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COMPARATIVE ASSESSMENT OF SELECTED POTENTIALLY TOXIC METALS (PB, MN, NI, ZN, CD, AND CU) IN SELECTED VEGETABLES (CABBAGE AND LETTUCE), WATER AND SOIL SAMPLES FROM FARMS ALONG SOME IRRIGATION AREAS IN JIGAWA NORTH WEST SENETORIAL ZONE

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Abstracts

Small amounts of heavy metals are commonly found in our environment and diet, and they are actually necessary for good health. However, large amounts of heavy metals can cause acute or chronic toxicity. This is a concern because heavy metals can be harmful to humans and animals, and they have the potential to bioaccumulate in the food chain. In a study conducted in the Jigawa North West Senatorial Zone, the levels of selected potentially toxic metals (Pb, Mn, Ni, Zn, Cd, and Cu) were assessed in selected vegetables (cabbage and lettuce), water, and soil from farms along some irrigation areas. The samples were analyzed using an Agilent Technologies 200 series Atomic Absorption Spectrometer 240FS after being digested with a freshly prepared aqua regia. The results showed that the concentrations of zinc in both water, soil, and vegetables were below the allowable levels recommended by the World Health Organization (WHO), the United States Environmental Protection Agency (EPA), and the United States Food and Drug Administration (FDA). On the other hand, manganese concentrations in water, soil, and vegetables were also below the allowable levels recommended by the WHO. However, lead concentrations in water exceeded the allowable level set by the WHO, while the concentrations in soil and vegetables were within the recommended limits. For cadmium, the concentrations in both water and vegetables were below the allowable levels set by the WHO, while the concentration in soil was within the recommended limit. The values of copper in both soil and vegetables exceeded the allowable level set by the WHO. Finally, nickel concentrations in water were above the allowable level set by the WHO, while the concentrations in soil and vegetables were within the recommended limits. It is important to note that high concentrations of copper can be toxic to organisms and can negatively impact aquatic ecosystems. Additionally, nickel in soil can adversely affect plant growth and soil microbial diversity. The transfer factor of manganese and zinc in both lettuce and cabbage was categorized as low, indicating that the transfer of these metals from soil to plants is limited. On the other hand, the transfer factor of cadmium in lettuce and cabbage varied across different months, with some categorized as moderate.

Key Word: Heavy Metal Concentration, Environment, AAS, Vegetables and Bioaccumulation

INTROUCTION

The presence of heavy metals in our environment, including in air, water, and food sources, poses significant risks to human health. Heavy metals such as zinc (Zn), manganese (Mn), copper (Cu), cadmium (Cd), lead (Pb), and nickel (Ni) are naturally occurring elements that can also be released into the environment through industrial activities and human practices (). Vegetables cultivated on heavily toxic soil consume the heavy metals and store them in their tissues, causing detrimental health problems, including metabolic abnormalities in people who consume the vegetables since the body lacks a system to digest heavy metals (Arora *et al.,* 2008).

Research on seasonal variation in heavy metal accumulation on vegetables has indicated that there are notable fluctuations in metal concentrations throughout the year. These variations can be attributed to several factors, including meteorological conditions, agricultural practices, contamination sources, and plant characteristics. Study conducted by Li et al. (2019) demonstrated that the concentration of cadmium in leafy green vegetables showed significant seasonal fluctuations. The research highlighted that in the winter season, with low temperatures, reduced sunlight, and limited plant growth, the accumulation of cadmium was notably higher compared to other seasons. Conversely, during the summer season, with increased temperature and rainfall, the concentration of cadmium was relatively lower.

Another study by Wang et al. (2017) explored the seasonal variation of lead accumulation in common fruits and vegetables. The findings revealed that lead concentrations differed significantly across different seasons. It was observed that lead levels were higher during the dry season as compared to the wet season, which could be attributed to atmospheric deposition and irrigation water quality.

The transfer factor (TF) measures the movement of heavy metals between different environmental compartments. It quantifies the extent to which a metal is transferred from one compartment to another. For instance, in evaluating the transfer from soil to plants, the transfer factor reflects the concentration of a specific metal in the plants divided by its concentration in the soil. Grade limits for transfer factors differ based on the particular metal, the environmental compartments involved, and the associated ecological concerns. These limits ensure that the transfer process remains within acceptable ranges to prevent widespread contamination (Zeng et al., 2020).

According to Filipović-Trajković *et al.,* (2012), the concentrations of heavy metals in plants differ due to their differences in absorption and accumulation capacities. Similarly, Muamar *et al.,* (2014) revealed that, the main source of contamination of irrigation water is waste water from channel. Again studies have also shown the relationship between soil and contaminated water on the build-up of heavy metals in plants (Ernst, 1996).

Consequently, consumption of these heavy metal above recommended levels is reported to have been associated with several health problems such as diarrhea, cancer, fetal brain damage, kidney damages, renal disorder, liver damage and heart ailments (Kamunda *et al.,* 2016).

Zinc is an essential mineral required by the human body for normal growth and development, immune function, and enzyme activity. However, excessive exposure to high levels of zinc through occupational settings or contaminated water sources can lead to acute and chronic health effects. Inhalation of zinc oxide fumes or dust can cause respiratory irritation, while long-term exposure to elevated levels of zinc may result in neurological disorders, gastrointestinal disturbances, and impaired immune function (Tariba et al., 2021).

Manganese is necessary for several biological processes, including enzyme activation, bone development, and metabolism. However, chronic inhalation or ingestion of high levels of manganese can lead to neurological disorders, known as manganism, which resemble symptoms of Parkinson's disease. Occupations involving manganese exposure, such as welding or mining, are at higher risk. Long-term exposure to elevated manganese levels has been associated with impaired cognitive and motor skills (Fitsanakis and Au 2019).

Copper is an essential trace element required for various physiological processes, including iron metabolism and antioxidant defense mechanisms. However, excessive copper intake, often resulting from contaminated water or improperly formulated dietary supplements, can lead to gastrointestinal distress and liver damage. Genetic conditions that impair copper metabolism, such as Wilson's disease, can result in copper accumulation in vital organs and cause severe health complications (Reiser et al., 2020).

