jošić, D.L. (2013). Assessment of soil and plant contamination by select heavy metals along a major European highway. *Polish Journal of Environmental Studies*, 22: 1465-1472.
- Rahman, S.H., Khanam, D., Adyel, T. M., Islam, M. S., Ahsan, M. A. and Akbor, M. A. (2012). Assessment of Heavy Metal Contamination of Agricultural Soil around Dhaka Export Processing Zone (DEPZ),



Bangladesh: Implication of Seasonal Variation and Indices. *Applied Science*, 2: 584-601.

Ratul, A. K., Hassan, M., Uddin, M. K., Sultana, M. S., Akbor, M. A. and Ahsan, M. A. (2018). Potential health risk of heavy metals accumulation in vegetables irrigated with polluted river water. *International Food Research Journal*, 25(1): 329-338.

Sheikh, I. (2016). Cobalt poisoning: A comprehensive review of the literature. *Journal of Medical Toxicology and Clinical Forensic Medicine*, 2: 1-6.

Singh, A., Sharma, R.K., Agrawal, M. and Marshall, F.M. 2010. Health risk

assessment of heavy metals via dietary intake of foodstuffs from the wastewater irrigated site of a dry tropical area of India. *Food and Chemical Toxicology*, 48: 611-619.

Tsor JO and Jombo GTA (2022). Heavy Metals Contaminating Vegetables in Nigerian Markets, Sources and Health Implications: A Search Perspective View. *West J Med & Biomed Sci*, 3 (1): 9-22.