Health Risk Assessment of Heavy Metals in Lettuce and Spring Onion on Human Health in Kumasi, Ghana

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ABSTRACT

INTRODUCTION: The demand and consumption of vegetables are significantly increasing worldwide, which has resulted in urban farming on anthropogenic sites. This study assessed the concentrations of some selected heavy metals in lettuce and spring onion in line with the WHO/FAO required standard and its implications on human health.

METHODS: The study was carried out in Kumasi, within moist semi-deciduous forest vegetation, Ghana. The digested samples were analyzed for heavy metals (Cu, Cr, Fe, Mg, Ni, and Zn) using atomic absorption spectrophotometer (AAS Model AA 400p). Analysis of variance was used to test the level of significance at $\alpha = .05$.

RESULTS: The study found mean concentrations of chromium and iron in lettuce and spring onion to be below detection level (BDL) in all study sites based on WHO/FAO permissible level. Also, while copper in lettuce was BDL at all the sites, there were higher mean concentration of copper in spring onion at BSGS (131.5 ± 0.31 mg/kg) and BSG (120.8 ± 0.01 mg/kg). The mean concentration of nickel in lettuce (137.15 ± 0.0231) and spring onion (173.55 ± 0.02 mg/kg) at BSGS were higher than WHO/FAO permissible level. Mean concentration of zinc in both lettuce and spring onion were higher than WHO/FAO permissible level in all the study sites, except zinc in spring onion at KT. The ANOVA test statistics showed no significant difference among the concentrations of heavy metals in all sites, except zinc in lettuce and nickel in spring onion. The study found cancer risk factor for nickel, which exceeded the benchmark of 1×10^{-6} for both lettuce and spring onion, indicating that long-term consumption could increase the risk of cancer in consumers.

CONCLUSION: The study's findings call for strict regulation and regular monitoring of heavy metals in vegetables cultivated at anthropogenic sites in urban areas to ensure food safety and consumer health.

PLAIN LANGUAGE SUMMARY

The study assessed the concentrations of some selected heavy metals in lettuce and spring onion in line with the WHO/FAO required standard and its implications on human health. **Why was the study done?** The WHO recommends consuming at least 400 g fruits and vegetables each day to reap health and nutritional benefits. This has resulted in increased advocacy for vegetable consumption and production. However, farmlands have become very scare due to proliferation of illegal mining activities in Ghana, making urban anthropogenic sites the idea sites for farming. Meanwhile, these sites can have adverse effect on human health since it may contain heavy metals in the soil used for planting and this could be easily absorbed into the food chain, particularly for leafy vegetables such as lettuce and spring onion. **What did the research do?** The research team selected samples of lettuce and spring onion for laboratory analysis. The digested samples were analyzed for heavy metals; copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), nickel (Ni) and zinc (Zn); using atomic absorption spectrophotometer (AAS Model AA 400p) so that we can determine the presence of heavy metals in the leafy vegetables. **What did the research find?** The study found permissible level of chromium and iron in both lettuce and spring onion in all the study sites. Also, while copper in lettuce was within the permissible limit at all the sites, there were higher concentration of copper in spring onion at BSGS and BSG. Nickel concentration in lettuce and spring onion at BSGS were higher than WHO/FAO permissible level, however, in AH and KT, they were less than the permissible limit. There was high concentration of zinc in both lettuce and spring onion in all the study sites, except zinc in spring onion at KT. The ANOVA test statistics showed a significant difference among the concentrations of zinc in lettuce and nickel in spring onion.

KEYWORDS: Heavy metals, leafy vegetables, health risk, hazard quotient, anthropogenic activities

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Introduction

The global demand for vegetables continues to rise due to their essential role in human nutrition. Public education on the consumption of a healthy diet, in addition to increased knowledge among the urban population on the health benefits of vegetables, might have contributed to this rise or high demand.[1,2] However, to reap its nutritional benefits, WHO recommends consuming at least 400 g of vegetables each day.[3]

