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HEAVY METALS IN TOMATO, BELL PEPPER AND ONION PRODUCED UNDER THE KANO RIVER IRRIGATION PROJECT

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ABSTRACT

The presence of heavy metals (HMs) in food crops is an issue of public health significance, which is progressively evolving into a worldwide predicament. The continuous discharge of HMs into the environment through a range of anthropogenic practices and natural occurrences has raised concerns regarding food safety and human well-being. HMs exhibit substantial resistance and when they infiltrate the food chain, they establish a sustainable cycle within the food web. Samples of Tomato, Bell pepper and Onion were taken from 10 different locations across the irrigation scheme. Concentrations of Zn, Pb, Cd, Ni, Co, Cu, Cr and Hg were determined in Tomato, Bell pepper, Onion bulb and Onion leaf samples. The mean concentrations of Zn, Pb, Cd, Ni, Co, Cu, Cr in Tomato are 2.437, 0.869, 0.367, 1.325, 0.649, 2.090, 15.255 mg/kg respectively. Average concentrations of these HMs in Bell pepper are 3.713, 1.225, 0.361, 1.619, 0.382, 3.071, 9.279 mg/kg respectively. While in Onion bulb are 4.123, 0.878, 0.282, 2.438, 1.175, 5.848, 28.219 mg/kg respectively. Mean concentrations observed in Onion leaves are 3.697, 1.001, 0.716, 1.145, 1.017, 1.191, 10.993 mg/kg for Zn, Pb, Cd, Ni, Co, Cu, Cr respectively. The orders for HMs accumulations in vegetables are Cr>Zn>Cu>Ni>Pb>Co>Cd for Tomato and Bell pepper samples, Cr>Cu>Zn>Ni>Co>Pb>Cd for Onion bulb and Cr>Zn>Cu>Ni>Co>Pb>Cd for Onion leaves. Hg was not detected in all the vegetable samples. The mean concentrations for Zn, Cd and Cr exceeded permissible limits in all the vegetable samples.

Keywords: Heavy metals, vegetables, food contamination, food safety, human health

INTRODUCTION

The interconnection between food safety, human health, and environmental contamination is intimate (Rai et al., 2019). The challenge of food crop contamination by HMs poses a significant impediment to human well-being (Vatanpour et al., 2020; Zwolak et al., 2019). They are potentially deleterious substances characterized by their high persistence and non-biodegradability (Garrigues et al., 2019; Liao et al., 2016). The presence of these substances in food poses threat to human health (Massoud et al., 2019) and their subsequent ingestion can lead to their accumulation in various body organs (Ngure and Kinuthia, 2020).

Tomatoes, Bell peppers, and Onions are widely used vegetables in various culinary preparations. These vegetables can potentially be contaminated with heavy metals. Research has shown that these vegetables can absorb HMs from contaminated soil or by deposits on air-exposed parts from contaminated air (Bekele, 2021). The presence of heavy metals in vegetables can pose a risk to human health, especially if consumed in large quantities (Sirajo et al., 2023). Some studies have found that the concentration of heavy metals in vegetables, such as Tomatoes, lettuce, cabbage, and Onions, can exceed the recommended limits set by organizations like the World Health Organization and the Food and Agriculture Organization (Feseha et al., 2021; Jibrin et al., 2022). However, it is important to note that not all vegetables are equally affected, and the levels of heavy metals contamination can vary depending on the region and farming practices (Ara and Bhatti, 2015). Continuous monitoring of heavy metal levels in vegetables is necessary to ensure their safety for consumption.

Human activities account for the rise in HMs levels along the Hadejia-Jama'are River Basin (Bichi et al., 2016; Mustapha et al., 2014). The Tiga dam, which is the main source of irrigation, is also prone to contamination from the local mining activities going on in the neighbouring Doguwa local government. Ahmad (2018) reported population growth, pollution and water quality among the leading challenges facing the Kano River Irrigation project. Other sources of contamination are heavy traffic along the Kano-Zaria road (Anongo et al. 2015) and abuse of agrochemicals (Isah et al., 2020; Isah et al., 2021). The main objective of this research is to determine the concentrations of Zn, Pb, Cd, Ni, Co, Cu, Cr and Hg in Tomato, Bell pepper, Onion bulb and Onion leaf samples collected from ten (10) different locations across the irrigation scheme.

MATERIALS AND METHODS

Study Area

The Kano River Irrigation Project (KRIP) comprises of a total area of approximately 62,000 hectares. The primary water source utilized for irrigation purposes within the region is derived from the Tiga Dam and Ruwan Kanya Reservoir. The irrigation project is located about 30 km south of Kano City, encompassing both sides of the Kano-Zaria expressway.

Sampling Locations

Samples of Tomato, Bell pepper and Onion were collected from 10 different locations. Only the samples of edible portions were taken for Tomato, Bell pepper and Onion. The Onion was divided into bulbs and leaves. Tomato samples were collected from Kadawa, Kadawa (Gorau), Gafan, Kwalele, Cigyada, Raje, Kura (Kofar Kudu), Kura (Gorubawa), Imawa (Rimin Kwarya) and Imawa I. Bell pepper samples were collected from Barnawa, Shiye, Gorau, Yangajiri, Dorawar Sallau, Makunturi, Kura (Kofar Kudu),

Kura (Gorubawa), Imawa II (Rimin Kwarya) and Imawa I. Onion samples were obtained from Gafan I, Gafan II, Agalawa, Danmanzo, Dogon Bulo, Kukoki, Kura (Kofar Kudu), Kura (Gorubawa), Imawa (Rimin Kwarya) and Imawa I. Crops were harvested at their optimal maturity and samples were collected for determination of Zn, Pb, Cd, Ni, Co, Cu, Cr and Hg in the edible portions.

