

# Comparative Assessment of Cd, Cr, Cu and Fe Accumulation Potential in Mango (*Mangifera Indica*) and Guava (*Psidium Guavaja*) Fruits Obtained from Wawanrafi Dam Plantation and Kazaure Market in Kazaure Local Government Area of Jigawa State, Nigeria

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**Abstract:** The numerous activities carried out at Wawanrafi dam and farm site requires that a study of the aftermath of such activities be investigated. This study is aimed at determining the levels of heavy metals in some selected commonly consumed fruits (mango and guava) grown in the vicinity of the dam and in Kazaure market place. The levels of cadmium, copper, chromium and iron were determined in the edible and non-edible parts of mango, (*Mangifera indica*) and guava (*Psidium guavaja*) grown in Wawanrafi village and Kazaure market, Kazaure, Jigawa state Nigeria and in the soil where they are cultivated and the in the water used in irrigating the crops using atomic absorption spectrophotometric analysis, AAS techniques. The results revealed the heavy metal burden such as Cd, Cr, Cu and Fe in mango parts, seed, skin and pulp are in the range 0.2466 – 0.7500 $\mu\text{g/g}$ ; 0.1660 – 0.9000 $\mu\text{g/g}$  and 0.4333 – 2.2170 $\mu\text{g/g}$  respectively. The ranges of concentration of heavy metals in various parts of guava such as seed, skin and pulp are 0.2570 – 1.5300  $\mu\text{g/g}$ ; 0.2570 – 1.133 $\mu\text{g/g}$  and 0.3600 – 1.1770 $\mu\text{g/g}$ . The findings reported the following ranges for Kazaure market fruits samples parts viz a viz seed, skin and fleshy pulp: Kazaure market guava fruit sample, KMGFS, 0.0827 – 0.8340 $\mu\text{g/g}$ , 0.1960 – 0.6410 $\mu\text{g/g}$  & 0.2670 – 1.017 $\mu\text{g/g}$  and Kazaure market mango fruit sample, KMMFS, 0.0836 – 0.611 $\mu\text{g/g}$ , 0.0450 – 0.7460 $\mu\text{g/g}$  & 0.0853 – 0.726 $\mu\text{g/g}$ . The results also show that on the whole plant basis, guava concentrated more of Cd and Cu than mango, while mango has higher levels of Cr and Fe than guava. Chromium is least detected in the pulp of guava. It could be concluded that mango and guava obtained in Wawanrafi village contained the heavy metals in variable proportions due to different activities such as fertilizer application, irrigation with dam water, coupled with other human activities like fishing, washing of clothes, vehicles and motorcycles, tourism. The heavy metal levels were lower than the WHO maximum limit, hence the fruit crops are considered safe for consumption.

**Key words:** Fruits, Heavy metals, Accumulation, Market, Wawanrafi dam

## I. Introduction

Fruits harbor carbohydrates, proteins, vitamins, minerals and trace elements thus constituting a major part of human diet. The availability of biologically active ingredients such as antioxidants, antibacterial makes fruits to be effective in the treatment of numerous diseases (Grembecka & Szefer, 2013) Also fruits are made up of essential and non-essential elements, though some of these elements like lead, cadmium, mercury and nickel have hazardous effects that often cumulate in bodies of living creatures thus threatening their lives (Grembecka & Szefer, 2011). Advancement in technology has led to high levels of industrialization leading to the discharge of effluent containing heavy metals into our environment (Chata et al., 2018). In municipal sewage, the metallic contents are often absorbed on the sewage solids or sewage sludge when the sludge is disposed into farmlands; these metallic contents are taken up by plants in some amount. These amounts may have unpleasant effects on the vegetables, obtainable from such land as they may be rendered unsuitable for human consumption (Ogunkunle et al., 2014). Cadmium is one of the toxic metals with sterilizing, teratogenic and carcinogenic effects. It is an inhibitor of the enzymes with sulfhydryl groups that can disrupt the paths for oxidative metabolism and may lead to cardiovascular disease. Its toxicity affects brain, heart, blood vessels, kidneys and lungs. Department of Agriculture recommended a limit value of 0.01 mg/kg cadmium in fruits and vegetables (Kayika et al., 2017). However, chronic exposure to Cr(VI) compounds may lead to permanent eye injury or allergic contact dermatitis. According to IARC classification (IARC Monographs 2012), Cr(VI) and Ni are established human carcinogens. Also Cr(III) is required in trace amounts for sugar metabolism in humans (Grembecka & Szefer, 2011). Fe is a constituent of some enzymes like hemoglobin, myoglobin. Additionally, almost 30 percent of Fe is stored as ferritin and hemosiderin in the spleen, liver, bone marrow of human body. A meager quantity is present in blood transport protein transferrin

(Goldhaber, 2003). Conversely, excess Fe is causal factor of colorectal cancer while iron deficiency leads to anaemia with one third of the world population being affected (Abdel.Rahman & Abdellseid, 2013; Hassan et al., 2014). Copper is one of the important mineral elements required for crucial biochemical duties and the maintenance of human well-being (Yan et al., 2012; Hassan et al., 2014). Cu is equally a useful component of a number of metal enzymes aiding hemoglobin synthesis and catalysis of metabolic oxidation (Hassan et al., 2014). Cu is also utilized for the maintenance of a healthy nervous system, body pigmentation in addition to iron (Duran et al., 2007). The deficiency of Cu may results to gastrointestinal imbalances, bone demineralization and depressed growth, while, excess of the essential metal may give rise to dermatitis, liver cirrhosis, neurological disorders (Hassan et al., 2014). Heavy metals entering the body through inhalation of dust and consumption of food plants grown at metal contaminated soils, are harmful for the human body and its proper functioning (Jaishankar *et al.*, 2014). Due to industrial activities, metal contamination of soils may be widely spread in urban areas (Dangana et al., 2018). Wastewater effluents from industries and sewage system in cities and towns are sources of diverse pollutants, including heavy metals. Wastewater irrigation is known to contribute significantly to the heavy metal contamination of cultivated soils and the water bodies, nearby (Enukorah and Ozuah, 2018). These metals, gradually taken up by the plants grown at the wastewater irrigated fields, ultimately, enter the food material (Ismail *et al.*, 2005). A prolonged consumption of heavy metals-contaminated food, may lead to accumulation of these metals in the body organs, such as kidney and liver, causing a severe toxicity (Salhotra & Verma, 2017). In the report of Bugaje (2025) HMs like Fe, Zn, Pb, Co and Ni were determined in mango fruits sold in Katsina market. The need for the research stemmed from the un-checked usage of artificial ripening of fruits sold in Katsina markets. Similarly, Muhwezi and co-worker carried out the assessment of metals concentrations in Mango fruits grown in Kasese district Uganda (Muhwezi et al., 2021). Also Yap et al., (2020) used guava fruits as bio-monitor of HMs to assess health risk in Kluang Malaysia. Khalaf et al., (2024) studied the HMs contamination of soil and guava plants at Rosetta, Egypt. Domestic waste water discharged from the residential areas and industrial effluents may contaminate the nearby lake or river waters (Mbah and Mohammed, 2015), therefore, assessment of their pollutant level is necessary in the industrial waste water management and also for the safety of the public health.