Generally, leafy vegetables have health-promoting bioactive metabolites that possess antioxidant, anti-inflammatory, and anticancer properties that assist in reducing the development of non-communicable diseases.[4] They are highly beneficial for strengthening the immune system and maintaining good health. Specifically, lettuce and spring onion play a vital role in nutrient metabolism and retard degenerative diseases. Their low caloric and lipid nature makes them ideal for health promotion by lowering the risk of cardiovascular diseases and cancer.[4,5] Lettuce contains bioactive compounds such as folate, β-carotene, lutein, and phenolics that reduce the risk of chronic and degenerative diseases caused by oxidative stress.[6,7] Spring onion, especially, contains vitamin C, which keeps the immune system strong and resistant against illness and flu, as well as being rich in minerals such as potassium, calcium, phosphorous, magnesium, and several others.[8-10]

Vegetable farming is gradually gaining prominence in Ghanaian cities due to its economic potential and high demand.[11] These vegetables are cultivated in both commercial and domestic quantities.[1] Urban vegetable farming is commonly conducted on anthropogenic sites,[12] where farmlands are scarce. This scarcity is often due to rapid urbanization and the proliferation of illegal mining activities in Ghana, especially in areas rich in natural resources such as gold and bauxite.[13] These human activities cause anthropogenic pollution. Anthropogenic lands are contaminated by various sources, including urban and industrial waste, mining and smelting, and metallurgical industries. Contaminated lands may contain heavy metals, which can be absorbed by vegetables and pose a risk to human health.[14]

In recent years, heavy metals have been considered a highly risky environmental issue due to their ubiquity, toxicity at trace levels, and persistence in the environment.[15,16] The presence of heavy metals in the soil is an environmental pollutant that contributes to the bioaccumulation of metals in plants. Studies have reported that heavy metals commonly found in agricultural soil include zinc (Zn), cadmium (Cd), copper (Cu), chromium (Cr), iron (Fe), nickel (Ni), lead (Pb), and manganese (Mn), and these metals can easily be absorbed in leafy vegetables.[14,17] Ni in particular is consistently found to possess the highest cancer risk in the soil.[18,19] Heavy metals have been found to be among the most significant contaminants in vegetables grown in urban anthropogenic sites across the globe.[20-22]

In addition, research indicates that persistent use of industrial or municipal wastewater for irrigation is likely to accumulate heavy metals in agricultural soils and plants.[17,23] Even so, the use of contaminated sites and untreated wastewater for irrigation is common in major Ghanaian cities, such as Accra and Kumasi. In dry seasons, large parcels of land for vegetable farms in Accra and Kumasi are irrigated using untreated wastewater so that they earn a higher income for the products during that period.[17,24,25] In addition, findings from an existing study done in some communities in Asokwa and Oforikrom Municipalities in the Ashanti region confirm that vegetable farming thrives on the use of urban anthropogenic sites and polluted streams for irrigation.[17,26] Vegetable farmers usually use streams or freshwater that have been polluted by domestic, industrial, and institutional waste to irrigate their vegetables.[27,28] Meanwhile, the polluted stream or freshwater may be contaminated with heavy metals, which are harmful to human health.

To promote public health and safety through the consumption of urban-grown vegetables, this study assessed the concentrations of selected heavy metals (Cu, Cr, Fe, Ni, and Zn) in two leafy vegetables, lettuce and spring onion, in accordance with WHO and FAO standards. Leafy vegetables were chosen because they tend to accumulate these metals more than grain and fruit crops.[29,30] Prolonged consumption of vegetables contaminated with heavy metals poses significant health risks, potentially depleting essential nutrients critical for immune defense. Consequences may include intrauterine growth retardation, impaired psychosocial development, malnutrition-related disabilities, and increased rates of upper gastrointestinal cancer.[31]

Also, we acknowledged the similar work done by Sackey et al[17], as it informed our decision to carry on with the study. The authors determined the presence and level of potential trace elements in lettuce and spring onion grown and sold at Kwame Nkrumah University of Science and Technology (KNUST) and its environs. However, our study had a wider scope since it used popular sites (Ahodwo, Kentikrono, and KNUST and its environs) in the Kumasi Metropolitan Area, where vegetable farming is commonly done. In addition, our work used an atomic absorption spectrophotometer (AAS Model AA 400p). This instrument uses light absorption to measure the concentration of specific elements in a sample. The sample needs to be digested before analysis with AAS. On the other hand, Sackey et al's[17] study used a Thermo Scientific Niton XL3t XRF Analyzer. This is an X-ray fluorescence (XRF) analyzer, which uses X-rays to identify and measure the elemental composition of a sample. It should be appreciated that the study area chosen in both articles is a densely populated area with a large number of students who consume a lot of vegetables. The concerns about irrigation practices, industrial activities, or historical land use near KNUST call for the need for this study, and similar work helps to validate what has already been done. These studies give a broad understanding of the levels of heavy metals in vegetables grown in these areas.