Sample preparation and HMs determination

Harvested crops were thoroughly washed using deionized water to remove surface dust and soil. Fresh tissues of Tomato, Bell pepper, Onion bulb and Onion leaf samples were digested using mixtures of acids: HNO_3:HCl (in ratio of 3:1). Twenty millilitres of the acid mixture were used for each 1 g of the sample. Each mixture was heated up to 100 ºC for 1 h on the heating digester. Then the acid digest was allowed to cool and filtered into 100 mL bottles, using Whatman filter paper and made up to mark with deionized water (Akinyele and Shokunbi, 2015). The concentrations of Zn, Pb, Cd, Ni, Co, Cu, Cr and Hg in the plant tissues were determined in triplicates using an Atomic Absorption Spectrophotometer (AAS) machine **(PerkinElmer PinAAcle 900H)** and results were reported as Mean±SD.

RESULTS AND DISCUSSION

Tomato

The values of Heavy metals contents (mg/kg) of Tomato samples collected across various locations along KRIP are presented in Table 1.

Results of Zinc (Zn) concentration in Tomato samples

Values for Zn in Tomato samples range from 1.353 – 8.780 mg/kg and the average value was 2.437 mg/kg. The values for different locations were significantly different from each other except for samples from Gafan and Imawa (R/Kwarya) and samples from Raje and Kura (K/Kudu). The highest concentration of Zinc (8.780 mg/kg) was obtained in samples from Imawa while the lowest concentration was obtained from Kura Goribawa. Generally, the mean concentration of Zinc has exceeded the WHO permissible limit.

Results of Lead (Pb) concentration in Tomato samples

The values for the concentration of Pb in the Tomato samples collected along KRIP ranged from 0.273 – 1.207 mg/kg and the average concentration was 0.89 mg/kg. Tomato samples from Gorau (KDW), Gafan, Kwalele, Raje, Kura Goibawa and Imawa were not significantly different from each other. Samples from Kadawa and Cigyada were also not significantly different. Kura (K/Kudu) and Imawa (K/Kwarya) Tomato samples were also not significantly different in the concentration of Lead. The highest lead concentration was obtained in Tomato samples from Kura Goribawa (1.207 mg/kg) while the lowest concentration (0.273mg/kg) was obtained in Tomato samples from Kura (K/Kudu). The values from Tomatoes were all within the WHO permissible limit.

Results of Cadmium (Cd) concentration in Tomato samples

The values for the concentration of Cadmium in Tomato samples along KRIP range from 0.300 to 0.413 mg/kg with a mean concentration of 0.367 mg/kg. The concentrations of Cd in Tomato samples obtained from Kadawa, Gorau KDW, Gafan, Kwalele, Cigyada, Raje and Kura Goribawa were not significantly different from each other. On the other hand, concentrations of Cd in Tomato samples obtained from Cigyada, Kura (K/Kudu) and Imawa were significantly different from each other. The highest Cd concentration (0.413 mg/kg) was obtained in the Tomato sample from Cigyada while the least was obtained in the sample from Imawa (R/Kwarya) all values exceeded the WHO permissible limit for Cd.

Results of Nickel (Ni) in Tomato samples

The concentration of Nickel in Tomato samples from different locations along KRIP ranges from 0.553 – 1.953 mg/kg and the mean concentration across the various locations was 1.325 mg/kg. The concentration of Ni in Tomato samples from Kadawa and Gorau (KDW) was not significantly different from each other as well as samples from Gafan, Kwalele and Imawa (R/Kwarya). All other samples were significantly different in Ni concentration. The highest Ni concentration in the Tomato sample was found in the sample from Imawa with 1.953 mg/kg, while the lowest Ni concentration of 0.553 mg/kg was found in the Tomato sample from Kura Goribawa. The concentrations of Ni in all Tomato samples across all locations were far below the WHO permissible limit of 10mg/kg.

Results of Cobalt (Co) concentration in Tomato samples

The concentration of Co in Tomato samples across the various locations along KRIP ranges from 0.453 – 0.887 mg/kg and the average content was 0.649 mg/kg. The concentration of Co in Tomato samples from Kadawa, Gorau KDW, Gafan, Kwalele, Raje, Kura Goribawa, Imawa (R/Kwarya) and Imawa were all not significantly different from each other. On the other hand, Co concentration in Tomato samples from Cigyada, Raje and Kura K/Kudu were significantly different from each other. The highest Co concentration was obtained in the Tomato sample from Kura K/Kudu (0.887 mg/kg) while the lowest concentration 0.453 mg/kg was found in the Tomato sample from Cigyada. All values obtained were far below the 50 mg/kg WHO permissible limit.

Results of Copper (Cu) concentration in Tomato samples

The concentration of Cu in Tomato samples obtained across the various locations along KRIP ranges from 0.767 to 4.253 mg/kg and the average content was 2.090 mg/kg. The concentration of Cu in Tomato samples obtained from Kadawa, Cigyada and Raje were not significantly different. On the other hand, the concentration of Cu in Tomato samples from Gorau KDW, Gafan, Kwalele, Kura K/Kudu, Kura Goribawa, Imawa (R/Kwarya) and Imawa were significantly different from each other. The highest concentration of Cu (4.253 mg/kg) was obtained in the Tomato sample from Kura Goribawa while the least Cu concentration was found in the Tomato sample from Gorau KDW. All values were below the 10 mg/kg WHO permissible limit for Cu.