Wawanrafi dam obtained its water from over flows from waste water from far and near-by residents, including various activities conducted at the dam site and rainwater from seasonal streams. The dam provides sources of water for domestic usages and few small-scale industrial processes. The dam water is also used for fishing and other agricultural purposes as well as recreation activities such as swimming. However, due to human activities around the dam, the water is contaminated. The sources of contamination may be direct and indirect disposal of refuse and sewage sludge, fertilizers and pesticides from irrigation sites or in flow of waste water from culverts. The significance of the present study is to unveil the extent of contamination of the dam via the use of the edible fruits like mango (*Mangifera indica L*) and guava (*Psidium guajava*) and water and soil in the vicinity of the dam. The outcome is also compared with obtainable results from the Kazaure market.

A great deal of research has been conducted on the determinations of heavy metal contents of fruits, but few experiments have been carried out to discover the most appropriate class of fruits cum parts of the fruit to be used in detecting heavy metal accumulation both in water bodies and in the atmosphere to support effective monitoring of environmental pollution especially in Kazaure Local Government Area of Jigawa State. The scope of the study is to determine the level of heavy metals, such as cadmium (Cd), chromium (Cr), copper (Cu), and iron (Fe) in Guava and Mango Fruits in Kazaure LGA with respect to samples obtained from Wawanrafi Dam and Kazaure market sites. Also the water and soil metal analysis will furnish us the source of contamination of fruit samples gotten from the dam.

## **II. Materials and Methods**

### **Reagents**

Chromium nitrate ( $\geq 99.9\%$ ), copper (II) nitrate (98%), ferrous sulphate (97%) and cadmium acetate ( $\geq 99\%$ ) used for the preparation of standards for atomic Absorption Spectroscopy (AAS) analysis were all obtained from Sigma-Aldrich (St. Louis, USA). Nitric acid (75%) and hydrochloric acid (65%) used for digestion were purchased from Fluka (Durban, South Africa). Hydrogen peroxide (99.8%) and sulphuric acid (95-97%) were bought from Friendemann Schmidt (Parkwood, Australia). Ammonium pyrrolidine dithiocarbamate methyl isobutyl ketone. Other chemicals are of qualitative analytical grade. Deionized water was used to prepare the aqueous solutions.

### **Equipment**

A digital balance used to accurately measure the weight of solids was supplied by A&D company (Tokyo Japan). An oven purchased from Thermo Fisher Scientific Company (Chicago, USA) is used for drying of glass wares and surface removal of water from samples. Atomic absorption spectrophotometer model 1100B Perkin Elmer (AAS) (Oregon, USA). All glass wares are washed with distilled water and oven dried and all plastic wares are washed with detergent, rinsed with distilled water and air dried in the laboratory. De-ionized water is used throughout the course of the experiment.

### **The study area**

The area of study is Kazaure local Government area of Jigawa state. Kazaure is geographically located at latitude  $11.00^{\circ}$  to  $13.00^{\circ}$  north and longitude  $8.00^{\circ}$  to  $10.35^{\circ}$  east and covers about 2.24100 hectares of land. The area is covered with non-marshy soil that favours agricultural practice. Kazaure is bounded to east by Amaryawa, south by Roni, west by Babura and north by Yankwashi.

Wawanrafi dam which is located at East of Kazaure occupies about one-third of the area covered by the town.

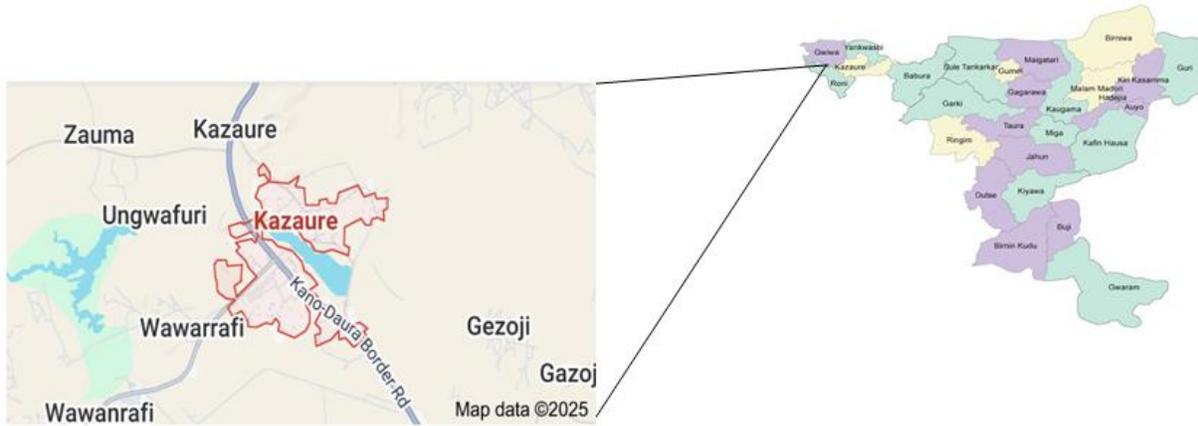


Fig.1 Map showing the sampling sites

**Sample Collection and Preparation**

The samples of mango and guava fruits were collected from Wawanrafi dam plantation and Kazaure open market. The samples were collected at random adopting simple random method of sampling from the three blocks of the Guava and Mango plantation. The fruits (Mango and Guava) were collected from different areas of each block and they were labeled as follows:

Sample A: Mango fruit (seed, skin and fleshy pulp) Sample B: Guava fruit (seed, skin and fleshy pulp). Each fruit was identified by a botanist from the Forestry Technology Department of the College of Agricultural Technology of Hussaini Adamu Federal Polytechnic Kazaure. These samples were washed thrice with detergent and distilled water and finally with de-ionized water to remove any solids attached to them. The samples were wiped with clean tissue paper, air dried and cut into small pieces with a stainless steel knife. The fruits were separated into skin, seed, and fleshy pulp. The samples were air dried and then grounded using mortar and pestle to obtain fine powder and stored in plastic containers, getting set for digestion stage.