Cadmium is a highly toxic heavy metal commonly found in industrial settings and tobacco smoke. Human exposure to cadmium occurs primarily through inhalation or ingestion of contaminated air, food, or water. Long-term exposure to cadmium can lead to kidney damage, lung cancer, and skeletal problems. Additionally, cadmium has been associated with cardiovascular diseases and adverse reproductive outcomes, such as reduced fertility and developmental abnormalities in offspring (Tinkov et al., 2018).

Lead is a well-known toxic heavy metal that can cause serious health problems even at low levels of exposure. Lead exposure commonly occurs through contaminated drinking water, airborne particles in older buildings with lead-based paint, and certain occupations. Lead adversely affects the nervous system, leading to cognitive and behavioral disorders, especially in children. Additionally, chronic lead exposure can contribute to hypertension, renal dysfunction, and reproductive disorders (Bellinger 2019).

Nickel is a ubiquitous heavy metal found in various industrial processes and is associated with allergic contact dermatitis. Prolonged exposure to nickel compounds through inhalation or dermal contact can cause lung and nasal cancers. Furthermore, nickel has been linked to respiratory problems, cardiovascular diseases, and adverse effects on the immune system (Carpenter et al., 2019).

For that reason it is imperative to evaluate the level of these heavy metals in vegetables, irrigation water sources and agricultural soils in order to determine the variability in concentration level and translocation of the heavy metals between the various water sources, agricultural soil irrigated with the contaminated water and some selected vegetables on this soil. The study will be a novel investigation of the absorption capacity and transfer factor of potential toxic metals between selected vegetables in the study area.

Reagents and Methods

Reagent

All reagents used are of analytical grade and were used without further purification. They includes; Concentrated HNO_3 65 % Pure, Concentrated HCl 37 % Pure, Concentrated Perchloric Acid HClO 70-72% pure, Lead Nitrate $Pb(NO_3)_2$ 99% Pure, Zinc Oxide, (ZnO) 99.5% Pure, Anhydrous Cadmium Chloride ($CdCl_2$) 99.0% Pure, Copper Nitrate Tri-Hydrate, $Cu(NO_3)_2.3H_2O$ 98.0% Pure, Nickel Nitrate Hexa-Hydrate $Ni(NO_3)_2.6H_2O$ 99.0% Pure and Manganite Chloride Tetra Hydrate ($MnCl_2$) 99.0% Pure

Description of Study Area

The **Coordinate** of Kazaure local government fall between *12° 39′ 10″ N, and 8° 24′ 43″E, it* **covers** a land mass of about 690 sq mi or 1,780km^2 of land as in figure 1 a) and b). The general land form is undulating with sand dunes (Sagagi et al., 2022).

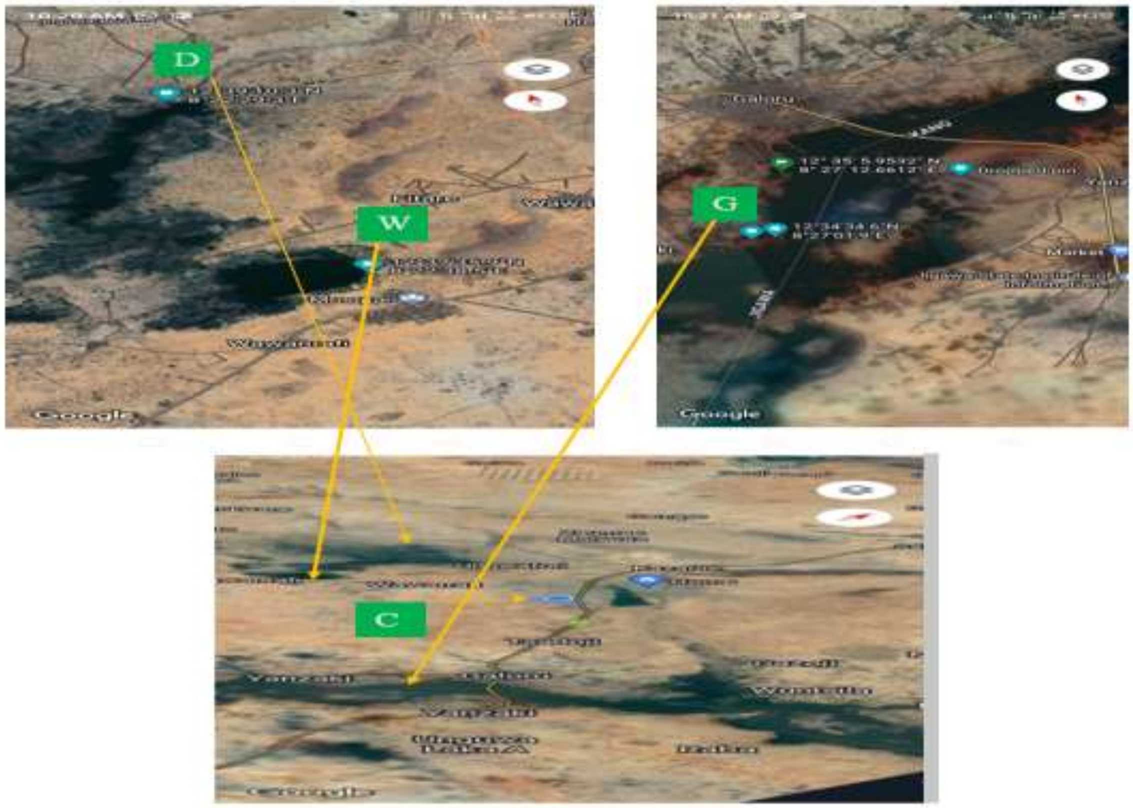

Figure 1: Google view of part of Jigawa showing Wawan Rafi (W), Dambo Dam (D), Gada River (G) and C= control site)

Plant, Soil and Water Sample collection

Leaves of the two of vegetables samples (Cabbage and Lettuce) were collected from Dambo Dam, Gada River banks and Wawan Rafi using random sampling techniques, and stored in a freezer to keep them in prime condition prior to analysis. For each of the sampled plants, the surrounding soils will be collected using Scoop or trowel as described in Onianwa and Fakayode, (2000). The coordinate location of each sampling site was read and recorded using Garmin GPS 60^{TM} Personal Navigator site. The soil samples were dried in an oven at 40 ºC for 24 h, ground with pestle and motor and sieved. A representative sample was obtained by coning and quartering techniques as described in Campos-M and Campos-C, (2017). The samples of each site was separately analysed.