Results of Chromium (Cr) concentration in Tomato samples

The concentration of Chromium in Tomatoes harvested across various locations along KRIP ranges from 2.883 to 31.447 mg/kg. The mean value was 15.255 mg/kg. The concentration of Cr in Tomato samples from Kura K/Kudu and Kwalele was not significantly different so samples from Raje and Cigyada. On the other hand, samples from Kadawa, Gorau KDW, Gafan, Kwalele, Kura Goribawa, Imawa (R/Kwarya) and Imawa differ significantly in Cr content in Tomato samples. The highest concentration of 31.447 mg/kg was obtained in the Tomato sample from Imawa (R/Kwarya) followed by Imawa while the lowest concentration (2.833 mg/kg) was found in the Kura Goribawa Tomato sample. The concentrations of Cr in all analyzed samples from all locations have far exceeded the WHO permissible limit of 1.3 mg/kg.

The Cd, Ni and Pb concentrations reported by Ahmed et al. (2022) in Market samples were below what was observed in this study. Sulaiman et al. (2019) reported lower concentrations of Ni, Cr, Pb and Cu in Tomato samples collected from Kwadon, Gombe State. Lower concentrations of Zn, Cu and Pb were also reported by Magaji et al. (2020) in samples collected from Kembu, Gombe State. Concentrations of Cu, Cd, Ni, Cr and Co reported by Ndinwa et al. (2014) were also below what was reported in this research. Market samples collected from Umuahia also contain lower concentrations of Cu, Zn, Pb, Cr and Ni when compared with the results of this research (Onwuka et al., 2019). Also, Cu and Cr concentrations were reported by Bassey et al. (2014) in Tomato samples grown in Asaba.

Higher concentrations of Cd, Pb, Zn, Ni, Cu and Co were reported in Tomato samples produced in Ekiti (Adefemi and Awokunmi, 2013). The concentrations of Cu, Co, Cr and Cr in this research are far above what was reported in canned Tomato samples collected from Umuahia (Uroko et al., 2019). Sulaiman et al. (2019) reported higher concentrations of Cd and Zn in Tomato samples produced in Gombe. Pb and Zn concentrations reported by Ndinwa et al (2014) in Tomato samples collected from Asaba also exceeded what was observed in this study. Also, the Pb, Ni and Zn concentrations were reported by Bassey et al. (2014).

Bell Pepper

The results of the heavy metal contents (mg/kg) in Bell Pepper samples grown and harvested across various locations along KRIP are presented in Table 2.

Results of Zinc (Zn) concentration in Bell Pepper samples

The concentration of Zn in Bell pepper in various locations across KRIP ranges from 1.460 – 9.200 mg/kg and the mean concentration was found to be 3.713 mg/kg. The concentrations of Zn were significantly different in Bell Pepper samples from Barnawa, Shiye, Gorau, Makuntiri, Kura K/Kudu, Imawa R/Kwarya and Imawa. On the other hand, concentrations in Pepper samples from Gorau, Yangajiri, D/Sallau and Kura Goribawa were not significantly different. The highest Zn concentration (9.200 mg/kg) was obtained in the Pepper sample from Imawa followed by Shiye while the lowest concentration (1.460 mg/kg) was found in the sample from Makuntiri. The concentration of Zn in all analysed samples far exceeded the 0.6 mg/kg WHO permissible limit

Results of Lead (Pb) concentration in Bell pepper samples

The concentration of lead in Bell pepper samples in locations across KRIP ranged from 0.887 – 1.493 mg/kg and the average concentration was found to be 1.225 mg/kg. Samples of Pepper from Barnawa, Shiye, Yangajiri and Makunturi were not significantly different in lead concentration, so also samples from Dorawar Sallau, Makuntiri, Kura K/Kudu, Kura Goribawa, Imawa R/Kwarya and Imawa. The highest lead concentration 1.493 mg/kg was found in Barnawa, followed by Shiye and Yangajiri. While the least 0.887 mg/kg was found in Gorau. The concentrations of lead in all analysed samples of Bell Pepper were within the WHO permissible limit of 2.0 mg/kg.

Results of Cadmium (Cd) concentration in Bell pepper samples

The concentration of Cd in Bell pepper samples grown and harvested in various locations along KRIP ranges from 0.287 – 0.400 and the average concentration is 0.361 mg/kg. Concentrations of Pb in Pepper samples from Barnawa, Shiye, Gorau and D/Sallau were not significantly different, so also samples from Yangajiri, D/Sallau, Makuntiri and Kura K/Kudu. On the other hand, concentrations of Pb significantly differ in pepper samples from Gorau, Yangajiri, Kura Goribawa and Imawa R/Kwarya. The highest Cd concentration of 0.400mg/kg was found in pepper samples from Shiye and Gorau while the lowest concentration of 0.287 mg/kg was found in samples from Imawa. All analysed Pepper samples have Cd concentration above the WHO permissible limit of 0.02 mg/kg.

Results of Nickel (Ni) concentration in Bell pepper samples

The concentration of Ni in pepper grown in various locations across KRIP ranges from 0.553 – 6.447 mg/kg while the mean concentration of Ni was 1.619 mg/kg. Bell pepper samples from Shiye, Gorau, Yangajiri, Kura K/Kudu, Imawa R/Kwarya and Imawa significantly differ in Ni concentration. No significant difference was observed in concentration at Ni in pepper samples from Barnawa, Yangajiri and D/Sallau. The highest concentration of Nickel in pepper was found in the sample from Shiye (6.447 mg/kg) while the lowest concentration of 0.553 mg/kg was found in the pepper sample from Kura K/Kudu. The concentration of Ni in all analysed pepper samples did not exceed the WHO permissible limit of 10 mg/kg.