Three plots from each block were identified for soil sampling. The soil samples so collected randomly from each of the plots at 0.25cm depth were pooled together to obtain a composite sample in accordance with the methods described by (Khairiah, *et al.*, 2006). The composite soil sample was passed through a 2mm sieve and air dried in the laboratory. The resulting sample was then stored on polythene bottle and then placed in desiccators at room temperature prior to analysis. Sterilized plastic containers were used to collect a litre of each dam water sample at different location as shown in the table below.

Table 1: Water sampling approach used in the present study

S/N	Sample	Description of sampling points
1	A	5 metres away from the fruit plantation
2	B	20 metres away from the fruit plantation
3	C	50 metres away from the fruit plantation
4	D	100 metres away from the fruit plantation

Samples for this analysis were preserved in the laboratory by the addition of 25ml concentrated nitric acid (HNO<sub>3</sub>) per litre of sample. This is to adjust the pH of the sample to below 2 and to retard adsorption.

**Extraction of Heavy Metals from fruit Plant Samples**

4.0g of the powdered sample was accurately weighed into a porcelain crucible dashed into a muffle furnace with temperature set to 450<sup>0</sup>C to heat the sample to constant weight. One gram of each heated sample was weighed into conical flask, then 10ml of HNO<sub>3</sub> was added followed by 3ml of HClO<sub>4</sub> (2:1) and then left for 3 hours in a water bath. Ten millilitres (10ml) of HCl was then added to dissolve inorganic salts and oxides. The digested samples were finally filtered through Watman filter paper into a labeled plastic container and made up to 50ml with distilled water. The digested samples were stored awaiting metals contents determination through AAS. (Khairiah, *et al.*, 2006)

**Extraction of Heavy Metals from Soil**

All experiments were carried out using analytical grade reagents. 5g portion of each of the air dried sieve soil sample were weighed and transferred into 100ml beakers and digested with 10ml portion of concentrated HCl:HNO<sub>3</sub> (3:1) mixture. The residue was cooled, diluted to 30ml with de-ionized water and filtered (Khairiah, *et al.*, 2006). Calibration standard were prepared from stock solutions by dilution and were matrix match with the acid concentration of the digested samples (Khairiah, *et al.*,

2006). The digested samples were then analyzed for heavy metal using Atomic Absorption Spectrophotometer (Abdallah *et al.*, 2011).

### Extraction of Heavy Metals from Water

To 100ml of each sample measured into 250ml separating funnel, 4ml of 5% ammonium pyrrolidine dithiocarbonate was added. This was followed by addition of 25ml methyl isobutyl ketone. The separating funnel was stopped and shaken manually for 6minutes after which the organic phase separated at the top while, the aqueous phase remained at the bottom and tapped off, leaving the organic phase in the funnel. The organic phase extracted was preserved for the determination of the metals. Heavy metals analysis was carried out using the method described by Ademoriti (1996). The metals Cu, Cd, Cr and Fe were determined using atomic absorption spectrophotometer at the wavelength of Cd (228.8nm), Cu (500nm), Cr (228.8nm) and Fe (248nm). The individual elements were read for each calibration curve. It is advisable to run a set of standard with each group of sample (Abdallah *et al.*, 2011).

### III. Results and Discussion

The results of the heavy metals content of fruit samples from both Wawanrafi dam and Kazaure Market as determined via AAS are presented in Tables 2 and 3. The concentration the heavy metals (HMs) in microgram per gram were read for each calibration curve for the individual elements. The permissible limits of these HMs were reported in Table 4.

#### Inter-location Studies (Intra-Fruit Analysis)

Table 2: Heavy metal loads in mango fruit parts from Wawanrafi dam and Kazaure market

Fruits	Wawanrafi Dam (Mango)			Kazaure Market (Mango)		
	Seed	Skin	Pulp	Seed	Skin	Pulp
Cd	0.7500±0.0100	0.900±0.1000	0.433±0.0577	0.247±0.1050	0.747±0.1150	0.357±0.1102
Cr	0.2470±0.1050	0.166±0.0151	0.175±0.0150	0.084±0.0090	0.045±0.0092	0.085±0.0087
Cu	0.7290±0.0900	0.801±0.0446	1.719±0.0952	0.611±0.0977	0.732±0.0951	0.726±0.1250
Fe	0.4420±0.0951	0.487±0.0901	2.217±0.2050	0.437±0.0729	0.153±0.0843	0.409±0.0500

#### Values are expressed in mean ± Standard error for three replicates (n=3)

The results for Cadmium ranged between 0.25–0.90mg/L values are between the permissible levels for human consumption going by Table 2. But Cadmium is very harmful to human being, causing high blood pressure and skeletal disease even at low concentration (Kayika *et al.*, 2017). The concentration of the Cadmium as reported in Table 2, revealed that the skin of mango in both the dam sample (0.900 µg/g) and market sample (0.747 µg/g) is higher than in the other fruit parts namely the seed and fleshy pulp. This implies that the skin of the mango from the dam concentrated more cadmium than that from the market while the reverse is the case for the fleshy pulp. The total level of cadmium in the Wawanrafi dam mango sample (WDMS) is 2.083µg/g while its corresponding level in the Kazaure market sample (KMMS) is 1.351µg/g based on the three parts of the fruit samples assayed from both locations. This implies that the WDMS concentrated more cadmium than KMMS. It could be deduced that the obtained average values for cadmium (WDMS = 0.694 µg/g, and KMMS = 0.450 µg/g) during these studies are not harmful but further analysis are needed before drawing a conclusive statement. The concentration of cadmium in mango sampled from both sites should not prevent the populace of Kazaure from consuming them because they are within the acceptable value for human consumption (see Table 4).