Water samples were collected from various depth (0.5 m, 1.0 m, and 1.5 m) using modified Van Dorn sampler, then transfer to an amber coloured polythene bottles. The temperature and was read and recorded immediately and acidify with HNO_3 acid to stabilize the metals before being transported to the laboratory where the samples was filtered through Whatman No: 42 filter paper and stored in refrigerator at 4 °C as described in Campos-M and Campos-C, (2017).

Vegetables samples from each site was washed with distilled water and allowed to drain at room temperature. Then, the edible (vegetable) parts was chopped and dried in hot air oven at 60 °C for 48 h. Samples was ground into powder using pestle and motor as described in Egwu *et al.,* (2019), and was stored in a polythene bags for further analysis. The lettuce and cabbage control samples was planted in the Hussaini Adamu Polytechnic garden, which is located at *12^{O}.63'42"N, 8 ^{O}.42'14"E* on the globe. The control sample's soil, cabbage, and lettuce was collected using the same approach as the other samples, while the water use to irrigate the control was collected from borehole using a plastic bottle after it had ran for five minutes and was prepared the same manner as the other samples for the metal analysis.

Table 1. GPS reading of water sample collected from Gada River, Dambo Dam and Wawan Rafi between June and august 2023

Months	Water Sample ID	Depth(m)	Longitude and Latitude
June	G_{W1},G_{W2} and G_{W3}	0.5	Long:N12°355'.9532 Lat:E008°27'1206612
July	G_{W4},G_{W5} and G_{W6}	1.0	Long:N12°355'.9532 Lat:E008°27'1206612
August	G_{W7},G_{W8}, and G_{W9}	1.5	Long:N12°355'.9532 Lat:E008°27'1206612
June	D_{W1},D_{W2} and D_{W3}	0.5	Long:N12°39'10.3' Lat:E008°22'29.3
July	D_4,D_{W5} and D_{W6}	1.0	Long:N12°39'10.3' Lat:E008°22'29.3
August	D_{W7},D_{W8} and D_{W9}	1.5	Long:N12°39'10.3' Lat:E008°22'29.3
June	W_{W1},W_{W2} and W_{W3}	0.5	Long:N12 ° 37'35.9" Lat:E008 ° 22'23.5"
July	W_{W4},W_{W5} and W_{W6}	1.0	Long:N12 ° 37'35.9" Lat:E008 ° 22'23.5"
August	W_{W7},W_{W8} and W_{W9}	1.5	Long:N12 ° 37'35.9" Lat:E008 ° 22'23.5"

Key: G_W = Gada River, W_W = Wawan Rafi and D_W = Dam and Dambo water samples respectively.

2. Soil, Cabbage and Lettuce Samples collected from Dambo Dams (D), Gada River (G) and Wawan Rafi (W)

S/N	Sample I.D Soil	Cabbage	Lettuce	Longitude and Latitude
June	G_{S1},G_{S2} and G_{S3}	G_{C1},G_{C2} and G_{C3}	G_{L1},G_{L2} and G_{L3}	Lat: E008°27.126’ Long: N12°35.595’
July	G_{S4},G_{S5} and G_{S6}	G_{C4},G_{C5} and G_{C6}	G_{L4},G_{L5} and G_{L6}	Lat: E008°27.126’ Long: N12°35.595’
August	G_{S7},G_{S8} and G_{S9}	G_{C7},G_{C8} and G_{C9}	G_{L7},G_{L8} and G_{L9}	Lat: E008°27.126’ Long: N12°35.595’
June	W_{S1},W_{S2} and W_{S3}	W_{C1},W_{C2} and W_{C3}	W_{L1},W_{L2} and W_{L3}	Lat: E008°22.359’ Long: N12°37.839’
July	W_{S4},W_{S5} and W_{S6}	W_{C4},W_{C5} and W_{C6}	W_{c4},$W_{L5}$and W_{L6}	Lat: E008°22.359’ Long: N12°37.839’
August	W_{S7},W_{S8} and W_{S9}	W_{C7},W_{C8} and W_{C9}	W_{L7},W_{L8} and W_{L9}	Lat: E008°22.359’ Long: N12°37.839’
June	D_{S1},D_{S2} and D_{S3}	D_{C1},D_{C2} and D_{C3}	D_{L1},D_{L2} and D_{L3}	Lat: E008°22.293’ Long: N12°39.103’
July	D_{S4},D_{S5} and D_{S6}	D_{C4},D_{C5} and D_{C6}	D_{L4},D_{L5} and D_{L6}	Lat: E008°22.293’ Long: N12°39.103’
August	D_{S7},D_{S8} and D_{S9}	D_{C7},D_{C8} and D_{C9}	D_{L7},D_{L8} and D_{L9}	Lat: E008°22.293’ Long: N12°39.103’

Key: S, C, L are soil sample, Cabbage sample, and Lettuce sample respectively.

Sample Digestion

Digestion of Vegetable Samples

1 g each of the dried powdered vegetables (Cabbage and Lettuce) samples were weighed into separate porcelains crucible and dry ash in a muffle furnace at a temperature of 550 ºC for 2 hours. The ash samples were transferred in to separate 100 mL digestion tube and 9mL of freshly prepared a*qua regia*, was added and was make up to 50mL with distilled water. The mixture was allowed to boil gently over a hot plate (at 120 ºC) until close to dryness. Then cooled and filtered with Whatmann No.42 filter paper and diluted to 50 mL as describe in Uddin *et al.,* (2016) and Sagagi et al., (2022)

Digestion of Soil Samples

1g of each soil samples were placed in to 250 mL beakers and 20 ml of freshly prepared *aqua regia* was added and the mixtures was allowed to boil gently over a hot plate in fume hood chamber with periodic addition of 10 mL of concentrated nitric acid until the production of red nitrous oxide (NO_2) ceased. The samples was allowed to cool and 4 mL of 70 -72 % perchloric acid ($HClO_4$) was added and then heated until a clear solution is obtained. Then allowed to cooled, filtered and diluted to 50 mL as describe in Sagagi et al., (2022a).