Results of Cobalt (Co) concentration in Bell pepper samples

The concentration of Co in pepper samples grown and harvested from KRIP ranges from 0.140 – 0.727 mg/kg and the mean Co concentration stands at 0.382 mg/kg. Cobalt concentration in samples of pepper from Barnawa, Shiye, Yangajiri and D/Sallau differ significantly. On the other hand, the concentration of Cobalt did not differ significantly in pepper samples from Barnawa, Gorau, Kura K/Kudu and Imawa. The highest Co concentration (0.727 mg/kg) was found in the sample from Shiye while the lowest concentration (0.140mg/kg) was found in the pepper sample from Imawa R/Kwarya. Cobalt concentrations in all analysed samples were within the WHO permissible limit of 50mg/kg.

Results of Copper (Cu) concentration in Bell pepper samples

The range of concentration of Cu in pepper samples from various locations in KRIP was 0.293 – 11.347 mg/kg. The mean concentration was 3.071 mg/kg. Pepper samples from Barnawa, Shiye, Gorau, Makuntiri, Kura K/Kudu, Kura Goribawa, Imawa R/Kwarya and Imawa significantly differ from each other. No significant difference was observed in copper concentration in pepper samples from Gorau, Yangajiri, and D/Sallau. The highest Cu concentration (11.347 mg/kg) was found in pepper samples from Shiye while the lowest concentration of Cu was found in Makuntiri pepper. All the analysed samples except the Shiye sample were within the WHO permissible concentration of Cu.

Results of Chromium (Cr) concentration in Bell pepper samples

The concentrations of Cr in pepper samples grown and harvested from various locations across KRIP were in the range of 2.753 – 32.767 mg/kg and the average concentration stands at 9.279 mg/kg. No significant difference was observed in Cr concentration in pepper samples from Gorau, D/Sallau, Makuntiri, Kura K/Kudu and Kura Goribawa. On the other hand, there is a significant difference in Cr concentration in pepper samples from Barnawa, Shiye, Gorau, Yangajiri, and Imawa. The highest Cr concentration in pepper was found in Imawa (32.767 mg/kg) and the lowest was found in the Gorau

pepper sample. All analysed samples were above the 1.3 mg/kg WHO permissible limit.
Lower concentrations of Pb, Cd, Cu, Hg and Zn were reported by Makanjuola and Osinfade (2016) in Bell pepper commercial samples collected from Abeokuta, Ogun State. The concentrations of Cr, Ni, Cu and Zn reported by Antonious (2016) were also below what was observed in this research. Heavy metal contamination was reported to cause biochemical changes in Bell peppers (Reddy et al., 2016). Excessive HM contamination can reduce photosynthetic activities in Bell peppers (Stavreva-Veselinovska and Živanović, 2020)

Onion bulb
The results of the heavy metal contents (mg/kg) in Onion bulb samples grown and harvested across various locations along KRIP are presented in Table 3.

Results of Zinc (Zn) concentration in Onion Bulb samples
The concentration of Zn in the Onion bulbs grown in various locations along the KRIP ranges from 1.707 – 11.380 mg/kg and the average concentration stands at 4.123 mg/kg. The concentration of Zinc differs significantly in Agalawa, Dan Manzo, Dogon Bulo, Kikoki, Kura K/Kudu, Kura Goribawa, Imawa R/Kwarya and Imawa. On the other hand, no significant difference in zn concentration was found in bulbs from Gafan I and Gafan II. The highest concentration of Zn (11.380 mg/kg) was found in Agalawa while the lowest concentration (1.707 mg/kg) was found in Onions from Gafan I. The concentration of Zn in analysed Onion bulbs from all locations exceeded the WHO permissible limit of 0.6 mg/kg.

Results of Lead (Pb) concentration in Onion bulb samples
The concentration of Pb in Onion bulbs from various locations along KRIP was in the range of 0.400 – 1.473 mg/kg and the average concentration was 0.878 mg/kg. The Pb concentration in Onion bulbs from different locations differ significantly except for bulbs from Kura Goribawa and Imawa R/Kwarya. The highest Pb concentration in Onion bulbs was found in Dogon bulo followed by Agalawa while the lowest Pb concentration (0.400 mg/kg) was found in bulbs from Imawa R/Kwarya. The concentrations of Pb in analysed samples from all the locations were within the WHO permissible limit of 2.0mg/kg.

Results of Cadmium (Cd) concentration in Onion bulb samples
Cadmium concentrations in the Onion bulbs grown across various locations in KRIP range from 0.227 – 0.367 mg/kg. The mean concentration of Cd was 0.282 mg/kg. The concentrations of Cd in bulbs from Gafan II, Agalawa, Dogon Bulo, Kura and K/Kudu were significantly different from each other. On the other hand, no significant difference was observed in the Cd concentration in bulbs from Gafan I, Gafan II and Imawa. There is also no significant difference in concentration of Cd in bulbs from Agalawa, Dan Manzo, Kukoki, Imawa, R/Kwarya and Imawa I. The highest Cd concentration (0.367 mg/kg) was found in bulbs from Kura K/Kudu followed by samples from Dogon Bulo while the lowest concentration (0.227 mg/kg) was found in Bulb samples from Gafan II. The concentrations of Cd in all analysed Onion bulb samples from all locations have exceeded the WHO permissible limit for Cd in vegetables.