As shown in Table 2, the level of chromium metal is highest in the seed of WDMS (0.247µg/g) and least in the skin of KMMS (0.045µg/g) across the two site locations. The level of chromium in KMMS seed (0.084µg/g) almost equal that of the fleshy pulp (0.085µg/g). Considering, the accumulation of chromium in the parts of mango fruits from both locations under study, the Wawanrafi dam mango samples, WDMS (0.588 µg/g) accumulated more of the metal than the Kazaure market mango samples, KMMS (0.214 µg/g). This may be due to the application of excessive fertilizer, pesticides and fungicides during the planting of the mangoes around the dam. Interestingly, the average level of chromium estimated from Table 2 for WDMS (0.196 µg/g) is far above the permissible level while that of KMMS (0.071 µg/g) is below the recommended level. The high level of chromium observed in the WDMS may pose serious concern since the results are above the acceptable limits of 0.100µg/g (Table 4). The disparity in the results unveiled from these two sites may be attributed to the exposure of samples to various factors which include human (anthropogenic) and natural (topographic) factors.

The fleshy pulp of WDMS concentrated 1.719 µg/g of Copper, which is the highest concentration compared to the seed (0.729µg/g) and skin (0.801µg/g) from the same site. The skin of KMMS (0.732 µg/g) accumulated high level of copper slightly above the seed (0.611µg/g) and fleshy pulp (0.726µg/g) from the same location. The level of copper in KMMS skin and fleshy pulp almost approximated 0.730µg/g. Thus the range of the level of copper in the mangoes sample across the two sites is 0.611 – 1.719 µg/g. On the overall the mango samples from Wawanrafi dam (3.249µg/g) accumulated more of copper than the Kazaure market samples (2.069µg/g). The variation in the amount of copper reported may arise from the various anthropogenic activities

and chemicals used for planting the mangoes obtained from the dam site. The level of Cu in mango fruit reported in this study is higher than the mean value observed by Chata et al., (2018) in their study titled Determination of Heavy Metals in Four Mango Fruit Varieties Sold in Minna Modern Market, Niger State, Nigeria, where the Cu ranges from 0.09 – 0.20 µg/g.

The level of iron found in various parts of mango assayed across the two sites revealed a range of 0.153 – 2.217µg/g. Iron is highly accumulated in the fleshy pulp (2.217µg/g) of WDMS while is least in the skin (0.153µg/g) of KMMS across the two sites studied. However, the concentration of iron in the seed (0.442µg/g), skin (0.487µg/g) of WDMS and seed (0.437µg/g), fleshy pulp (0.409µg/g) of KMMS are not significantly differs among the parts of mangoes sampled from the two locations. The levels of iron in the seeds of both WDMS and KMMS approximated to 0.440µg/g. Summing up the amount of iron in the various parts of mango samples assayed from each site, the WDMS (3.146 µg/g) accumulated more iron than its KMMS (0.999 µg/g) counterpart. The mean values of iron level in WDMS (1.049µg/g) and KMMS (0.333µg/g) are lower than the permissible value (Table 4). Remarkably, iron from mango or any other fruit is an indicator of source of elemental nutrients needed for the physiological development of the human body. The concentration of Fe in this study agreed with values reported by Chata et al., (2018)

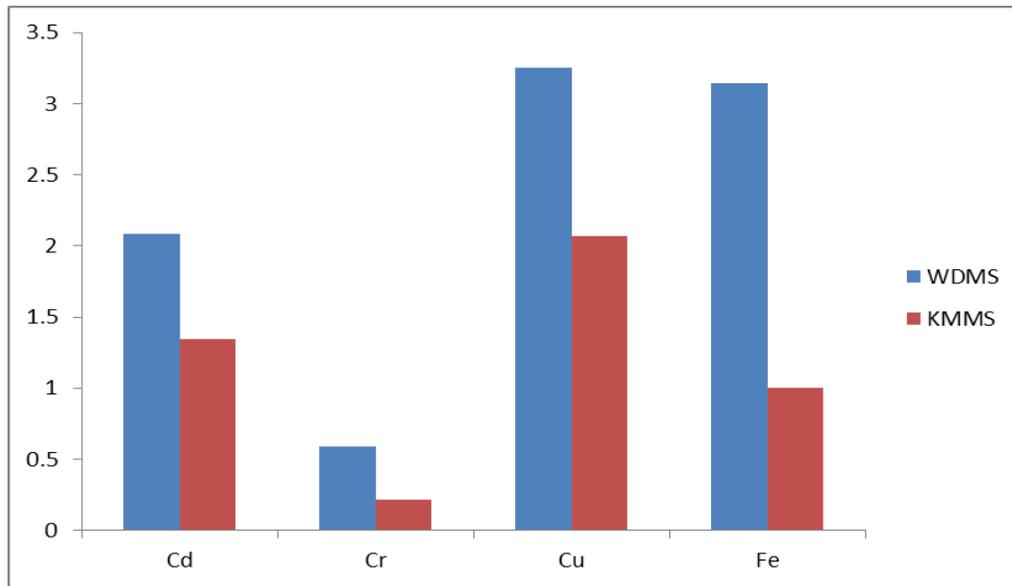


Fig. 2 Whole fruit HMs Concentration in mango samples from Wawanrafi dam (WDMS) and Kazaure market (KMMS)

Whole mango fruit analysis as displayed in Fig. 2 compare the accumulation potential of the mango samples from the dam (WDMS) to their counterparts from the market (KMMS) on an inter-location basis. The recorded values of the various metals in both sites are as follows, the whole mango fruit sample from Wawanrafi dam site accumulated Cd (2.083 µg/g), Cr (0.588 µg/g), Cu (3.249 µg/g) and Fe (3.146 µg/g) while the total mango fruit sample from the kazaure market concentrated Cd (1.348 µg/g), Cr (0.214 µg/g), Cu (2.069 µg/g) and Fe (0.999 µg/g). Based on metal analysis, the WDMS exhibited higher accumulation potential over the KMMSAs shown in Fig. 2 the mango samples from the dam displayed higher accumulation potential of HMs against the Kazaure market mango samples, on inter-location basis. As evident in Fig. 1, the WDMS gave higher level of all analyzed HMs over the KMMS counterparts. This may be due to the numerous man-made factors playing at the dam site such as agricultural practices which are obviously absent at the market site. This may be due to the location of the samples on the plantation unlike the market samples which had gone through many other processes such as harvesting, storage, transportation, preservation, etc prior to reaching the market place.

