Assessment of Heavy Metals in Vegetables Grown on Irrigated Land in Butura, Bokkos LGA, Plateau State, Nigeria

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Abstract: *Vegetables have positive antioxidative properties and are abundant in vitamins, minerals, and fiber. However, if consumed in large quantities, eating vegetables polluted with heavy metals may be harmful to human health. Therefore, this study assessed the effects of heavy metals on irrigated pepper, cabbage and Irish potatoes grown in Butura. Atomic absorption spectrophotometry (AA240FS) was used to analyze cadmium (Cd), cobalt (Co), nickel (Ni), lead (Pb), zinc (Zn), copper (Cu), chromium (Cr) and arsenic (As) levels. Three samples were selected from each of the vegetables grown on nine selected farms at distances of 0 m, 10 m, and 30 m. This forms a composite sample of vegetables at each farm. The study showed that the concentrations of cobalt, chromium, cadmium, copper, arsenic, zinc and nickel were within the standard limits set by the FAO/WHO, except for lead, which is higher than the allowable limits for vegetables. These patients may have behavioral problems, neurological complications and hematologic disorders. Thus, these findings could lead to a risk for the human population consuming these vegetables. It is recommended that irrigation water and agricultural soils be constantly monitored to determine the concentration of metals accumulated by crop plants to ensure that crop plants are safe for consumption by humans.*

Keywords: Vegetable, Cabbage, Heavy Metals, Irrigated, Irish Potato, Bokkos, Pepper

INTRODUCTION

The human diet must include vegetables since they are essential for maintaining normal physiological functioning and supplying nutrients (Wuyep, Rampedi, and Ifegbesan, 2021). Edible plant portions known as exotic vegetables are typically consumed raw or prepared in combination with other varieties of food (Chacha and Laswai, 2020). Due to the presence of certain nutritional elements that are necessary for human survival, vegetables are consumed more often. They are also known as protective foods since they help prevent sickness in humans (Heiner et al. 2012). They are known to be a vital part of our diet since they provide enough fiber, vitamins, minerals, and trace elements (Hu, Chaffai, and Koyama, 2011; Gharibi, 2014; Chacha and Laswai, 2020).

Despite their nutritional value, these vegetables can become contaminated by heavy metals found in the soil, water, and atmosphere. In the soils where these vegetables are cultivated, the excessive use of both organic and inorganic fertilizers has a substantial impact on the uptake of heavy metals in high quantities by crops (Sagagi, Bello, and Danyaya, 2022). Heavy metals are metallic components that are highly dense and toxic to humans (Clemens and Ma, 2016; Kolawole, Ukwede, and Igwemmar, 2022). Heavy metal buildup in vegetables is a result of the extensive use of herbicides, fertilizers, and irrigation water from mining ponds. When heavy metal-contaminated wastewater is used for irrigation for an extended period of time, the concentration of heavy metals increases above allowable limits (Yargholi, and Azimi, 2008).

However, because of their toxicity, ubiquity, persistence, nonbiodegradability, and bioaccumulation, heavy metals are now a global health problem (Diagomanolin, Farhang, Ghazi-Khansari and Jafarzadeh, 2004). The toxicity and cumulative nature of heavy metals make their excessive accumulation in ecosystems a major environmental concern (Ali et al. 2021; Tauqeer, Turan, and Iqbal, 2022). However, the physiological development of plants and other living things depends on certain heavy metals. However, these products can cause severe danger to both human and environmental health when they are present in excessive amounts. Heavy metals in the environment are absorbed by edible plants and are a sign of a developing environmental problem that may affect food quality and human health downstream in the food chain (Sandeep, Vijayalatha and Anitha, 2019; Mwelwa, Chungu, Tailoka, Beesigamukama and Tanga, 2023).