Results of Nickel (Ni) concentration in Onion bulb samples
The concentration of Ni in Onion bulbs grown in various locations along KRIP was in the range of 0.460 – 12.460 mg/kg and the average concentration was 2.438 mg/kg. The concentration of Ni in the bulbs from Dogon Bulo, Imawa I, Imawa R/Kwarya, Kura Goribawa, Kura K/Kudu and Dan Manzo significantly differ. There is no significant difference in Ni concentration in Onion bulb samples from Gafan I, Agalawa, Kukoki and Kura K/Kudu. The highest Ni concentration (12.460 mg/kg) was obtained in samples from Dogon Bulo while the lowest concentration (0.460 mg/kg) was obtained in bulbs from Dan Manzo. The concentration of Ni in Bulb samples from Dogon Bulo has exceeded the WHO permissible limit for Ni. The concentrations in all other samples were within the limit.

Results of Cobalt (Co) concentration in Onion bulb samples
The concentration of Cobalt in Onion bulb samples from various locations along KRIP was in the range of 0.887 – 2.073 mg/kg and the mean concentration was 1.175 mg/kg. The concentration of Co in Onion samples from Gafan II, Agalawa, Dan Manzo, Dogon Bulo and Kura Goribawa were significantly different while no significant difference was observed in Co concentration in samples from Gafan II, Kura K/Kudu and Imawa I. The highest Co concentration (2.073 mg/kg) was obtained in the Onion sample from Dogon Bulo while the lowest concentration was obtained in Bulb samples from Agalawa. The concentrations of Co in all samples analysed from various locations were within the WHO permissible limit.

Results of Copper (Cu) concentration in Onion Bulb samples
The concentration of Cu in Onion bulbs grown in various locations along the KRIP was in the range of 1.487 – 26.227 mg/kg and the mean concentration was 5.848 mg/kg. There is no significant difference in the Cu concentration in bulbs from Gafan I, Dan Manzo and Kukoki. The same was observed for Gafan II and Imawa I. All other concentrations were significantly different. The highest Cu concentration in Bulbs was observed in samples from Dogon Bulo while the least (1.487 mg/kg) was obtained in samples from Gafan I. All concentrations of Cu were within the permissible limit except samples from Dogon Bulo which is exceedingly high.

Results of Chromium (Cr) concentration in Onion bulb samples
The concentration of Cr in the Onion bulb samples obtained from various locations along the KRIP was in the range of 3.640 – 65.747 mg/kg and the mean concentration was 28.219 mg/kg. The concentration of Cr in Bulb samples from Gafan I, Gafan II, Agalawa, Dan Manzo, Kukoki, Kura K/Kudu, Kura Giribawa, and Imawa R/Kwarya were significantly different from each other while no significant difference in concentration of Cr was observed in samples from Dogon Bulo and Imawa I. The highest Cr concentration in the bulbs was obtained in samples from Imawa I and is closely followed by samples from Dogon Bulo and Imawa R/Kwarya. The lowest concentration was obtained in samples from Kukoki. The concentration of Cr in all analysed samples exceeded the WHO permissible limit of 1.3mg/kg. Four samples Imawa I, Dogon Bulo, Imawa R/Kwarya and Gafan II stand out as exceedingly far above the limit.

Onion leaf
The results of the heavy metal contents (mg/kg) in Onion leaf samples grown and harvested across various locations along KRIP are presented in Table 4.

Results of Zinc (Zn) concentration in Onion leaf samples
The concentrations of Zn in the Onion leaf grown across various locations along KRIP range from 2.660 – 4.847 mg/kg and the mean concentration stands at 3.697mg/kg. The concentration of Zn in the Onion leaf did not significantly differ in samples from Kukoki, Kura K/Kudu and Kura Goribawa, as also samples from Gafan I, Gafan II and Dan Manzo. Other samples differ significantly. The highest concentration of Zn in the samples was obtained in the sample from Kukoki closely followed by the sample from Kura Goribawa. The lowest concentration was found in the sample from Imawa I. All analysed samples have far exceeded the WHO permissible limit of 0.6 mg/kg.

Results of Lead (Pb) concentration in Onion leaf samples
The concentration of lead in Onion leaf grown along the KRIP was in the range of 0.560 – 1.280 mg/kg and the mean concentration was 1.001 mg/kg. The Pb concentration did not significantly differ in samples from Gafan I, Kukoki, Kura K/Kudu, Imawa R/Kwarya and Imawa I. Agalawa, Kukoki and Kura K/Kudu samples did not significantly differ. All other samples differ significantly. The highest concentration of Pb (1.280 mg/kg) was found in leaf samples from Dan Manzo while the least concentration of 0.56 mg/kg was found in the Kura Goribawa sample Pb concentrations in all analysed samples were within the WHO permissible limit of 2.0 mg/kg.

Results of Cadmium (Cd) concentration in Onion leaf samples
The concentration of Cd in the Onion leaf sample varies from 0.333 to 3.600 mg/kg and the mean concentration was 0.716 mg/kg. the concentration of Pb in samples differed significantly except for samples from Gafan I, Dan Manzo, Kukoki, Kura Goribawa and Imawa which did not differ significantly. The highest concentration of Cd was found in the sample from Gafan II while the lowest concentration was found in samples from Imawa R/Kwarya. The concentrations of Cd in all samples analysed have far exceeded the WHO permissible limit.

Results of Nickel (Ni) concentration in Onion leaf samples
The concentration of Ni in Onion leaf samples grown in various locations along the KRIP was in the range of 0.667 – 1.493 mg/kg and the average concentration stands at 1.145 mg/kg. The concentration of Ni in Gafan I, Gafan II, Dogon Bulo, Kukoki and Kura K/Kudu did not significantly differ from each other but the concentration of Ni in Gafan II, Agalawa, Dan Manzo and Imawa I differ significantly from each other. The highest Ni concentration in the samples (1.493 mg/kg) was obtained in the sample from Dogon Bulo followed by Kukoki while the lowest concentration (0.667 mg/kg) was obtained in samples from Imawa I. Ni concentrations in all analysed samples from the various locations were within the WHO permissible limit of 10mg/kg.