Digestion of water Samples

50 mL of water samples each was measured into separate 100 mL digestion tube and 9 mL of freshly prepared *aqua regia* was added. Then, the mixture was allowed to boil gently over a hot plate until evaporated to 20mL. Then 5 mL of HNO_3 was added and allowed to continue boiling until a clear solution is obtained. The samples was filtered and diluted to 50 mL.

The metals (Pb, Mn, Ni, Zn, Cd, and Cu) in the digested aliquot of the samples and control was analysed by Agilent Technologist 200 series Atomic Absorption Spectroscopy 240FS and the concentration of each metals in water, soil and vegetables was calculated using the formula in Equation (1) and (2) respectively. The blank values was below the detection limits of the instrument.

$$metal(mg/L) = C\ X\ V_1/V_2 \quad - \quad - \quad - \quad - \quad - \quad - \qquad (1)$$

$$metal(mg/Kg) = C\ X\ V_1/M \quad - \quad - \quad - \quad - \quad - \quad - \qquad (2)$$

Where: C is the concentration in mg/L of the metal in the final extract

V_1 is the volume of the final extract (50 mL), and

V_2 is the volume of original sample in mL

M is the mass of original sample in grams (1 g) (Wang *et al.,* 2019)

Preparation of standards for the AAS Analysis

Standard stock solution (1000 mg/L) was prepared from metal compounds of Zinc, Manganese, cadmium, lead, copper and Nickel of high purity, where appropriate volumes was diluted to obtain the working standard solutions of various concentrations for the plotted calibration curves. Digested samples was then be analyzed for the metal content.

RESULT AND DISCUSSION

The Result of water temperature, water pH and potentially toxic metals (Pb, Mn, Ni, Zn, Cd, and Cu) analysed in water, soil, vegetables (cabbage and lettuce) and control sample, from farms along some irrigation areas of Kazaure are presented in the tables 3,4,5,6 and 7, while that of transfer factor is presented in table 8 respectively.

Table 3: pH and temperature of the water samples and the control between June and August 2023

Location	Months	pH	Min	Max	Temp ^{O}C	Min	Max
Gada River	June	7.37±0.09	7.31	7.50	28.83±0.47	28.50	29.50
	July.	7.91±0.01	7.90	7.92	28.50±0.41	28.00	29.00
	August.	7.50±0.08	7.40	7.60	28.52±0.02	28.50	28.55
Dambo Dam	June	7.45±0.06	7.37	7.50	27.17±0.47	26.50	27.50
	July.	7.77±0.04	7.72	7.80	27.50±0.41	27.00	28.00
	August.	7.62±0.13	7.50	7.80	27.83±0.24	27.50	28.00
Wawan Rafi	June	7.59±0.12	7.50	7.75	28.83±0.24	28.50	29.00
	July.	7.09±0.25	6.91	7.44	29.20±0.28	29.00	29.60
	August.	7.65±0.11	7.50	7.73	28.83±0.24	28.50	29.00
Control Sample		7.33±0.19	7.17	7.60	28.17±1.03	27.00	29.50

Table 4: Conc. of the potentially toxic Metals in Water Sample and the control (mg/L) between June and August 2023

Metals		Concentration of the potentially toxic Metals in Water Sample according to depth (mg/L)																	
Months	Sample location	Zn	Min	Max	Mn	Min	Max	Cd	Min	Max	Pb	Min	Max	Cu	Min	Max	Ni	Min	Max
June, 2023	Dambo Dam	0.030±0.016	0.008	0.045	0.382±0.001	0.328	0.410	-	-	-	0.008±0.008	-0.004	0.008	-	-	-	0.189±0.033	0.142	0.213
	Gada River	0.054±0.007	0.049	0.063	0.321±0.032	0.279	0.356	-	-	-	0.014±0.056	-0.053	0.056	-	-	-	0.159±0.009	0.146	0.168
	Wawan Rafi	0.011±0.002	0.008	0.013	0.312±0.199	0.153	0.593	0.003±0.001	-0.007	0.008	0.050±0.022	0.019	0.050	-	-	-	0.156±0028	0.124	0.192
July, 2023	Dambo Dam	0.019±0.002	0.017	0.022	0.308±0.080	0.199	0.386	-	-	-	0.060±0.023	0.023	0.080	-	-	-	0.163±0.057	0.086	0.220
	Gada River	0.062±0.009	0.050	0.072	0.399±0.027	0.367	0.434	-	-	-	0.079±0.008	0.008	0.088	-	-	-	0.328±0.324	0.036	0.780
	Wawan Rafi	0.023±0.008	0.017	0.035	0.196±0.068	0.147	0.292	-	-	-	0.069±0.003	0.003	0.070	-	-	-	0.075±0.057	0.033	0.156
August, 2023	Dambo Dam	0.014±0.001	0.012	0.015	0.325±0.014	0.316	0.345	-	-	-	0.058±0.013	0.013	0.058	-	-	-	0.084±0.022	0.067	0.115
	Gada River	0.052±0.008	0.043	0.063	0.491±0.024	0.460	0.519	-	-	-	0.082±0.065	0.065	0.173	-	-	-	0.107±0.025	0.076	0.137
	Wawan Rafi	0.021±0.008	0.016	0.032	0.248±0.019	0.228	0.273	-	-	-	0.015±0.006	0.006	0.015	-	-	-	0.094±0.004	0.091	0.099
Control	Sample	0.022±0.000	0.002	0.002	0.102±0.014	0.091	0.122	-	-	-	0.004±0.000	0.000	0.004	-	-	-	0.091±0.004	0.088	0.097

Key: (-) Metals below the detection limit.