Table 3 Heavy Metal Loads in Guava Fruit parts from Wawanrafi Dam and Kazaure Market

Location/Fruits	Wawanrafi Dam (Guava)			Kazaure Market (Guava)		
	Seed	Skin	Fleshy pulp	Seed	Skin	Fleshy pulp
Cd	1.530 ±	1.133 ±	0.740 ±	0.750 ±	0.247 ±	0.643 ±
	0.1082	0.2754	0.1054	0.0900	0.1050	0.1150
Cr	0.257 ±	0.257 ±	0.250 ±	0.083 ±	0.196 ±	0.176 ±
	0.1002	0.0902	0.1152	0.0105	0.0641	0.0903
Cu	1.351 ±	0.841 ±	1.177 ±	0.834 ±	0.641 ±	1.017 ±
	0.1056	0.1052	0.1051	0.1050	0.1052	0.1258

Fe	0.540 ± 0.1016	0.481 ± 0.1000	0.360 ± 0.1015	0.333 ± 0.1005	0.335 ± 0.1145	0.267 ± 0.1050
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**Values are expressed in mean ± Standard error for three replicates (n=3)**

Heavy metal loads in various parts of guava fruit sampled across the two studied sites are presented in Table 3. All the analyzed HMs is present.

Cadmium metal is more concentrated in the seed (1.530µg/g) of Wawanrafi Dam Guava Sample, WDGS and is least concentrated in the skin (0.247µg/g) of Kazaure Market Guava Sample, KMGS across both sites studied. The level of cadmium is higher in the WDGS (3.403µg/g) compared to the KMGS (1.640µg/g) when the concentration in the whole fruit is combined. The same reason advanced for mango fruits may equally sufficed here as well.

The metallic load of chromium across the two sites revealed that the WDGS seed and skin (0.257µg/g) has the highest level of the metal while the KMGS seed (0.083µg/g) has the least level. The amount of chromium metal in the seed (0.257µg/g) and skin (0.257µg/g) of WDGS is the same. On a whole fruit basis, WDGS (0.764µg/g) concentrated more of chromium than its KMGS (0.455µg/g) counterpart. The load of Cr reported in this study is much higher than the value gave by AbdelKareem and co-workers in their study of essential and toxic HMs Status in some fruits from Turaba District (Saudi Arabia) (Abdelkareem et al., 2018)

The WDGS seed (1.351µg/g) accumulated the largest amount of copper metal while the KMGS skin (0.641µg/g) accumulated the least amount of the HM. The level of copper in WDGS skin and KMGS seed approximate to the same amount of 0.800µg/g. considering, the levels of copper in all the fruit parts assayed, the WDGS (3.369 µg/g) has a higher level than the KMGS (2.492µg/g).

The value of iron metal is highest in WDGS seed (0.540µg/g) and least in KMGS fleshy pulp (0.267µg/g). The accumulation potential of KMGS seed, skin and fleshy pulp approximate to 0.300µg/g. on the overall, the WDGS (1.381µg/g) accumulated more iron than KMGS (0.935µg/g) across the two sites.

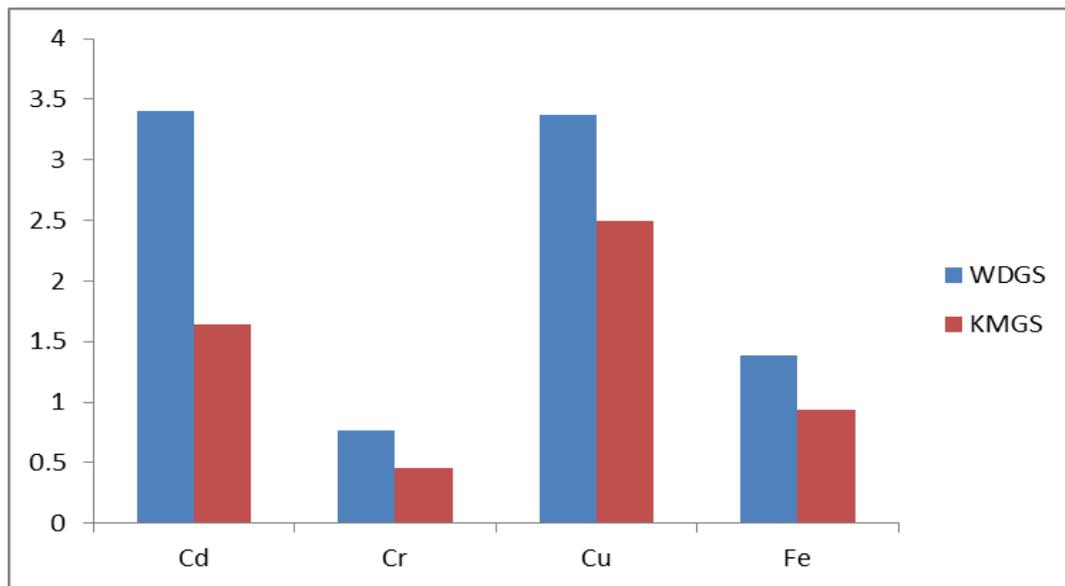


Fig. 3 Whole fruit HMs levels in Guava samples from Wawanrafi dam (WDGS) and Kazaure market (KMGS)

The dam samples revealed the following HMs levels Cd (3.403 µg/g), Cr (0.764 µg/g), Cu (3.369 µg/g) and Fe (1.381 µg/g) while the corresponding levels of HMs from the market samples are Cd (1.639 µg/g), Cr (0.455 µg/g), Cu (2.492 µg/g) and Fe (0.935 µg/g). As revealed in Fig. 3 the guava fruit samples from the dam exhibited higher accumulation potential towards HMs against the Kazaure market guava samples.