Results of Cobalt (Co) concentration in Onion leaf samples
The concentrations of Co in Onion leaf samples grown in various locations across the KRIP were in the range of 0.920 – 1.133mg/kg and the mean concentration stands at 1.017 mg/kg. The Co concentrations from Gafan I, Agalawa, Dan Manzo, Dogo Bulo, Kukoki, Imawa R/Kwarya and Imawa I did not significantly differ from each other. So also samples from Kura K/Kudu, Kura Goribawa, and Imawa I. Other samples differ significantly. The highest Co concentration (1.133 mg/kg) was found in Kura K/Kudu while the lowest Co concentration was obtained in samples from Gafan II. The concentrations of Co in all the analysed samples were within the permissible WHO limit of 50 mg/kg.

Results of Copper (Cu) concentration in Onion leaf samples
The concentration of Cu in the leaf samples from various locations in KRIP were in ranges 0.747 – 2.100 mg/kg and the average concentration was 1.191 mg/kg samples from Gafan I, Gafan II, Dan Manzo, Dogon Bulo and Kukoki did not differ significantly. On the other hand samples of leaves from Agalawa, Kura K/Kudu and Imawa differ significantly in Cu concentrations. The highest Cu concentration was obtained in Onion leaf samples from Kura K/Kudu while the lowest concentration (0.747 mg/kg) was obtained in samples from Agalawa. The concentrations of Cu in all analysed samples were within the WHO-permitted limit of 10mg/kg.

Results of Chromium (Cr) concentration in Onion leaf samples
The concentrations of Chromium in the Onion leaf samples from various locations in KRIP were within the range of 3.753 – 18.987 mg/kg and the mean concentration was 10.993 mg/kg. The concentration of Cr in samples of Gafan I and Gafan II did not differ significantly. So also, that of Agalawa and Kura Goribawa. The concentration of Cr in samples from Agalawa, Dan Manzo, Dogon Bulo, Kukoki, Kura K/Kudu, Imawa R/Kwarya and Imawa I differ significantly from each other. The highest Cr concentration in KRIP was found in samples from Kukoki which is closely followed by the sample from Dan Manzo. The lowest concentration (3.753 mg/kg) was found in samples from Imawa R/Kwarya concentrations of Cr in all analysed Onion leaf samples have far exceeded the WHO permitted limit of 1.3 mg/kg.
The concentrations of Cd, Pb and Cr reported by Karu et al. (2021) in Onion bulb samples collected from Danbam were far below what was observed in this research. Also, the Cd and Zn concentrations reported by Yaradua et al. (2020) in Onion samples collected from different Locations in Katsina State.

Table 1: Heavy Metals Contents (mg/kg) of Tomato Samples Collected from KRIP

Location	Zn	Pb	Cd	Ni	Co	Cu	Cr	Hg
Kadawa	$1.480^{f}\pm0.03$	$0.640^{b}\pm0.08$	$0.373^{ab}\pm0.01$	$0.853^{e}\pm0.05$	$0.567^{b}\pm0.03$	$0.960^{g}\pm0.03$	$6.020^{g}\pm0.33$	ND
Gorau KDW	$1.407^{g}\pm0.01$	$1.173^{a}\pm0.19$	$0.393^{ab}\pm0.02$	$0.893^{e}\pm0.06$	$0.693^{ab}\pm0.27$	$0.767^{h}\pm0.03$	$7.507^{f}\pm0.38$	ND
Gafan	$2.127^{b}\pm0.02$	$1.093^{a}\pm0.34$	$0.400^{a}\pm0.02$	$1.680^{b}\pm0.17$	$0.613^{b}\pm0.09$	$1.920^{e}\pm0.14$	$18.887^{d}\pm0.38$	ND
Kwalele	$1.767^{d}\pm0.01$	$1.053^{a}\pm0.48$	$0.387^{ab}\pm0.03$	$1.807^{ab}\pm0.10$	$0.713^{ab}\pm0.01$	$1.553^{f}\pm0.07$	$20.680^{c}\pm0.19$	ND
Cigyada	$1.600^{e}\pm0.02$	$0.760^{b}\pm0.04$	$0.413^{a}\pm0.01$	$1.393^{c}\pm0.06$	$0.453^{c}\pm0.03$	$1.080^{g}\pm0.02$	$10.907^{e}\pm0.18$	ND
Raje	$1.880^{c}\pm0.02$	$1.040^{a}\pm0.26$	$0.387^{ab}\pm0.02$	$1.153^{d}\pm0.17$	$0.567^{b}\pm0.01$	$1.113^{g}\pm0.05$	$10.760^{e}\pm0.47$	ND
Kura K/Kudu	$1.887^{c}\pm0.04$	$0.273^{c}\pm0.01$	$0.353^{b}\pm0.02$	$1.380^{c}\pm0.07$	$0.887^{a}\pm0.10$	$3.053^{c}\pm0.02$	$20.747^{c}\pm0.43$	ND
Kura Goribawa	$1.353^{g}\pm0.03$	$1.207^{a}\pm0.04$	$0.360^{ab}\pm0.03$	$0.553^{f}\pm0.09$	$0.627^{b}\pm0.03$	$4.253^{a}\pm0.06$	$2.833^{h}\pm0.34$	ND
Imawa (R/Kwarya)	$2.087^{b}\pm0.06$	$0.387^{c}\pm0.17$	$0.300^{c}\pm0.00$	$1.587^{b}\pm0.12$	$0.687^{ab}\pm0.11$	$3.560^{b}\pm0.11$	$31.447^{a}\pm0.43$	ND
Imawa	$8.780^{a}\pm0.07$	$1.060^{a}\pm0.25$	$0.307^{c}\pm0.01$	$1.953^{a}\pm0.06$	$0.680^{ab}\pm0.12$	$2.640^{d}\pm0.18$	$22.767^{b}\pm0.41$	ND
Range	**1.353-8.780**	**0.273-1.207**	**0.300-0.413**	**0.553-1.953**	**0.453-0.887**	**0.767-4.253**	**2.833-31.447**	
Mean Conc.	**2.437**	**0.869**	**0.367**	**1.325**	**0.649**	**2.090**	**15.255**	
WHO Permissible Limits	0.6^{*}	2.0^{*}	0.02^{*}	10^{*}	50^{**}	10^{*}	1.3^{*}	