Table 5: Conc. of the potentially toxic Metals in the Soil (mg/Kg) between June and august 2023

Metals		Concentration of the potentially toxic Metals in Soil Sample (mg/Kg)																	
Months	Sample location	Zn	Min	Max	Mn	Min	Max	Cd	Min	Max	Pb	Min	Max	Cu	Min	Max	Ni	Min	Max
June, 2023	Dambo Dam	0.641±0.016	0.625	0.663	6.022±0.941	5.196	7.095	0.008±0.009	-0.003	0.020	0.138±0.061	0.061	0.205	-	-	-	0.204±0.022	0.184	0.234
	Gada River	0.734±0.042	0.683	0.785	5.978±0.795	4.648	6.669	0.003±.005	-0.004	0.009	0.391±0.079	0.079	0.435	0.131±0.050	0.060	0.172	0.419±0.154	0.203	0.548
	Wawan Rafi	0.646±0.022	0.624	0.676	3.662±0.941	3.168	4.217	0.005±0.004	0.000	0.010	0.078±0.154	-0.127	0.154	-	-	-	0.257±0.051	0.193	0.317
July, 2023	Dambo Dam	0.710±0.015	0.691	0.727	4.591±1.541	3.832	5.475	0.016±0.009	0.007	0.028	0.449±0.073	0.073	0.449	-	-	-	0.192±0.067	0.103	0.266
	Gada River	0.614±0.015	0.601	0.635	6.335±0.677	4.917	8.477	-	-	-	0.522±0.117	0.117	0.590	0.147±0.040	0.096	0.192	0.155±0.028	0.118	0.186
	Wawan Rafi	0.599±0.046	0.536	0.644	3.467±0.007	3.051	3.876	0.01±0.016	-0.013	0.023	0.514±0.134	0.134	0.663	-	-	-	0.360±0.079	0.291	0.471
August, 2023	Dambo Dam	0.604±0.053	0.530	0.650	4.818±1.318	3.116	6.329	0.009±0.001	0.008	0.010	0.541±0.050	0.050	0.541	0.016±0.126	-0.158	0.139	0.259±0.103	0.114	0.343
	Gada River	0.715±0.020	0.701	0.743	5.675±0.888	4.420	6.313	0.009±0.003	0.003	0.011	0.207±0.123	0.123	0.472	-	-	-	0.166±0.052	0.126	0.240
	Wawan Rafi	0.624±0.021	0.601	0.651	4.518±1.235	3.004	6.029	0.009±0.005	0.003	0.014	0.207±0.040	0.040	0.477	0.077±0.101	-0.017	0.218	0.239±0.089	0.152	0.361
Control Sample		0.391±0.069	0.337	0.488	2.616±0.286	2.317	3.001	-	-	-	0.228±0.014	0.216	0.248	-	-	-	0.093±0.005	0.087	0.099

Key: (-) Metals below the detection limit.

Table 6: Conc. of the potentially toxic Metals in the Cabbage (mg/Kg) between June and august 2023

Metals		Concentration of the potentially toxic Metals in Cabbage Sample (mg/Kg)																	
Months	Sample location	Zn	Min	Max	Mn	Min	Max	Cd	Min	Max	Pb	Min	Max	Cu	Min	Max	Ni	Min	Max
June, 2023	Dambo Dam	0.249±0.059	0.191	0.330	0.375±0.112	0.292	0.534	0.009±0.004	0.004	0.014	0.273±0.067	0.067	0.273	-	-	-	0.253±0.061	0.192	0.337
	Gada River	0.383±0.033	0.347	0.427	0.313±0.114	0.166	0.443	0.005±0.003	0.000	0.008	0.349±0.042	0.042	0.349	0.056±0.012	0.041	0.070	0.199±0.028	0.172	0.238
	Wawan Rafi	0.207±0.103	0.134	0.352	0.372±0.059	0.298	0.443	0.002±0.001	0.002	0.003	0.250±0.049	0.049	0.317	-	-	-	0.240±0.035	0.211	0.289
July, 2023	Dambo Dam	0.207±0.103	0.134	0.352	0.571±0.141	0.417	0.758	0.002±0.00	0.002	0.002	0.681±0.128	0.128	0.821	0.013±0.004	0.036	0.046	0.242±0.040	0.192	0.291
	Gada River	0.249±0.059	0.191	0.330	0.312±0.073	0.209	0.367	0.002±0.001	0.001	0.003	0.913±0.068	0.068	1.002	-	-	-	0.120±0.036	0.089	0.171
	Wawan Rafi	0.154±0.032	0.128	0.200	0.409±0.192	0.257	0.679	-	-	-	0.747±0.117	0.117	0.793	-	-	-	0.148±0.052	0.110	0.221
August, 2023	Dambo Dam	0.13±0.005	0.123	0.135	0.516±0.127	0.341	0.642	0.005±0.002	0.002	0.007	0.358±0.088	0.088	0.358	-	-	-	0.215±0.064	0.161	0.305
	Gada River	0.19±0.079	0.134	0.302	0.469±0.178	0.241	0.677	0.002±0.001	0.000	0.004	0.670±0.107	0.107	0.670	-	-	-	0.124±0.056	0.068	0.200
	Wawan Rafi	0.163±0.017	0.150	0.188	0.291±0.148	0.127	0.485	0.001±0.00	0.000	0.001	0.358±0.088	0.088	0.358	-	-	-	0.149±0.036	0.107	0.194
Control Sample		0.096±0.005	0.090	0.101	0.122±0.000	0.122	0123	-	-	-	0.089±0.006	0.006	0.089	-	-	-	0.121±0.007	0.111	0.127

Key: (-) Metals below the detection limit.