Because of pedogenetic processes, including the weathering of parent materials, heavy metals are naturally present in the soil environment in amounts considered to be trace (<1000 mg kg^{-1}) and rarely toxic (D'Amore, Al-Abed, Scheckel and Ryan, 2005; Macías et al. 2022). Heavy metals can be essential, e.g., copper (Cu), gold (Mn), zinc (Zn), iron (Fe), cobalt (Co), nickel (Ni), molybdenum (Mo), and selenium (Se), or nonessential, such as chromium (Cr), gold (Au), lead (Pb), titanium (Ti), silver (Ag), mercury (Hg), arsenic (As), cadmium (Cd), vanadium (V), tin (Sn), aluminum (Al), antimony (Sb), bismuth (Bi), platinum (Pt), tellurium (Te), strontium (Sr), uranium (U), and palladium (Pd) (Osma, Serin, Leblebici and Aksoy, 2013; Boyd and Rajakaruna, 2013). However, when it is in excess, it can become quite harmful to plants (Chacha and Laswai, 2020). However, nonessential metals, such as aluminum (Al), arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg), are not necessary for regular biological processes and can become poisonous (Boyd and Rajakaruna, 2013).

Vegetables grown in heavy metal-contaminated fields or those close to sources of pollution may acquire greater quantities of heavy metals than other types of vegetables. The kinds of sources, the modes of deposition, and the amounts and oxidation states of heavy metals may all affect the biotoxicity of heavy metals (Duruibe, Ogwuegbu, and Egwurugwu, 2007). Vegetables absorb heavy metals into various vegetable tissues after they are deposited on their surface (Kachenko and Singh, 2005). Because the roots and leaves of herbaceous plants retain larger quantities of heavy metals than do the stems and fruits, leafy vegetables collect more heavy metals (Yargholi and Azimi, 2008).

The toxicity of consuming contaminated vegetables and subsequent exposure to heavy metals are major concerns (Javid, Manoj, and Khursheed, 2018; Ali et al. 2021). The presence of these bacteria in vegetable and agricultural soils is thought to be one of the world's most serious ecological issues (Boyd and Rajakaruna, 2013; Javid, Manoj, and Khursheed, 2018). The main way that heavy metals are exposed to humans is through various food chains, which can also cause important biological processes in plants to be disrupted (Kachenko and Singh, 2005). Among the factors that increase a person's risk of heavy metal exposure is eating vegetables grown in contaminated soils (Gebeyehu and Bayissa, 2020; Idowu, 2022).

Heavy metals can accumulate in the kidneys and liver of humans who consume polluted food. This disturbance of many biochemical processes can result in disorders of the heart, neurological system, kidneys, and bones (Sharma, Agrawal, and Marshall, 2009). The concentration and oxidation states of heavy metals, their manner of deposition, the chemical composition of vegetables, their physical characteristics, and the rate of ingestion all affect how biotoxic heavy metals are (Duruibe, Ogwuegbu and Egwurugwu, 2007). Consuming food supplemented with heavy metals can severely deplete the body of several vital nutrients, which can lead to a decline in immune function, altered physico-social behavior, intrauterine growth retardation, and malnutrition-related impairments (Waisberg, Joseph, Hale, and Beyersmann, 2003; Arora et al., 2008). According to the reports of the International Agency for Research on Cancer, nonessential heavy metals (As, Cd, Cr) are major cancer-causing agents (Kim, Kim, and Kumar, 2005).

Tin mining in Butura, Bokkos, experienced tremendous success in the early 1900s, brought about economic benefits, and made a substantial contribution to the global industrialization of nations. Tin has detrimental social and environmental repercussions despite its economic significance for the area, state, and nation as a whole. Because of the environmental contamination associated with tin mining, hazardous and chemical chemicals are released into the environment during mineral extraction and processing. The mineral comprises the minerals monazite, thorite, xenotime, and zircon (Heiner et al. 2012). Similar practices are employed to irrigate food crops in abandoned mining ponds. By increasing the concentration of heavy metals in the soil and increasing the likelihood that crops will absorb them, this approach could seriously endanger the health of consumers. However, it is crucial to examine the concentrations of heavy metals in edible vegetables such as Pepper, *Capsicum*, potato, *Solanum tuberosum and* cabbage and *Brassica oleracea* grown in the Bokkos LGA Plateau State. To achieve this goal, the following objectives were set to determine the concentrations of heavy metals, such as cadmium (Cd), cobalt (Co), nickel (Ni), lead (Pb), zinc, (Zn), copper (Cu), chromium (Cr), arsenic (As), and potassium (K), in irrigated pepper, potato and cabbage plants. However, the above chemicals were analyzed on irrigated vegetables in March 2024.