*(Ogundele et al., 2015)
**(Chiroma et al., 2014)

Table 2: Heavy Metal Contents (mg/kg) of Bell Pepper Samples Collected from KRIP

Location	Zn	Pb	Cd	Ni	Co	Cu	Cr	Hg
Barnawa	$2.673^{d}\pm0.09$	$1.493^{a}\pm0.17$	$0.400^{a}\pm0.03$	$0.813^{de}\pm0.06$	$0.473^{b}\pm0.08$	$0.727^{f}\pm0.07$	$4.680^{c}\pm0.16$	ND
Shiye	$7.287^{b}\pm0.09$	$1.373^{ab}\pm0.20$	$0.400^{a}\pm0.02$	$6.447^{a}\pm0.20$	$0.727^{a}\pm0.01$	$11.347^{a}\pm0.22$	$30.987^{b}\pm0.72$	ND
Gorau	$1.860^{f}\pm0.02$	$0.887^{c}\pm0.01$	$0.400^{a}\pm0.02$	$0.687^{e}\pm0.08$	$0.487^{b}\pm0.03$	$0.547^{fg}\pm0.08$	$2.753^{d}\pm0.30$	ND
'Yangajiri	$2.007^{ef}\pm0.01$	$1.307^{ab}\pm0.33$	$0.373^{b}\pm0.01$	$0.940^{d}\pm0.06$	$0.367^{c}\pm0.03$	$0.500^{g}\pm0.02$	$4.733^{c}\pm0.39$	ND
D/ Sallau	$1.913^{f}\pm0.01$	$1.247^{b}\pm0.25$	$0.393^{ab}\pm0.01$	$0.800^{de}\pm0.05$	$0.187^{d}\pm0.01$	$0.600^{fg}\pm0.02$	$2.893^{d}\pm0.05$	ND
Makuntiri	$1.460^{g}\pm0.02$	$1.300^{ab}\pm0.14$	$0.360^{bc}\pm0.00$	$0.780^{e}\pm0.05$	$0.187^{d}\pm0.01$	$0.293^{h}\pm0.03$	$2.833^{d}\pm0.31$	ND
Kura K/Kudu	$2.027^{e}\pm0.03$	$1.200^{b}\pm0.28$	$0.360^{bc}\pm0.00$	$0.553^{f}\pm0.08$	$0.507^{b}\pm0.03$	$1.833^{e}\pm0.16$	$3.153^{d}\pm0.55$	ND
Kura Goribawa	$1.880^{f}\pm0.09$	$1.153^{b}\pm0.05$	$0.347^{c}\pm0.01$	$0.627^{e}\pm0.04$	$0.313^{c}\pm0.10$	$6.493^{b}\pm0.11$	$3.327^{d}\pm0.16$	ND
Imawa R/Kwarya	$6.820^{c}\pm0.03$	$1.253^{b}\pm0.18$	$0.287^{d}\pm0.03$	$2.013^{c}\pm0.10$	$0.140^{d}\pm0.02$	$2.987^{d}\pm0.03$	$4.667^{c}\pm0.32$	ND
Imawa	$9.200^{a}\pm0.07$	$1.040^{b}\pm0.06$	$0.287^{d}\pm0.03$	$2.533^{b}\pm0.14$	$0.433^{bc}\pm0.01$	$5.387^{c}\pm0.19$	$32.767^{a}\pm0.69$	ND
Range	**1.460-9.200**	**0.887-1.493**	**0.287-0.400**	**0.553-6.447**	**0.140-0.727**	**0.293-11.347**	**2.753-32.767**	
Mean Conc.	**3.713**	**1.225**	**0.361**	**1.619**	**0.382**	**3.071**	**9.279**	
WHO Permissible Limits	**0.6^{*}**	**2.0^{*}**	**0.02^{*}**	**10^{*}**	**50^{**}**	**10^{*}**	**1.3^{*}**	

*(Ogundele et al., 2015)
**(Chiroma et al., 2014)

Table 3: Heavy Metal Contents (mg/kg) of Onion (bulb) Samples Collected from KRIP