**Intra-location studies (Inter-Fruits Analysis)**

Considering inter-fruit analysis, Figures 4 and 5 relayed the results of the findings from the present study. The HMs burdens in the whole fruits of mango and guava from Kazaure market site are as follows: Cd, (KMMS = 1.348 µg/g ; KMGS = 1.639 µg/g) Cr (KMMS = 0.214 µg/g ; KMGS = 0.455 µg/g) Cu (KMMS = 2.069 µg/g; KMGS = 2.492 µg/g) and Fe (KMMS = 0.999 µg/g; KMGS = 0.935 µg/g). It is evident that the guava fruit concentrated more of Cd, Cr and Cu over the mango fruit samples in the kazaure market survey. However, the burden of iron in the mango fruit sample is slightly higher than that of guava from the same site. These results may suggest guava fruit as a better bio-accumulator of HMs or bio-indicator of environmental pollution emanating from HMs over its mango fruit counterpart in the studied areas.

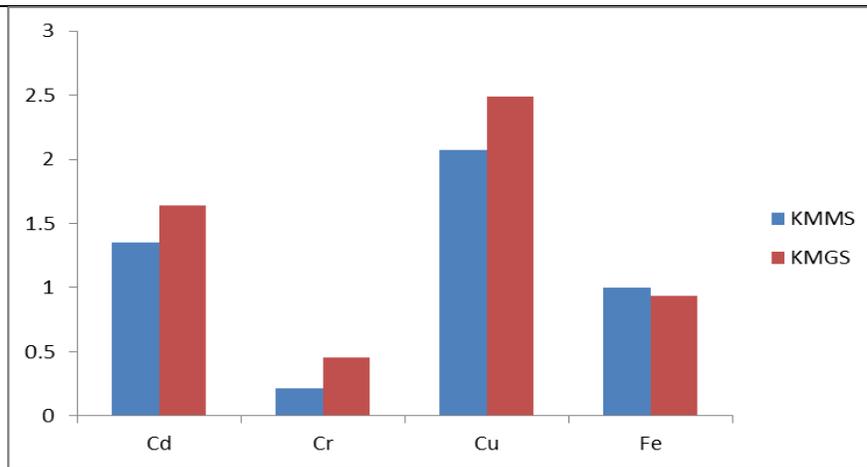


Fig. 4 HMs burdens in mango fruit samples and guava fruit samples from kazaure market location

The levels of HMs in the whole fruits of mango and guava from Wawanrafi dam site are as follows: Cd (WDMS = 2.083  $\mu\text{g/g}$ ; WDGS = 3.403  $\mu\text{g/g}$ ), Cr (WDMS = 0.588  $\mu\text{g/g}$  ; WDGS = 0.764  $\mu\text{g/g}$ ) Cu (WDMS = 3.249  $\mu\text{g/g}$ ; WDGS = 3.369  $\mu\text{g/g}$ ) and Fe (WDMS = 3.146  $\mu\text{g/g}$ ; WDGS = 1.381  $\mu\text{g/g}$ ). The results showed that the guava fruit samples accumulated more of cadmium, chromium and copper over the mango fruit samples from the same location. The only exception is iron whereby the mango fruit sample concentrated more of the metal over the guava fruit counterpart (Fig. 5).

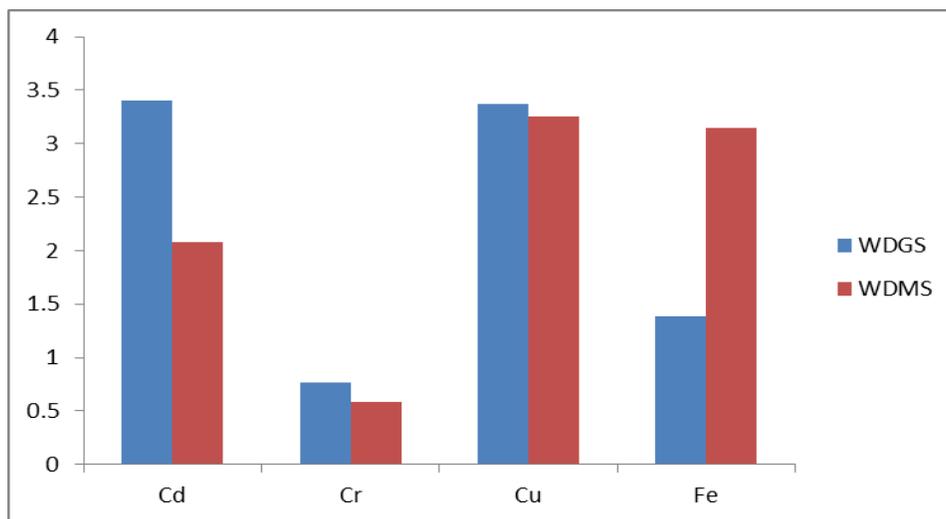


Fig. 5 HMs loads in mango fruit samples and guava fruit samples from Wawanrafi dam location

Metals detected in the both Guava and Mango plants were mainly plants nutrients namely iron and copper and these nutrients are require for optimal growth and various enzyme activities in the plants (Hopkin, 1999). Interestingly, iron is important for some enzyme activities is a constituent in chlorophyll and is involved in electron transfer in the photo system (Hopkin, 1999). Copper is an essential trace element required for proper health in an appropriate limit. Its high uptake in fruit can be harmful for human health and in the same way the lower uptake in human consumption can cause a number of symptoms, e.g. growth retardation, skin ailment, gastrointestinal disorder e.t.c. Copper is required as cofactor in difference oxidation and reductive enzymes. According to (Nair et al., 1997), the recommended limit for dietary consumption is up to 10ppm and average dietary daily requirement for copper is 1-3mg (Dara, 2004).

In general it can be stated that the Guava and Mango plants have a tendency to accumulate heavy metals which are important plants nutrients. Statistically, no significant correlation was observing between the amount of heavy metals in the soil, water and the fruits plants. This could be due to the ability of the fruit plants (Guava and Mango) to accumulate heavy metals. The uptake of these metals probably was via the transpiration system on the other land, these finding clarify that the heavy use of fertilizers and pesticides do not appear to cause an increase in the heavy metal content in the fruits plant at the plantation.

Heavy metals in soil samples occurred for a very wide range of concentration. The highest value of Cadmium was found in the soil whereas Chromium has the least value (Table 4). The concentration of heavy metals decreasing order were Cadmium> Copper>Iron> Chromium. Generally, the studied soil contained lower heavy metal concentration compared to other agricultural soil such as those found in Sepang, Bangi and Cameron highland (Ismail *et al.*, 2005). These finding suggest low heavy metal contents in marine alluvial soils.