MATERIALS AND METHODS

The Bokkos LGA is located at an elevation of 1,324 meters above mean sea level, and its population is 264,100 (National Population Commission, 2022) (Figure 1). Due to the high altitude of the study area, it has a moderate temperature. The maximum temperature is approximately 22°C, while the mean minimum temperature is approximately 180°C (Wuyep, Dadiel, Ogbole, Selzing, and Monday, 2023). The study area has two seasons: the wet and the dry season. The wet season extends from April to October, and the dry season occurs during the Harmattan period, which is characterized by dry and dusty blowing from the Sahara Desert from November to March. The weather is generally cold, especially from July to August and from November to February. However, the relative humidity depends on the temperature, and a temperature increase leads to an increase in the quantity of water vapor in the atmosphere. The area has an average rainfall of 1458 mm annually (Wuyep, Jatau and Williams, 2022). According to Dung-Gwom, Gontul, Baklit, Galadima, and Gyang (2009), soils in the study area are ferruginous and characterized by textural clay and the subsurface horizon where they are formed over biotype granite or gneiss. The soil is moderate for its water holding capacity, intensely leached, and has a low organic matter content. Even if the soil is clay in nature, it has little fertility, which can be good for the production of crops. Agriculture is the main economic activity in the study area. A wide variety of crops are cultivated; these include Irish potatoes, tomatoes, carrots, cabbage and cucumber.