Location	Zn	Pb	Cd	Ni	Co	Cu	Cr	Hg
Gafan I	1.707^{i}±0.02	0.867^{de}±0.06	0.240^{cd}±0.03	0.700^{e}±0.05	0.913^{de}±0.06	1.487^{g}±0.05	7.433^{f}±0.42	ND
Gafan II	1.753^{i}±0.03	0.733^{f}±0.03	0.227^{d}±0.01	2.140^{c}±0.14	1.140^{c}±0.09	6.700^{b}±0.02	46.000^{c}±0.19	ND
Agalawa	11.380^{a}±0.03	1.280^{b}±0.06	0.287^{c}±0.01	0.713^{e}±0.06	0.887^{e}±0.04	2.627^{e}±0.06	8.547^{e}±0.09	ND
'Danmanzo	2.513^{g}±0.01	0.800^{e}±0.08	0.273^{c}±0.02	0.460^{f}±0.02	0.980^{d}±0.05	1.567^{g}±0.04	4.967^{h}±0.025	ND
Dogon Bulo	7.120^{b}±0.04	1.473^{a}±0.01	0.327^{b}±0.03	12.460^{a}±0.22	2.073^{a}±0.01	26.227^{a}±0.18	65.200^{a}±1.20	ND
Kukoki	2.700^{f}±0.08	0.900^{d}±0.00	0.280^{c}±0.03	0.853^{e}±0.05	0.980^{d}±0.03	1.493^{g}±0.01	3.640^{i}±0.30	ND
Kura K/Kudu	4.727^{c}±0.06	1.120^{c}±0.08	0.367^{a}±0.01	0.753^{e}±0.01	1.120^{c}±0.05	4.420^{d}±0.12	5.780^{g}±0.10	ND
Kura Goribawa	3.533^{d}±0.05	0.493^{g}±0.03	0.320^{b}±0.02	1.400^{d}±0.08	1.300^{b}±0.00	2.100^{f}±0.02	16.153^{d}±0.37	ND
Imawa R/Kwarya	3.447^{e}±0.04	0.400^{g}±0.08	0.260^{c}±0.04	2.240^{c}±0.06	1.273^{b}±0.01	5.167^{c}±0.11	58.727^{b}±0.24	ND
Imawa I	2.347^{h}±0.08	0.713^{f}±0.19	0.240^{cd}±0.02	2.660^{b}±0.02	1.080^{c}±0.02	6.693^{b}±0.02	65.747^{a}±0.25	ND
Range	**1.707-11.380**	**0.400-1.473**	**0.227-0.367**	**0.460-12.460**	**0.887-2.073**	**1.487-26.227**	**3.640-65.747**	
Mean Conc.	**4.123**	**0.878**	**0.282**	**2.438**	**1.175**	**5.848**	**28.219**	
WHO Permissible Limits	**0.6***	**2.0***	**0.02***	**10***	**50****	**10***	**1.3***	

*(Ogundele et al., 2015)
**(Chiroma et al., 2014)

Table 4: Heavy Metal Contents (mg/kg) of Onion leaf Samples Collected from KRIP

Location	Zn	Pb	Cd	Ni	Co	Cu	Cr	Hg
Gafan I	3.720^{b}±0.03	1.227^{ab}±0.06	0.380^{cd}±0.02	1.227^{ab}±0.02	0.953^{bc}±0.05	1.193^{bc}±0.08	12.107^{d}±0.10	ND
Gafan II	3.620^{b}±0.04	0.580^{e}±0.00	3.600^{a}±0.00	1.420^{a}±0.06	0.920^{c}±0.06	1.313^{b}±0.08	12.267^{d}±0.20	ND
Agalawa	2.773^{d}±0.02	0.973^{c}±0.11	0.440^{b}±0.03	0.880^{c}±0.16	1.013^{b}±0.06	0.747^{d}±0.09	5.867^{g}±0.45	ND
'Danmanzo	3.780^{b}±0.02	1.280^{a}±0.06	0.400^{c}±0.02	1.193^{b}±0.05	1.053^{b}±0.03	1.293^{b}±0.03	17.613^{b}±0.39	ND
Dogon Bulo	3.113^{c}±0.02	0.833^{d}±0.15	0.353^{d}±0.01	1.493^{a}±0.03	0.960^{bc}±0.04	1.367^{b}±0.07	15.000^{c}±0.34	ND
Kukoki	4.847^{a}±0.02	1.080^{bc}±0.00	0.400^{c}±0.02	1.440^{a}±0.09	0.987^{bc}±0.08	1.100^{bc}±0.02	18.987^{a}±0.12	ND
Kura K/Kudu	4.573^{a}±0.04	1.100^{bc}±0.07	0.453^{b}±0.01	1.400^{a}±0.20	1.133^{a}±0.08	2.100^{a}±0.02	11.080^{e}±0.39	ND
Kura Goribawa	4.627^{a}±0.03	0.560^{e}±0.06	0.393^{cd}±0.01	0.893^{c}±0.15	1.100^{a}±0.12	0.847^{d}±0.06	5.827^{g}±0.73	ND
Imawa R/Kwarya	3.260^{c}±0.02	1.160^{b}±0.04	0.333^{e}±0.02	0.833^{c}±0.09	0.987^{bc}±0.07	0.953^{c}±0.06	3.753^{h}±0.20	ND
Imawa I	2.660^{d}±0.02	1.220^{b}±0.08	0.407^{c}±0.02	0.667^{d}±0.09	1.067^{ab}±0.08	1.000^{c}±0.03	7.427^{f}±0.34	ND
Range	**2.660-4.847**	**0.560-1.280**	**0.333-3.600**	**0.667-1.493**	**0.920-1.133**	**0.747-2.100**	**3.753-18.987**	
Mean Conc.	**3.697**	**1.001**	**0.716**	**1.145**	**1.017**	**1.191**	**10.993**	
WHO Permissible Limits	**0.6***	**2.0***	**0.02***	**10***	**50****	**10***	**1.3***	

*(Ogundele et al., 2015)
**(Chiroma et al., 2014)

CONCLUSION

The orders for HMs accumulations are Cr>Zn>Cu>Ni>Pb>Co>Cd in Tomato and Bell pepper samples, Cr>Cu>Zn>Ni>Co>Pb>Cd in Onion bulb and Cr>Zn>Cu>Ni>Co>Pb>Cd in Onion leaves. Hg was not detected in all the samples collected during the period of the research. The mean concentrations for Zn, Cd and Cr exceeded permissible limits in all the vegetable samples.

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