This study specifically aims to highlight the health risks associated with consuming vegetables grown in urban centers and to emphasize the need for relevant policy considerations. Its significance lies in the increasing prevalence of vegetable farming on anthropogenic sites and the potential impact on public health.

Materials and Methods

Sampling site

The study was carried out at Ahodwo (AH), Kentinkrono (KT), and at Kwame Nkrumah University of Science and Technology (KNUST), specifically, behind School of Energy (BSE) and behind School of Graduate Studies (BSGS), Ashanti Region, Ghana. These sites were selected because they were the areas in Kumasi township where vegetable farming is usually done. The study sites are urban centers located in Kumasi, which is a metropolitan area situated within moist semi-deciduous forest vegetation. The climatic condition is characterized by both dry and wet seasons with twice maximum rainfall within the year. It has rich soil for farming and most of the indigenous people in the study area are farmers and hunters. According to Meteorological Services Department, Kumasi Airport Weather Station, the mean temperature is 28°C and the mean annual rainfall is 1300 mm.[32]

Ahodwo is a suburb of Kumasi, is a residential area in the Kumasi Metropolitan Assembly. It is about 7 km westwards from center of the regional capital. It lies between the latitude 6°7′N and longitude 1°7′W. The Ahodwo roundabout is a major intersection in the town. Kentikrono is about 20 km from the center of Kumasi. It is a dormitory town and serves mainly as a residential area for workers in various companies in Kumasi. The KNUST is situated approximately on an 18 km^2 campus of undulating land and pleasant surroundings, about 7 km away from the central business district of the city of Kumasi. It lies between latitude 6°39′ & 6°47′N and longitude 1°26′ & 1°40′W.[33]

Sample collection and preparation

At each farming site, lettuce and spring onion samples were collected and washed using distilled water to remove soil and other solid contaminants. The cleaned samples were kept in polythene rubber, labeled, and sent to the laboratory for analysis.

Digestion of samples

The cleaned vegetable samples were air-dried and blended into a fine powder. For analysis, 1 g sample each of lettuce and spring onion was weighed, transferred to porcelain crucibles, and placed in the fume chamber. Subsequently, 10 mL of 70% nitric acid was added and heated until the dissipation of white fumes led to the formation of a clear solution. Thereafter, samples were cooled, filtered, and topped up to 50 mL volumetric flasks with distilled water.[34] The digestion was done in triplicate and later sent for analysis.

Quality control and assurance

Quality control procedures were followed to ensure reliability of the results obtained in this study. It was ensured that all chemical and reagents used were of good analytical quality and purity. The various glassware was washed and rinsed with deionized water before use. To obtain the quantification and detection limits of the Atomic Absorption Spectrophotometer (AAS), a blank solution was prepared and read 25 times. The standard deviation of the readings was determined and considered for noise generation levels for every heavy metal. The LOD (limit of detection) for each element was attained using the equation:

$$\mathrm{LOD} = \frac{3S}{M} \tag{1}$$

Where **S** is the blank readings standard deviation and **M** is the gradient of the calibration curve for each metal. The quantification limit was obtained using the equation:

$$\mathrm{LOQ} = \frac{10\mathrm{S}}{\mathrm{M}} \tag{2}$$

The analytical procedure's repeatability and accuracy were tested by spiking and homogenizing three replicates of each of the three selected samples. The triplicate of each sample was spiked with 3 diverse concentrations of the metal of interest as follows: Cu (1.0, 2.0, and 5.0 mg/L), Fe (2.0, 10.0, 20.0 mg/L), Ni (0.5, 2.0, and 3.0 mg/L) Zn (0.25,0.5,1.0) and Cr (1.0, 2.0,5.0 mg/L). The absorbance measured by the atomic absorption spectrophotometer was converted to concentrations using standard calibration curves. 1000 mg L^{-1}single element standards of the metals of interest, found from Fluka Analytical (Sigma Aldrich Chemie GmbH, Switzerland), were diluted using 10% HNO_3 and used to generate the calibration curves for the atomic absorption spectrophotometer analysis. The detection limit of Cu was <0.010 mg/kg, Fe was <0.010 mg/kg, Ni was <0.002 mg/kg, Zn was <0.050 mg/kg and Cr was <0.001.