Table 7: Average Conc. of the potentially toxic Metals in the lettuce (mg/Kg) between June and August 2023

Metals		Concentration of the potentially toxic Metals in Lettuce Sample (mg/Kg)																	
Months	Sample location	Zn	Min	Max	Mn	Min	Max	Cd	Min	Max	Pb	Min	Max	Cu	Min	Max	Ni	Min	Max
June, 2023	Dambo Dam	0.138±0.005	0.132	0.144	0.330±0.095	0.196	0.410	0.031±0.013	0.018	0.049	0.018±0.009	0.009	0.030	0.002±0.007	-0.003	0.011	0.182±0.079	0.123	0.293
	Gada River	0.428±0.047	0.387	0.494	0.446±0.376	0.135	0.975	0.008±0.003	0.004	0.010	0.049±0.020	0.020	0.060	0.044±0.016	0.025	0.064	0.222±0.073	0.138	0.316
	Wawan Rafi	0.269±0.064	0.216	0.358	1.844±0.182	1.586	1.975	0.016±0.012	0.002	0.031	0.103±0.033	0.033	0.135	-	-	-	0.203±0.016	0.183	0.223
July, 2023	Dambo Dam	0.309±0.049	0.243	0.361	0.538±0.137	0.345	0.645	0.023±0.011	0.008	0.033	0.071±0.006	0.006	0.071	-	-	-	0.143±0.045	0.109	0.207
	Gada River	0.476±0.100	0.401	0.617	0.674±0320	0.235	0.987	-	-	-	0.054±0.024	0.024	0.054	-	-	-	0.099±0.021	0.083	0.128
	Wawan Rafi	0.082±0.010	0.073	0.095	0.217±0.037	0.165	0.253	0.032±0.009	0.022	0.043	0.061±0.015	0.015	0.079	-	-	-	0.093±0.003	0.089	0.095
August, 2023	Dambo Dam	0.097±0.019	0.073	0.119	0.279±0.081	0.186	0.383	0.015±0.006	0.007	0.019	0.203±0.104	0.073	0.203	0.026±0.042	-0.026	0.076	0.129±0.015	0.118	0.149
	Gada River	0.454±0.045	0.389	0.487	2.018±1.941	0.332	4.737	0.004±0.001	0.002	0.005	0.197±0.055	0.055	0.197	-	-	-	0.073±0.004	0.070	0.078
	Wawan Rafi	0.247±0.027	0.221	0.284	1.121±0.504	0.762	1.834	0.004±0.006	-0.002	0.013	0.062±0.034	0.034	0.062	-	-	-	0.097±0.032	0.059	0.138
Control Sample		0.189±0.053	0.117	0.241	0.184±0.002	0.181	0.187	-	-	-	0.039±0.0.037	0.037	0.091	-	-	-	0.054±0.003	0.051	0.058

Key: (-) Metals below the detection limit

Table 8: Transfer Factor of the potentially toxic Metals in Cabbage Sample and the control between June and August 2023

Metals		Zn		Mn		Cd		Pb		Cu		Ni	
Months	Sample location	Cabbage	Lettuce	Cabbage	Lettuce	Cabbage	Lettuce	Cabbage	Lettuce	Cabbage	Lettuce	Cabbage	Lettuce
June, 2023	Dambo Dam	0.388	0.215	0.062	0.055	1.102	3.841	1.981	0.128	-	-	1.239	0.891
	Gada River	0.523	0.583	0.052	0.351	1.974	3.132	0.892	0.124	0.426	0.337	0.475	0.53
	Wawan Rafi	0.32	0.416	0.102	0.503	0.481	3.366	3.22	1.324	-	-	0.933	0.79
July, 2023	Dambo Dam	0.291	0.435	0.124	0.117	0.118	1.391	1.518	0.158	-	-	1.256	0.743
	Gada River	0.405	0.775	0.049	0.106	-	0.427	1.75	0.104	-	-	0.779	0.639
	Wawan Rafi	0.258	0.137	0.118	0.062	-	3.23	1.452	0.118	-	-	0.41	0.257
August, 2023	Dambo Dam	0.215	0.16	0.107	0.058	0.558	1.617	0.662	0.375	-	1.612	0.831	0.496
	Gada River	0.266	0.634	0.083	0.356	0.353	0.624	3.242	0.952	-	-	0.745	0.441
	Wawan Rafi	0.262	0.396	0.064	0.248	0.071	0.452	0.751	0.13	-	-	0.625	0.406
Control Sample		0.245	0.484	0.047	0.07	1	0	0.39	0.011	-	-	1.309	0.586

Key: (-) indicated that metal are not detected in soil or plant and therefore Transfer factor not calculated.

DISCUSSION

The water temperature of the water ranged between 27.17±0.47 to 29.20±0.28 which falls within the acceptable range. Higher temperatures can reduce the availability of soluble oxygen. The pH capacity of the water measured was observed to be weak acidic with mean pH ranged from 7.09±0.25 to 7.91±0.01. However, all pH values were within the WHO (2011) guideline range of 6.5-8.5.

The results of the assessment of selected potentially toxic metals (Pb, Mn, Ni, Zn, Cd, and Cu) in selected vegetables (cabbage and lettuce), water and soil samples from farms along some irrigation areas in Jigawa north west senatorial zone reveals that, Zinc concentrations in water sample varied between 0.021±0.008 to 0.062±0.009 mg/L, with the highest observed in Gada sample of July and the Lest in Wawan Rafi Sample in August. The control sample had Zn concentration of 0.022±0.000 mg/L. Zinc concentration in Soil varied between 0.599±0.046 mg/kg in July and 0.715±0.020 in August. The highest value was found in Gada Soil sample while Wawan Rafi sample had the least concentration which was also higher that 0.391±0.069 mg/Kg in the control. Also, in Cabbage Zinc concentration ranged between 0.13±0.005 and 0.383±0.033 mg/kg observed in June and August sample of Dambo and Gada respectively, with control Sample having 0.096±0.005 mg/kg which is lower than the highest value obtained in Wawan Rafi in the month of June. Lettuce had Zn level between 0.082±0.010 to 0.476±0.100 mg/kg allin June samples of Wawan Rafi and Gada Respectively. The lettuce control sample had 0.189±0.053mg/kg of Zn which is lower than the lowest value obtained in Dambo sample (0.097±0.019mg/kg). All the values of Zn in both water, Soil and vegetable are below the WHO-recommended allowable level of 10 mg/L for water by (WHO, 2011), 300 mg/kg in soil (United States Environmental Protection Agency (USEPA), 2005), and 2 mg/kg (United States Food and Drug Administration (FDA), 2021) for vegetables. Zinc, being an essential micronutrient for plants and animals, is generally not considered toxic at low concentrations. However, high concentrations of zinc have been shown to inhibit plant growth and reduce crop yields, ultimately affecting food production (Li Y, et al., 2021). Additionally, excessive zinc levels can disturb aquatic ecosystems by reducing species richness and altering the composition of microbial communities.