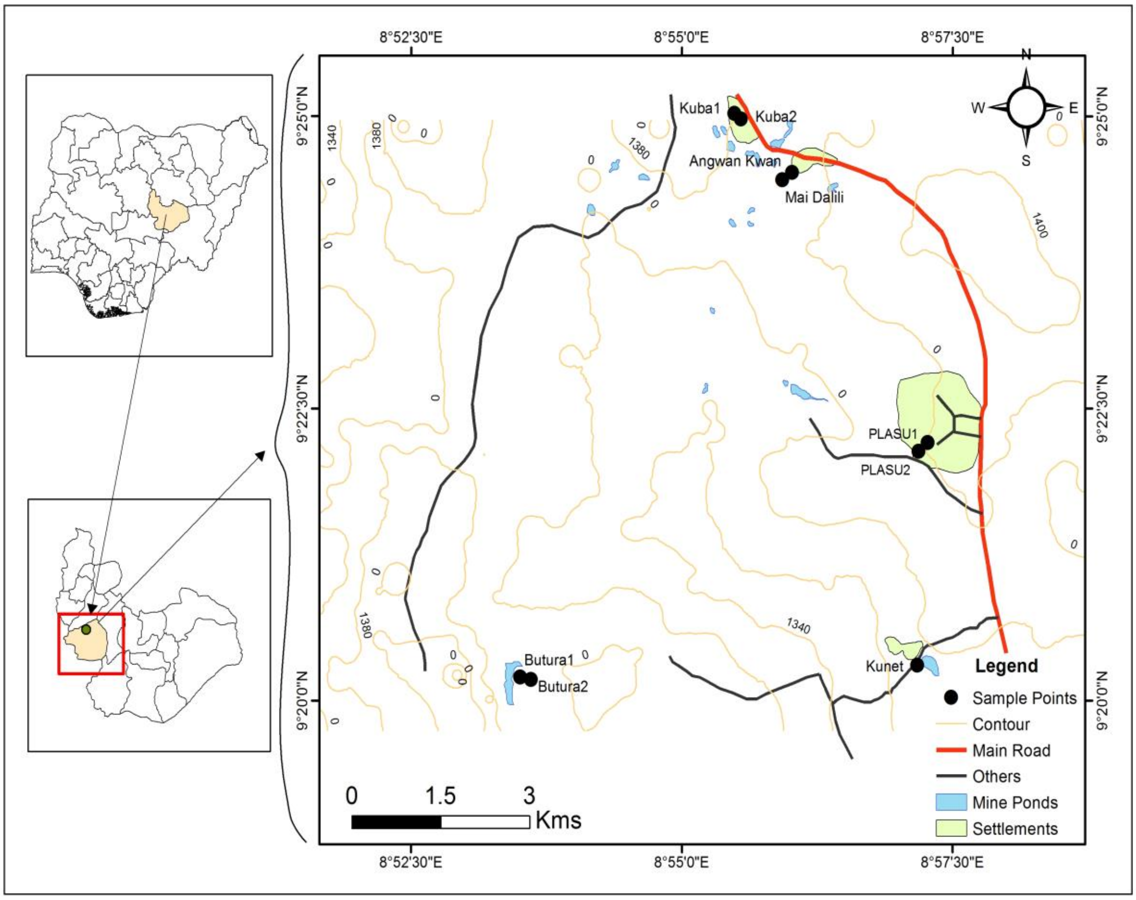

Figure 1: Nigeria showing Butura

Nine farms were selected randomly from the Butura district to analyze the concentrations of heavy metals, namely, cadmium (Cd), cobalt (Co), nickel (Ni), lead (Pb), zinc (Zn), copper (Cu), chromium (Cr), arsenic (As), and potassium (K), in edible vegetables (e.g., pepper, cabbage and Irish potatoes) considered for this study on irrigated land. Three samples were selected from each of the vegetables grown on a farm at distances of 0 m, 10 m, and 30 m. This approach afforded a composite sample of vegetables at each farm, as recommended by Tiwari, Singh, Patel, Tiwari, and Rai (2011).

Preparation of Vegetable Samples: Vegetable samples were transported to the laboratory and washed with distilled water to remove soil or mulch. Excess moisture was removed from the vegetables by air drying the samples. Thereafter, a porcelain mortar with a pestle was used to grind the sample, which was sifted through a sieve of 10 mesh.

Digestion Procedure: To analyze the concentration of heavy metals, approximately 1 g of each sample was separated and transferred to a Pyrex beaker. Ten (10) milliliters of a mixture of acids such as HNO_3, HCO_4, and H_2SO_4 at a ratio of 1:1:1 was added to the beaker and maintained in the laboratory for 24 hours. After the lag, the beaker was heated at 95°C using a hot plate until the volume was reduced to 10 ml. Again, 10 ml of the acid mixture was added until it reached 4 ml, and the mixture was heated. Subsequently, 50 ml of deionized water was added, and the digest was filtered. Finally, 100 ml of solution was made by adding double deionized water (Tiwari, et al., 2011).

The metal concentration was determined via an atomic absorption spectrophotometer (AAS). The samples were analyzed using an atomic absorption spectrophotometer (model: AA240FS). The parameters considered in Table 2 were compared to those of the World Health Organization (WHO) and Food and Agriculture Organization (FAO) standards. The geographic coordinates of the sampling points (Table 1) were recorded using a Global Positioning System (GPS) device (Garmin).

Table 1: Coordinate of Sample Collection Points

Location	Coordinate	Hight (m)
Butura 1	09.33691^{0}N 008.89108^0 E	1365
Butura 2	09.33657^0 N 008.89271^0 E	1368
Angwan Kwano	09.40888^{0}N 008.93291^{0}E	1364
Mai Dalili	09.40781^{0}N 008.93142^{0}E	1372
Kuba 1	09.41731^0 N 008.92402^{0}E	1384
Kuba 2	09.41650^{0}N 008.92503^0 E	1376
PLASU 1	09.37035 N 008.95378E	1395
PLASU 2	09.36909 N 008.95239E	1385
Kunet	09. 338596N 008.952160E	1374