Metal analysis

The digested samples were analyzed for heavy metals (Cu, Cr, Fe, Mg, Ni and Zn) using atomic absorption spectrophotometer (AAS Model AA 400p) in KNUST central laboratory, Kumasi, Ghana.

Data analysis

An analysis of variance (ANOVA) was used to test the level of significance at $\alpha = .05$, the generally acceptable level for scientific studies. Means were separated using the least significant difference test at the 5% level of significance.

Health risk assessment

The Estimated Daily Intake (EDI) is one method commonly used which helps to identify the number of pollutants consumed daily.[35] The EDI is directly linked to the metal concentration, food consumption, and body weight.

Therefore, the EDI of heavy metals or pesticides for adults was calculated using equation (3) described by US Environmental Protection Agency[36]:

$$\text{EDI} = \frac{C \times Cb}{Bw} \tag{3}$$

where C is the concentration of heavy metals in fish (mg/kg wet weight), C_b is the average daily consumption of fish in the local area, and Bw represents the body weight.

Calculations were made based on the standard assumption for an integrated USEPA risk analysis, considering an adult's average body weight of 70 kg([37]) and the average daily vegetable intake for adults is considered to be 0.345 kg person day.[38-40]

Determination of hazard quotient (HQ)

HQ values of <1 signify unlikely adverse health effects, while HQ values >1 indicate a likely adverse health effect.

$$HQ \; = \; EDI \;\; / \, RfD \tag{4}$$

HQ is the hazard quotient; EDI is the estimated daily intake and RfD is the reference dose (mg $kg^{-1}day^{-1}$). The RfD for the metals in vegetable consumption is 7.0×10^{-1} for Fe, 2.0×10^{-2} for Ni, 4.2×10^{-2} for Cu and 3.0×10^{-1} for Zn.[37,38-41]

Cancer risk assessment

Carcinogenic risk assessment estimates the probability of an individual developing cancer over a lifetime due to exposure to the potential carcinogen. In our study, only Ni is carcinogenic and has a cancer slope of 9.10×10^{-1} (mg/kg/day) and the formula shown in equation (3) as described by US Environmental Protection Agency.[36] The safety limit is 1×10^{-6} (the acceptable level of carcinogenic risk for humans).

$$\text{Cancer risk} = \text{EDI} \times \text{CSF}((\text{mg} / \text{kg} / \text{day}) \tag{5}$$

Where: CSF is the cancer slope factor and EDI is the estimated daily intake.

Results

Mean concentration of heavy metals in lettuce

Table 1 presented the mean concentration of heavy metals (Cu, Fe, Ni, Zn, and Cr) in lettuce collected from the study sites, AH, KT, BSE, and BSGS.

The study found the mean concentrations of both Cu and Cr in lettuce, collected from all the study sites, below detection level WHO/FAO[41] permissible value of 40 mg/kg and 5.0 mg/kg respectively. In addition, the mean concentrations of Fe in lettuce were 89.15 ± 0.0662 mg/kg at AH, 77.95 ± 0.105 mg/kg at KT, 220.6 ± 0.237 mg/kg at BSE, and 262.95 ± 0.1929 mg/kg at BSGS were all below WHO/FAO[41] permissible value of 450 mg/kg. Low levels of Fe concentrations suggest that the heavy (Fe) metal does not pose a health threats to consumers and it is safe with no implication on public health.

Although the mean concentration of Ni in lettuce was below detection level at AH, KT and 52.65 ± 0.047 at BSE, however, the mean concentration of Ni in lettuce (137.15 ± 0.0231) at BSGS was higher than WHO/FAO[41] permissible value of 67.90 mg/kg. Surprisingly, Zn concentration in lettuce was higher than WHO/FAO[41] permissible value of 60 mg/kg in all the study sites. However, the highest mean concentration of Zn (317.65 ± 0.9065) was recorded in KT, followed by BSE (118.35 ± 0.087) and the least (79.2 ± 0.0237) at AH.