Manganese (Mn) concentrations in water samples varied between 0.196±0.068 to 0.491±0.024 mg/L, with the highest observed in Gada sample of August and the least in Wawan Rafi Sample in July. The control sample had Mn concentration of 0.102±0.014 mg/L. in Dambo sample, the highest value was 0.382±0.001mg/L observed in June. Mn concentration in Soil varied between 3.467±0.007 and 6.335±0.677 mg/kg in July Wawan Rafi and Gada Sample respectively. Dambo soil had the highest concentration observed in June with 6.022±0.941 mg/Kg while the control sample had 2.616±0.286 mg/Kg. Furthermore, in Cabbage, highest Mn concentration are 0.571±0.141 mg/kg Dambo, 0.409±0.192mg/kg Wawan Rafi and 0.469±0.178mg/kg Gada observed in June, July and August Respectively, with control Sample having 0.122±0.000mg/kg which is lower than the highest value obtained in both site of each month. Lettuce had a highest Mn level of 1.844±0.182, 0.538±0.137 and 2.018±1.941mg/kg observed from Wawan Rafi, Dambo Dam and Gada samples in the month of June, July and August respectively. The lettuce control sample had 0.184±0.002 mg/kg of Mn which is lower than the lowest value obtained in Dambo sample (0.097±0.019mg/kg). All the values of Mn in both water, Soil and vegetable are below the WHO-recommended allowable level of 0.5 mg/L for Mn in drinking water and 800-1500 mg/kg for agricultural soil (Alloway, 2013). However, various studies suggest that vegetable crops typically have Mn concentrations within safe levels, and therefore, no specific limit is established (Martín-Medina A, et al., 2020). Manganese, another essential micronutrient, is necessary for various physiological processes in plant-s and animals. However, excessive levels can cause toxicity, impacting the growth and development of organisms (Chen et al. (2020). In humans, exposure to high manganese concentrations has been associated with neurological disorders, such as Parkinson's disease (Gao J, et al., 2021).

Lead (Pb) concentrations in water samples are 0.060±0.023 and 0.069±0.003mg/L in July of Dambo and Wawan Rafi Respectively. For Gada sample, 0.082±0.065 mg/L was the highest recorded in August. The control sample had Mn concentration of 0.004±0.000 mg/L. Pb concentration in Soil recorded are 0.522±0.117 and 0.514±0.134 in Gada and Wawan Rafi sample in July, while 0.541±0.050 mg/kg was recorded in August of Dambo Sample. Furthermore, Pb in Cabbage, had its highest concentration observed in July, with 0.681±0.128, 0.913±0.068 and 0.747±0.117 mg/kg, all in July observed in Dambo Dam, Gada and Wawan Rafi sample respectively, with control Sample having 0.089±0.006 mg/kg which is lower than the lowest value obtained in both site of each month. Lettuce had a highest Pb level of 0.103±0.033 mg/kg in Wawan Rafi, 0.203±0.104 and 0.197±0.055 mg/kg in Gada and Dambo, observed in the month of June and August respectively. The lettuce control sample had 0.039±0.0.037 mg/kg of Pb which is lower than the lowest value obtained except that of Dambo sample where 0.018±0.009mg/kg is observed in June. The values of Pb in both water, are above the WHO-recommended allowable level of 10 μg/L in drinking water (World Health Organization (WHO, 2017). That of Soil and vegetable are below the recommended limit of 400 mg/kg (United States Environmental Protection Agency (USEPA), 2001) and 2mg/Kg (United States Food and Drug Administration (FDA, 2021) respectively. Pb is a ubiquitous environmental toxicant known for its detrimental effects on human health. In their review, Bellinger discussed the neurodevelopmental effects of Pb exposure in children, including cognitive impairments and behavioral disorders (World Health Organization (WHO), (2017). The study emphasized the importance of continued efforts to minimize Pb exposure, particularly in vulnerable populations.

Cadmium (Cd) concentrations in water samples are 0.003±0.001 mg/L in June of Wawan Rafi. The concentration in Soil recorded are 0.016±0.009, 0.009±0.003 and 0.009±0.005 mg/kg in Dambo, Gada and Wawan Rafi sample in July and August. Furthermore, Cd in Cabbage, had its highest concentration observed in June, with 0.009±0.004, 0.005±0.003 and 0.002±0.001

mg/kg, in Dambo Dam, Gada, and Wawan Rafi sample respectively. Cd in Lettuce, had its highest concentration observed in June, with 0.031±0.013, 0.008±0.003 and 0.004±0.006 mg/kg in August, from Dambo Dam, Gada, and Wawan Rafi sample respectively. The values of Cd in both water, are below the WHO-recommended allowable level of 3 mg/kg, in drinking water (World Health Organization (WHO), 2011) and 2 mg/kg for Ni in fresh vegetables (European Commission, 2015). That of Soil and vegetable are below the recommended limit of 3 mg/kg, for Ni in agricultural soil (European Commission, 2002).