RESULTS AND DISCUSSION

The physical and chemical characteristics of the soil as well as the plant's ability to absorb each metal determine the heavy metal concentration in these vegetables, which varies depending on numerous human and environmental factors. The results of the analysis in Table 2 show that the concentration of cadmium (Cd) ranged between 0.2 mg/kg and 1.6 mg/kg, with a mean value of 1.0 mg/kg. The FAO/WHO permissible limit for determining the cadmium concentration in vegetables is 0.1-1 mg/kg. The concentration of cadmium obtained was within the standard limit, indicating that the vegetables in the study area were not contaminated with cadmium. Islam et al. (2018) reported that the concentration of cadmium in vegetables growing at different sites in the city of Dhaka varied between 0.03 mg/kg and 0.32 mg/kg, which is considerably lower than that obtained in this study. Cadmium is an endocrine-disruption chemical (EDC) that is responsible for serious health problems, such as chronic renal failure, cancer, cardiac failure, osteoporosis (skeletal damage), destruction of red blood cells, kidney damage and cataract formation in the eye (Rehman, Fatima, Waheed, and Akash, 2018; Haque, Morshedul, Khirul, Alam, and Teraq, 2021; Zuhra et al., 2024).

Table 2: Concentration of Heavy Metals on Irrigated Vegetables

Parameters	Ungwan kwano cabbage	PLASU 1 Cabbage	PLASU 2 pepper	Mai Dalili pepper	Kunet	Kuba 1 potato	Kuba 2 potato	Butura 1 potatoe	Butura 2 cabbage	Mean	WHO/FAO
Cadmium (mg/kg)	1.1	1.2	1.3	1.4	1.1	1.6	0.6	0.2	0.5	1.0	0.1-1 mg/kg
Cobalt (mg/l)	0.5	0.4	0.8	0.9	0.5	0.7	0.5	0.9	0.7	0.7	0.1-1 mg/kg
Nickel (mg/l)	4.0	4.3	4.3	2.3	4.4	4.4	4.3	5.0	2.4	3.9	1-10 mg/kg
Lead (mg/l)	1.7	2.8	1.8	2.5	1.9	2.4	1.8	2.1	2.1	2.1	0.1-2 mg/kg
Zinc (mg/l)	28.0	104.0	79.0	101.0	29.0	45.0	100.0	39.0	32.0	61.9	50-100 mg/kg
Copper (mg/l)	19.0	5.0	16.0	12.0	3.0	27.0	22.0	9.0	16.0	14.3	5-20 mg/kg
Chromium (mg/l)	1.9	1.8	1.9	1.6	1.8	1.4	1.9	1.3	1.3	1.7	0.1-2 mg/kg
Arsenic (mg/l)	0.7	1.0	0.2	0.3	0.7	0.4	0.9	0.8	0.7	0.6	0.1-1 mg/kg

WHO/FAO, 2011

Similarly, the concentration of cobalt (Co) in the vegetable samples ranged from 0.4 mg/kg to 0.9 mg/kg (Table 2). The mean concentration of cobalt in all the analyzed vegetable samples was 0.65 mg/kg, which is within the allowable limit of 0.1-1 mg/kg suggested by the FAO/WHO. The cobalt concentration in all the vegetables in this study was greater than that given by Ahmad et al. (2018), which ranged from 0.02-0.22 mg/kg. Excessive intake of cobalt can result in the overproduction of red blood cells (Kalagbor Barisere, Barivule, Barile, and Bassey, 2014).

Considering the concentration of copper (Cu) in the study area, the highest concentration was 27 mg/kg, and the lowest was 3 mg/kg, as shown in Table 2. The mean copper concentration in all the analyzed vegetable samples was 14.3 mg/kg. This value is within the standard limit of 5-20 mg/kg given by the FAO/WHO. Copper is an essential nutrient required for numerous biochemical and physiological functions, and an insufficient amount of copper may result in the disruption of metalloenzyme incorporation and hemoglobin formation (WHO/FAO, 1996). However, a surplus quantity of copper has been associated with cellular and tissue damage and has numerous deleterious effects on human health (Taylor et al., 2020; Haque et al., 2021). Similarly, the mean concentration of nickel was 4.0 mg/kg, which is below the permissible limits of the FAO/WHO, indicating that there is no serious health concern associated with nickel in the consumption of vegetables from the study area.