In all, the ANOVA teat statistics showed a significant difference among of the concentration Zn from all the sample locations, whereas all the other heavy metals (Cu, Fe, Ni, and Cr) had no significant difference among the concentrations recorded from all the sample locations.

Concentration of heavy metals in spring onions

Table 2 showed the mean concentration of heavy metals (Cu, Fe, Ni, Zn, and Cr) in spring onion collected from the study sites, AH, KT, BSE, and BSGS.

The results indicated that the mean centration of Fe in spring onion [189.25 ± 0.23 mg/kg at AH, 152.75 ± 0.11 mg/kg at KT, 121.80 ± 0.01 mg/kg at BSE, and 297.0 ± 0.06 mg/kg at BSGS] was below detection level in all the study sites based on WHO/FAO[41] permissible value of 450 mg/kg. Similarly, the mean concentration of Cr in spring onion was also below WHO/FAO[41] permissible value of 5.0 mg/kg in all the study sites.

On the contrary, there were higher mean concentration of Cu in spring onion at BSGS (131.5 ± 0.31 mg/kg) and BSG (120.8 ± 0.01 mg/kg) based on the WHO/FAO[41] permissible value of 40 mg/Kg. However, the mean concentration of Cu in spring onion was below detection level at AH and KT. Similar to the mean concentration of Cu in spring onion, the mean concentration of Ni in spring onion was below detection level at both AH and KT. On the other hand, mean concentration of Ni in spring onion was higher at BSGS (173.55 ± 0.02 mg/kg) and BSG (98.35 ± 0.03 mg/kg) in relation to WHO/FAO[41] permissible value of 67.90 mg/kg. In relation to the concentration of Zn in spring onion, apart from KT (53.4 ± 0.03 mg/kg), all the other study sites [161.95 ± 0.07 mg/kg at AH, 65.45 ± 0.07 mg/kg at BSE, and 83.7 ± 0.09 mg/kg at BSGS], recorded higher values based on WHO/FAO[41] permissible value of 60.0 mg/kg. The highest concentration of Zn in spring onion was recorded in AH, followed by BSGS and BSG.

Table 1. Mean of heavy metals in lettuce in the four sites.

HEAVY METAL	AH		KT		BSE		BSGS		WHO/FAO[41]	*P*-VALUE
	MEAN (MG/KG)	SD	MEAN	SD	MEAN	SD	MEAN	SD		
Cu	BDL	N/A	BDL	N/A	BDL	N/A	BDL	N/A	40	N/A
Fe	89.15	0.0662	77.95	0.1048	220.6	0.237	262.95	0.1929	450	.058
Ni	BDL	N/A	BDL	N/A	52.65	0.047	137.15	0.0231	67.90	.000*
Zn	79.2	0.0237	317.65	0.9065	118.35	0.087	102.7	0.0446	60	.579
Cr	BDL	N/A	BDL	N/A	BDL	N/A	BDL	N/A	5.0	N/A

Abbreviations: BDL, below detection limit; N/A, not applicable; SD, standard deviation.
*Means significant value.

Table 2. Mean of heavy metals on Spring Onions in the 4 sites.

HEAVY METAL	AH		KT		BSE		BSGS		WHO/FAO[41]	*P*-VALUE
	MEAN (MG/KG)	SD	MEAN	SD	MEAN	SD	MEAN	SD		
Cu	BDL	N/A	BDL	N/A	120.8	0.01	131.5	0.31	40	.165
Fe	189.25	0.23	152.75	0.11	121.80	0.01	297	0.06	450	.0508
Ni	BDL	N/A	BDL	N/A	98.35	0.03	173.55	0.02	67.90	.000*
Zn	161.95	0.07	53.4	0.03	65.45	0.07	83.7	0.09	60	.33
Cr	BDL	N/A	BDL	N/A	N/A	N/A	BDL	N/A	5.0	N/A

Abbreviations: BDL, below detection limit; N/A, not Applicable; SD, standard deviation.
*Means significance value.

Table 3. Health risk assessment for consuming lettuce and spring onion.