Table 4: Heavy Metals Concentration in Soil and Water from Wawanrafi Dam Site

Samples	Selected Heavy Metals ( $\mu\text{g/g}$ )			
	Cadmium	Chromium	Copper	Iron
Water	1.00 $\pm$ 0.0300	0.167 $\pm$ 0.0085	0.727 $\pm$ 0.0110	0.407 $\pm$ 0.0015
Soil	0.50 $\pm$ 0.1000	0.167 $\pm$ 0.0105	0.455 $\pm$ 0.0120	0.259 $\pm$ 0.0030

Values are expressed in mean  $\pm$  Standard error for three replicates (n=3)

**Bioaccumulation factor (BAF) and Translocation factor (TF)**

The BAF and TF is calculated for Wawanrafi dam fruit samples, WDFS while only TF was estimated for Kazaure market fruit samples, KMFS as shown in Tables 5, 6 and 7.

According to Rezvani and Zaefarian (2011) in Adesuyi et al., (2018), bioaccumulation factor is the ratio of the concentration of a specific metal in a given plant part to the concentration of the same element in the soil where the plant germinated into whole full plant. Likewise, the translocation factor is the ratio of the burden of a given metal in named parts of a give plant.

The bioaccumulation factors for shoots (Fruits) (BAF) and the transfer factors (TF) have also been provided to further buttress the understanding of the accumulation potential of the named fruits (Table 5) on location basis. Bio-accumulation Factor (BAF) is used to quantify the

toxic heavy metal accumulation efficiency in plants by comparing the concentration in the plant part and an external medium (Adesuyi et al., 2018). BAF has been categorized as: <1 excluder, 1 – 10 accumulator and >10 hyperaccumulator (Jha *et al.*,2016)

Table 5: Bioaccumulation factor of Fruit samples from Wawanrafi Dam site

Heavy metals	WDGFS (Whole)	WDMFS (Whole)
Cd	6.8060	4.1666
Cr	4.5750	3.5204
Cu	7.4044	7.1407
Fe	5.3320	12.1467

The above results revealed that BAFs for both guava and mango fruits in Wawanrafi dam site are qualitative bioaccumulators of HMs with BAF far greater than unity (Table 5). Additionally, mango fruit is a hyperaccumulator of Fe going by the outcomes presented in Table 5, with BAF well above 10.

The capability of a plant to translocate metals from the roots to the shoots or within its parts is quantified with the aid of the translocation factor (TF), and TF greater than 1 (>1) implies that the plant readily translocate heavy metals from roots to the shoots or from one of its part to another (Rezvani and Zaefarian, 2011). Therefore, low accumulation of HMs in the roots with high TF indicates the adequacy of such plant for phytoextraction. When the transfer factor for the plants species becomes less than unity (<1), it suggests that metals are accumulated by these plants and were largely retained in the roots. Thus high accumulation of heavy metals in roots and low translocation in shoots may indicate appropriateness of a plant species for phytostabilisation (Archer and Caiwell, 2004). This partitioning mechanism is a common strategy of plants to concentrate hazardous ions in the roots in order to prevent migration of such toxic elements to the leaves where photosynthesis and other metabolic activities are scheduled to occur (Jha *et al.*, 2016)

The translocation factors of fruits samples from Wawanrafi Dam site is displayed in Table 6. The translocation factors are classified based on two mechanisms the root uptake and foliar uptake pathways. The root uptake mechanism for translocation factor is defined from seed to fleshy pulp to skin while the foliar uptake mechanism stressed the movement from skin to fleshy pulp to seed.

Table 6: Translocation factor of Wawanrafi Dam Fruits Samples

Heavy metals WDGFS (Root uptake)				
Parts of Fruit	Cd	Cr	Cu	Fe
C <sub>Skin</sub> /C <sub>Fleshy pulp</sub>	1.5311	1.0280	0.7145	1.3361
C <sub>Fleshy pulp</sub> /C <sub>Seed</sub>	0.4837	0.9727	0.8712	0.6666
C <sub>Skin</sub> /C <sub>Seed</sub>	0.7405	1.0000	0.6225	0.8907

WDGFS (Foliar uptake)				
C <sub>Seed</sub> /C <sub>Fleshy pulp</sub>	2.0674	1.0280	1.1478	1.5001
C <sub>Fleshy pulp</sub> /C <sub>Skin</sub>	0.6531	0.9727	1.3996	0.7484
C <sub>Seed</sub> /C <sub>Skin</sub>	1.3504	1.0000	1.6064	1.1227
WDMFS (Root uptake)				
C <sub>Skin</sub> /C <sub>Fleshy pulp</sub>	2.0785	0.9469	0.4660	0.2197
C <sub>Fleshy pulp</sub> /C <sub>Seed</sub>	0.5773	0.7109	2.3580	5.0158
C <sub>Skin</sub> /C <sub>Seed</sub>	1.2000	0.6732	1.0988	1.1018
WDMFS (Foliar uptake)				
C <sub>Seed</sub> /C <sub>Fleshy pulp</sub>	1.7322	1.4067	0.4241	0.1994
C <sub>Fleshy pulp</sub> /C <sub>Skin</sub>	0.4811	1.0561	2.1459	4.5517
C <sub>Seed</sub> /C <sub>Skin</sub>	0.8333	1.4854	0.9101	0.9076

The root uptake TF is greater than unity for Cd, Cr and Fe in skin-fleshy pulp and skin-seed of Wawanrafi dam guava fruit sample, WDGFS (Table 6), while others are below unity. The TF in fleshy pulp-seed is less than one for all the HMs suggesting the close relationship and intermediary status of its position in the guava fruit. Thus majority of the HMs may be said to reside in the seed of guava fruits. However, on approximation all are unity with exception of Cd in fleshy pulp-seed. This may implies that majority of the metallic ions are still capable of transiting within the studied parts of the guava fruits. The foliar uptake TF is more than one in the seed of WDGFS for all the selected HMs and for Cu only in fleshy pulp. The foliar uptake TF displayed more prominent values over the root uptake counterpart as shown in Table 6. This corroborates the root uptake TF reported value. On approximation all the values tend to unity, establishing the fact that most of ions of HMs concentrated in the seed of the guava fruits. The root uptake TF is above one for Cd in skin-fleshy pulp and skin-seed of Wawanrafi dam mango fruit sample, WDMFS (Table 6). Similarly, root uptake TF is greater than one in fleshy pulp-seed and skin-seed for Cu and Fe in WDMFS. This results imply that majority of the metallic ions are being transited to the skin of mango this is antithesis to the guava fruits observation. The TF for Cr is below unity across the skin-fleshy pulp, fleshy pulp-seed and skin-seed combinations as unveiled in Table 6. Majority of the foliar uptake TF are above unity for the WDMFS suggesting that most the metallic ions reside in the skin. Comparatively, the WDGFS may be said to exhibit phytostabilization while WDMFS expresses phytoextraction.