Furthermore, the concentration of lead (Pb) varied between 1.7 mg/kg and 2.8 mg/kg, while the mean concentration of lead was 2.1 mg/kg (Table 2). The concentrations of lead in the vegetables were higher than the standard concentration limit of 0.1-2 mg/kg set by the FAO/WHO. This could be due to the use of contaminated irrigation water, farm soil or pesticides. The lead concentrations in this study are similar to those reported by Nimyel and Chundusu (2021) in Mangu, Nigeria; much lower than the values obtained by Mallik et al. (2017) in Kolkata, India; but higher than those documented by Latiff et al. Bilal, Asghar, Azeem and Ahmad (2018) in Dera Ghazi Khan District, Pakistan. Excess amounts of lead (Pb) in edible vegetables can pose severe risks to human health, such as neurological, hematological and behavioral problems (Kolawole et al., 2022).

The concentration of zinc (Zn) obtained ranged between 28 mg/kg and 104 mg/kg, with a mean value of 61.9 mg/kg. The zinc concentration was within the FAO/WHO permissible limit of 50-100 mg/kg (Table 2). Zinc, like copper, is also necessary in appropriate amounts for normal bodily functions, yet excessive zinc consumption can have harmful effects on human health (Chasapis, Ntoupa, Spiliopoulou, and Stefanidou, 2020; Duan et al., 2023). In this study, the chromium (Cr) concentration in the edible portions of the sampled vegetables varied from 1.3 mg/kg to 1.9 mg/kg, with a mean concentration of 1.7 mg/kg (Table 2); nevertheless, the concentration in all the vegetables sampled was below the permissible limit of 0.1-2.0 mg/kg set by the FAO/WHO (2012). In Ethiopia, similar findings of low chromium values were reported by Berihun Amare and Raju (2021); however, the chromium concentration was above the FAO/WHO maximum allowable limit, as documented by Gebeyehu and Bayissa (2020).

Additionally, the concentration of arsenic (As) in the vegetable samples ranged between 0.2 mg/kg and 1.0 mg/kg, with a mean value of 0.6 mg/kg (Table 2). Exposure to arsenic is of considerable concern due to its deleterious effects on human health, including on carcinoma; dermatological, neurological and neurobehavioral disorders; and hematologic disorders (leukopenia, anemia, and eosinophilia) (Joseph et al., 2015; Rahaman et al., 2022; Tchounwou, Udensi, Isokpehi, Yedjou, and Kumar, 2023; Lee & Davis, 2023). These values do not exceed the WHO guidelines; thus, consuming vegetables from these areas does not pose any health risk. In general, the concentration of lead in the sampled vegetables appeared to be greater than the standard limits, which may pose a serious health risk to the consumers of these vegetables. Conversely, the concentrations of cobalt, chromium, cadmium, copper, zinc, arsenic and nickel are within the maximum permissible limits established by the FAO/WHO since their concentrations are below the standard limits. Thus, no health risk is associated with the consumption of these heavy metals.

CONCLUSION AND RECOMMENDATIONS

The study showed that the concentrations of cobalt, chromium, cadmium, copper, arsenic, zinc and nickel were within the standard limits set by the FAO/WHO, except for lead, which is higher than the allowable limits for vegetables. These patients may have hematologic disorders, behavioral problems or neurological complications. Therefore, these findings indicate a significant risk for the human populace consuming these vegetables, which have high concentrations of lead, as well as for ruminants through the food chain. In general, the study concluded that the use of contaminated water from mining ponds for irrigation has resulted in high concentrations of heavy metals (lead) in farmlands and, consequently, vegetables growing there. To assess the potential risk of using vegetables grown in metal-contaminated soils or irrigation water, it is necessary to monitor agricultural soils and irrigation water to determine the presence of toxic metals accumulated by crop plants to ensure that crop plants are safe for consumption by humans.

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