VEGETABLE	METAL	MEAN (MG/KG)	EDI	HQ	CANCER RISK
Lettuce	Fe	162.6625	0.935	1.336	-
	Ni	47.45	0.273	13.641	0.248
	Zn	154.475	0.888	2.961	-
Spring onion	Cu	63.075	0.363	8.635	-
	Fe	190.2	1.093	1.562	-
	Ni	67.96	0.391	19.538	0.391
	Zn	91.125	0.524	1.747	-

In addition, the ANOVA test statistics showed no significant difference among the concentrations of Cu, Fe, Zn, and Cr recorded from all the sample locations, except for Ni, which indicated a significant difference among the concentration at .000 significance level.

Health risk assessment for consuming lettuce and spring onion

Table 3 summarizes the EDI, HQ, and cancer risk associated with various metals found in lettuce and spring onions grown in the study area. The findings highlight potential health concerns for consumers due to metal contamination. The NYSDOH hazard quotient system categorizes potential non-carcinogenic risks based on the EDI to RfD ratio for each metal. Fe and Zn in both lettuce and spring onion fall under the low-risk category (HQ 1-5 times RfD), indicating minimal health concerns. Cu in spring onion presents a moderate risk (HQ 5-10 times RfD), suggesting a potential public health concern. However, the most concerning finding is the presence of Ni in both lettuce and spring onion. The significantly elevated HQ values (HQ > 10 times RfD) suggest a high potential health threat to consumers.

Discussion

The main aim of the study was to assess the concentrations of some selected heavy metals in lettuce and spring onion in line with the WHO/FAO required standard and its implications on human health. The study found mean concentrations of chromium and iron in both lettuce and spring onion to be below detection level in all the study sites in based on WHO/FAO[41] permissible level. Specifically, the study by Sackey et al[17] collaborates our study findings, while both studies raise concerns about heavy metals, they differ in the specific metals identified and the level of risk they conclude. The study gives a broad understanding on the levels of heavy metals in vegetables grown in these areas. In another similar study in Ghana, Ametepey et al[42] reported on low iron concentrations in some vegetables (cabbage, carrot, green pepper, onion and tomato sampled) from Tamale Metropolis, which is an urban city in Ghana. Similarly, Akubugwo et al[43] reported a permissible concentration of 147.41 mg/kg for iron metal content in *Amaranthus hybridus* vegetables. Also, Naser et al's[44] study found iron, copper and zinc concentrations less than the maximum limits for vegetables. Permissible concentration of chromium and iron in both lettuce and spring onion imply that these leafy vegetables pose no health risk to human health.

The mean concentration of nickel in lettuce (137.15 ± 0.0231) and in spring onion (173.55 ± 0.02 mg/kg) at BSGS were higher than WHO/FAO[41] permissible level and seem consistent with Taghavi et al[18] and Peirovi-Minaee et al[19] studies. However, nickel concentration in lettuce was below detection limits at AH and KT. The finding suggests that lettuce and spring onion produced in BSGS can pose a health threat to consumers. There was statistically significant difference ($P = .00 < .05$) in nickel concentrations measured in the different locations. The high level of nickel in lettuce and spring onion may be due to the use of wastewater for irrigation. Similarly, study by Ackerson and Awuah[45] reported that vegetable farmers in KNUST used shallow wells as well as contaminated streams to irrigate their farms. The stream might be contaminated with Ni due to the disposal of waste sewage and sludge as well as fertilizer applications. The acute effects of ingesting large doses of soluble nickel salts include nausea, abdominal pain, diarrhea, vomiting, and shortness of breath.[46] However, Ni concentration found below the detection limit do not pose a health threat to consumers when consumed.

The mean concentration of zinc in both lettuce and spring onion were higher than WHO/FAO[41] permissible level in all the study sites, except the mean concentration of zinc in spring onion at KT. ANOVA test shows no statistically significant difference in the mean of Zn values measured in onions from the different sampling locations. Contrary to the study findings, zinc concentrations recorded in a study were 0.039, 0.184, and 0.067 mg/kg in *Hibiscus sabdariffa* (Roselle), *Letuca sativa* (Lettuce) and *Amaranthus caudatus* (Spinach) respectively, all within the permissible level.[47] Zinc is a vital metal needed for normal body growth and development in plants, animals, and humans. Mild zinc deficiency can aggravate infections by impairing immune defense, up to severe cases, in which the symptoms are obvious and cause reduced life expectancy.[48-50] However, it is toxic at high levels and consumption of highly contaminated zinc leafy vegetables could be detrimental to human health leading to acute adverse effects such as nausea, vomiting, loss of appetite, abdominal cramps, diarrhea, and headaches.[51] The presence of zinc on lettuce and spring onion can be due to the use of water that has been contaminated with effluent from domestic areas, sewage and industrial establishments for irrigation.