The root uptake TF > 1 for Cr across all the parts of Kazaure market guava fruits sample, KMGFS. It is also above one for Cu only in fleshy pulp-seed and Fe in skin-fleshy pulp and skin-seed of KMGFS (Table 7). The TF for Cd is below one across all the sampled parts of KMGFS. The reverse is the case for the foliar uptake TF. On approximation the TF for Cr, Cu and Fe are unity across all the parts of KMGFS while Cd is only presented in fleshy pulp-seed. This implies that Cd may tend to be more in the seed of the fruit than the skin. The root uptake TF is well above unity for Cd across all the KMMFS in contrast to the values observed in KMGFS. TF for Cu is well above unity across all the parts of fruit justifying its importance in the physiological activities of the plant. Fe recorded TF < 1 across all the parts of the fruit, while Cr recorded TF > 1 only in fleshy pulp-seed part of the fruit. These results depict slow translocation of Fe from seed to skin in the fruit. The foliar uptake TF presents the reciprocal outcome of the root uptake TF. On approximation, Cd, Cr and Cu are capable of motion across all the various parts of the KMMFS with exception of Fe. It may be summarized that the KMGFS is a potential phytostabilizer of Cd while KMMFS could phytostabilize Fe.

Table 7: Translocation factor of Kazaure Market Fruits Samples, KMFS

Heavy metals KMGFS (Root uptake)				
Parts of Fruit	Cd	Cr	Cu	Fe
C <sub>Skin</sub> /C <sub>Fleshy pulp</sub>	0.3826	1.1136	0.6303	1.2547
C <sub>Fleshy pulp</sub> /C <sub>Seed</sub>	0.8573	2.1282	1.2194	0.8018
C <sub>Skin</sub> /C <sub>Seed</sub>	0.3280	2.3700	0.7686	1.0060
KMGFS (Foliar uptake)				
C <sub>Seed</sub> /C <sub>Fleshy pulp</sub>	1.1665	0.4699	0.8201	1.2472
C <sub>Fleshy pulp</sub> /C <sub>Skin</sub>	2.6137	0.8980	1.5865	0.7970
C <sub>Seed</sub> /C <sub>Skin</sub>	3.0488	0.4219	1.3011	0.9940

KMMFS (Root uptake)				
C <sub>Skin</sub> /C <sub>Fleshy pulp</sub>	2.0955	0.5275	1.0083	0.3741
C <sub>Fleshy pulp</sub> /C <sub>Seed</sub>	1.4472	1.0203	1.1882	0.9359
C <sub>Skin</sub> /C <sub>Seed</sub>	3.0325	0.5383	1.1980	0.3501
KMMFS (Foliar uptake)				
C <sub>Seed</sub> /C <sub>Fleshy pulp</sub>	0.6910	0.9801	0.8416	1.0685
C <sub>Fleshy pulp</sub> /C <sub>Skin</sub>	0.4772	1.8957	0.9918	2.6731
C <sub>Seed</sub> /C <sub>Skin</sub>	0.3298	1.8577	0.8347	2.8563

### Comparing the results of the present study with other studies

Bugaje (2025) reported the following outcomes from his study of HMs in Mango fruits sold in Katsina markets; 0.570 µg/g of Fe against 0.80 (WHO), 0.510 µg/g of Zn against 0.320(WHO), 0.431 µg/g of Co against 0.05 (WHO), Pb not detected, and 0.106 µg/g of Ni against 1.40 (WHO). Iron is the only HMs that can be compared in this case. The level of Fe is higher in the present study than the value mentioned by Bugaje, (2025). This value difference may be attributed to the geographical locations of the mango fruits, the variety considered and the anthropogenic events around the study areas. The values of Fe in the present work are also above the WHO permissible limits. Muhwezi et al. (2021) revealed mean concentrations of Pb and Cr in the mango fruits as 0.32 ±0.08 µg/g and 0.4±0.07 µg/g respectively in Mango fruits grown in Kasese district Uganda. The level of Cr is almost in concordance with the value reported in this study for mango fruits in Kazaure market 0.455 µg/g but the value of Cr in mango fruits from Wawanrafi dam is higher (0.588 µg/g). This high value may be due to the fertilizer, pesticides and irrigation water used on the plantation dam. Yap et al., (2020) reported very elevated values of Cu (23.8 µg/g) and Fe (45.9 µg/g) in parts of Guava fruits used as bio-monitor of HMs in Malaysia. Those values were well above the levels of Cu and Fe determined in this work. The combination of topography and human activities play significant role in the levels of these metals accumulated in the guava fruits in Kluang, Malaysia and Kazaure, Nigeria.

### IV. Conclusion

The study indicate that heavy metals found in both Guava and Mango fruits were mostly nutrients which are require for plant growth and source of elemental nutrients for body physiological development. This is because the use of application of pesticides and fertilizer at this plantation was very low, following good management practices. Also, our findings revealed that both fruits from Wawanrfi dam sites are excellent bioaccumulators of Cd, Cr, Cu and Fe with the bioaccumulation factors well above unity. Moreso, mango fruit of the same site is a perfect hyperaccumulator of Fe with BAF well over 10. The Wawanrafi dam fruit samples displayed opposing characteristics, in that Wawanrafi dam guava fruits exhibit phytostabilization while its counterpart the mango fruits exhibit phytoextraction based on the reported translocation factors. The Kazaure market fruit samples portend a different observation. The KMGFS successfully phytostabilized Cd while KMMFS phytostabilized Fe. On the average most of the metallic ions studied are capable of movement with the parts of the fruits samples of guava and mango in both locations. Conclusively, the fruits contained lower levels of the HMs assayed thus may pose close to zero health threat to the consumers in Kazaure and its neighborhood. Besides both fruit plants are good bio-accumulators and bio-indicators of the heavy metals in the studied areas.

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