Copper was not detected in any of the water sample of Dambo, Wawan Rafi and Gada, but 0.131±0.050, 0.147±0.040 mg/kg in Gada and 0.016±0.126 and 0.077±0.101 mg/Kg in Dambo and Wawan Rafi were detected in soil sample of June and July as well as August respectively. In Cabbage, only 0.013±0.004 mg/kg of Cu was detected in July sample of Dambo, while 0.002±0.007, 0.044±0.016 and 0.026±0.042 was detected in lettuce sample of Dambo and Gada in June and Dambo in August Respectively. The values of Cu in Soil and Vegetable, are above the WHO-recommended allowable level of 10 μg/L in drinking water (World Health Organization (WHO), 2017). That of Soil and vegetable are below the recommended limit of 75 mg/kg for Cu, both the USEPA and the European Commission recommend a limit (United States Environmental Protection Agency (USEPA), 2005) and 0.3-2 mg/kg for vegetables (United States Food and Drug Administration (FDA), 2021) respectively. Copper, though essential in small amounts, can become toxic to organisms in high concentrations. It can impair aquatic ecosystems by disrupting the reproductive capacity and survival of various organisms.

Nickel (Ni) concentrations in water samples are 0.189±0.033 0.156±0028 mg/L in June of Dambo and Wawan Rafi Respectively. For Gada and control sample, 0.328±0.324 mg/L in July and 0.091±0.00 were detected respectively. Ni concentration in Soil recorded are 0.419±0.154, 0.360±0.079 and 0.259±0.103 mg/kg in Gada, Wawan Rafi and Dambo sample in June, July and August, while 0.093±0.000 mg/kg was recorded in the control sample. Furthermore, Ni in Cabbage, had its highest concentration observed in June, with 0.253±0.061, 0.199±0.028 and 0.240±0.035 mg/kg, in

Dambo Dam, Gada, and Wawan Rafi sample respectively. The control Sample having 0.121±0.007 mg/kg which is lower than the lowest value obtained in Dambo and Wawan Rafi. Ni in Lettuce, had its highest concentration observed in June, with 0.182±0.079, 0.222±0.073 and 0.203±0.016 mg/kg, in Dambo Dam, Gada, and Wawan Rafi sample respectively. The control Sample having 0.054±0.003 mg/kg which is lower than the lowest value obtained in both site in throughout the month. The values of Ni in both water, are above the WHO-recommended allowable level of 20 µg/L in drinking water (World Health Organization (WHO), 2011) and 0.2 mg/kg for Ni in fresh vegetables (European Commission, 2015). That of Soil and vegetable are below the recommended limit of 50 mg/kg for Ni in agricultural soil (European Commission, 2002). Nickel in soil adversely affects plant growth and alters soil microbial diversity.

The low concentration of heavy metals including zinc (Zn), manganese (Mn), cadmium (Cd), copper (Cu), lead (Pb), and nickel (Ni) in soil, water, and vegetables during the rainy season can be attributed to various factors. During the rainy season, rainwater acts as a natural cleanser, washing away pollutants from the surface of soil, water, and vegetables. According to a study by Tian et al. (2017), rainfall significantly influenced the concentration of heavy metals in different environmental media, with rainwater acting as the main mechanism for heavy metal removal from these matrices. As the rainwater falls onto the soil, water bodies, or vegetation, it carries the heavy metal contaminants, resulting in their dilution and consequently reducing their concentrations.

Leaching, another contributing factor, refers to the process by which water transports substances through the soil profile. Studies, such as the one conducted by Taiwo, (2019), have shown that heavy metals, being water-soluble, are prone to leaching during periods of increased soil moisture, such as the rainy season. The percolation of rainwater through the soil layers transports heavy metals deeper into the ground or even into groundwater reservoirs, thereby reducing their availability in the surface soil, water, and subsequently, in vegetables.

Microbial activity also influences the concentration of heavy metals during the rainy season. Research by Huang et al., (2018) highlights the role of microbial communities in heavy metal transformations and immobilization. Certain microorganisms possess the capability to convert heavy metal ions into less toxic forms or immobilize them by precipitating them out of the solution. The increase in soil moisture during the rainy season creates favorable conditions for microbial activity, promoting these important microbial processes that reduce the concentrations of heavy metals in the environment.

Transfer Factor of the potentially toxic Metals in Lettuce, Cabbage and the Control

Plants transfer factor is important component as it is an indicator of heavy metals in soil and a factor that quantifies bioavailability or influential factor on the prediction of uptake of such metals to agricultural products (Kim *et al.,* 2012). Manganese and Zn of both Lettuce and Cabbage Had Low transfer factor bas their values recorded were less than 1 categorized as low transfer factor. The Cd transfer factor of lettuce of June and wawan rafi July as well as cabbage of wawan rafi june, and gada August are categorized as Moderate Transfer Factor as their values were within $1 \leq C_F^i < 3$ standard as described in Limin and Changxu, (2019). Furthermore, the transfer factor is affected by a metal's bioavailability, soil metal quantities, chemical form of metal, plant absorption capabilities, and plant species growth rate (David and Kacholi, 2018). The highest factor values for Zn, Cd, and Pb in lettuce, as well as Cd and Pb in cabbage, may be due to greater mobility of these heavy metals due to natural occurrence (Alam *et al.,* 2003) and anthropogenic activities in the soil and the lower retention of them in the soil than other cations (David and Kacholi, 2018). Increased pollution from waste water drainage, solid waste management and sludge applications, solid waste burning, agrochemicals, and vehicular emissions may explain the higher concentrations of these heavy metals (Intawongse and Dean, 2006). While there was no obvious health danger to the local public from consuming individual heavy metals found in the vegetables, the risk could be multiplied when all of the heavy metals are considered together.

CONCLUSSION AND RECOMMENDATION

In conclusion, all the samples analyzed between June, July and August 2023, contains certain levels of these metals, indicated that all of the three sites were contaminated, which may be due to high levels of anthropogenic such as vehicular emissions along the road, disposal of refuge and domestic waste containing these metals. Also pollution from non-point sources such as residential run-off, offices, and other commercial facilities, as well as industrial discharge, chemical smoke stacks, and urban sewage, joins the river along its course. Even though, the metal are of low concentration, which is associated with rainwater falls at the time that carries the heavy metal contaminants, resulting in their dilution and consequently reducing their concentrations. It is therefore recommended that; assessment of these metals should be continues process as their concentrations could be increase at any time due to natural phenomena or anthropogenic activities and which can lead to bioaccumulation in the food chain.

Declarations Conflict of interest

The authors declare that there is no conflict of interest in this manuscript.

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