Copper concentration in lettuce was below detection limit at all the sites, however, there were higher concentration of copper in spring onion at BSGS (131.5 ± 0.31 mg/kg) and BSG (120.8 ± 0.01 mg/kg) based on WHO/FAO[41] permissible level. ANOVA test showed that there was no significant difference in copper concentrations detected for BSE and BSGS onion samples. The presence of copper in spring onion samples were probably due to the use of contaminated water for irrigation. According to Sharma et al[52], effluents containing paints, fuel, alloys and agricultural runoff introduce copper into rivers which are used for irrigation. In humans, acute effects of copper ingestion include gastrointestinal symptoms such as nausea or abdominal pain.[50]

Non-carcinogenic and carcinogenic health risks

The study found cancer risk factor for nickel, which exceeds the benchmark of 1×10^{-6} for both lettuce and spring onion. This indicates that long-term consumption (over 30 years) of vegetables with these nickel levels could increase the risk of cancer in consumers. Notably, previous studies have reported non-carcinogenic HQ values for nickel in seafood, highlighting the potential variation in risk profiles across different food sources.[53]

Chronic exposure to nickel through vegetable consumption raises public health concerns due to its potential carcinogenicity. Studies suggest that nickel accumulation in the body can lead to lung fibrosis, cardiovascular diseases, and kidney problems.[54] The primary exposure routes for nickel are inhalation and ingestion, and its presence in vegetables indicates a potential dietary exposure pathway for consumers.[54]

The presence of various heavy metals within the vegetables is an additional concern due to potential synergistic toxic effects. Exposure to multiple pollutants can lead to combined or interactive effects, with varying degrees of severity based on the specific metals and exposure pathways.[55] These combined effects can be synergistic, where the combined toxicity is greater than the sum of the individual metals, or antagonistic, where the combined effect is less severe than the individual effects. Additionally, metals may compete for absorption in specific tissues, influencing their individual impact within the body.

Studies from other regions have identified heavy metal contamination in various food sources, highlighting the widespread nature of this issue.[55,56] These studies also emphasize the potential health risks associated with consuming contaminated foods. In Bangladesh, for instance, certain vegetables were found to contribute to a potential carcinogenic risk due to Cd and Pb contamination.[56]

The findings from this study underscore the importance of monitoring metal levels in vegetables and implementing strategies to mitigate potential health risks for consumers. Further research is needed to determine the source of the nickel contamination and to investigate the potential synergistic effects of co-occurring metals within the vegetables.

Limitations of the study

The study is only limited to four sites in Kumasi metropolitan areas in Ghana. Extending it to other regions in Ghana may provide greater insights to relevant stakeholders. Moreover, based on human activities carried out in the study site, the study was limited to seven metals.

Conclusion

From the two vegetables analyzed, Fe, Cu, Ni, and Zn were the heavy metals investigated. Although most metals were within WHO standards, elevated nickel (highest mean observed is 173.55) and copper (highest mean observed is 131.5) levels at certain sites and widespread high zinc (highest mean observed is 83.7) concentrations are concerning. This suggests the need for strict regulation and regular monitoring of heavy metals in vegetables at urban anthropogenic sites to ensure food safety and protect consumer health. Academically, the study contributes to the understanding of heavy metal contamination in urban agriculture and emphasizes the need for ongoing research into environmental health impacts. To ascertain the extent and variability of contamination across different crops, the authors recommend further research on heavy metal contamination in other vegetables grown at the urban sites in Ghana.

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Author Contributions

Conceived and designed the study: POA and ASA. Analyzed the data: POA, KTA and ASA. Wrote the papers: POA, ASA, KTA and FA. Reviewed the available literature and performed the analyses: HA, ROA, and RH. Contributed to the interpretation of results and write-up: POA, ASA, KTA, FA, HA, ROA, and RH.

Data Availability Statement

Data will only be provided upon reasonable request and for academic purposes.

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