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Evaluation of toxic metal pollutants source identification and health risk assessment in water and vegetable from Getsi and Tatsawarki Rivers Kano Nigeria

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Abstract:
Assessment of pollution levels due to toxic heavy metals in surface water is of great importance considering the frequent utilization of contaminated rivers for drinking, irrigation and other domestic purposes which result in health complications. In this study, water and vegetable samples from Getsi and Tatsa warki Rivers were analyzed for Cd, Pb, Co, Cr, and Mn using atomic absorption spectrophotometer (AAS), including pH, electrical conductivity (EC), suspended solid (SS), and dissolve oxygen (DO) for the water samples only. The variations in the studied parameters were evaluated using chemometric techniques. The findings of principal component analysis (PCA) and linear discriminant analysis (LDA) suggested that industrial activities significantly contributed to the heavy metal loads of the rivers while the physico chemical parameters were associated with the surface runoff and domestic input. The LDA showed that water samples from Getsi River were much associated with Cr, Pb, Cd, and Co while DO, SS, pH, EC and Mn were associated with Tatsa warki River. Consumption of water from both rivers was found to be unsafe based on metal index analysis, while the average daily intake (ADI) of the vegetables grown identified Cr to be of more health concern. The findings of this research work would be of relevance considering the high rate of industrial discharges with continuous irrigation activities along the rivers and the frequent consumption of vegetables in our homes.

Keywords: Chemometric, Health risk, Pollution, River, Water quality

1. INTRODUCTION

The pollution of surface water and contamination of soil and plant with toxic metals is increasing in recent time with detrimental consequences for humans, aquatic organisms and plants (Abbas et al., 2020; Li et al., 2023). The establishment of industries near the river banks and close to residential areas introduces toxic substances such as heavy metals to the water and the environment (Azmi et al., 2017; Placido and Lee, 2022). The magnitude of the environmental contamination depends on the nature of the anthropogenic activity, history and the level of compliance with the existing environmental laws and regulations. The point sources of contamination to water bodies include industrial effluents, municipal/domestic wastewater, and abattoir

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waste, while non-point source include animal defecation, storm water drainage and urban runoff.

Several cases of heavy metal pollution in river waters are associated with indiscriminate discharge of untreated industrial effluents directly into the streams and drainages which subsequently find their way into the rivers and other surface water bodies (Palash et al., 2020; Joseph, 2022). The use of polluted water for irrigation practices along the rivers and drainages contaminates the soil and the cultivated plants (Omran et al., 2019), thereby resulting in the consumption of toxic metal-contaminated vegetables and other food items (Manzoor et al., 2018). The literature confirms the direct absorption of heavy metals from the soil to the plant shoot and leaves (Sandeep et al., 2019; An et al., 2011), in which the absorption may vary depending on the level of soil contamination and the plant's affinity for the metals.

Toxic heavy metals affect humans after consumption in both short time and long time exposure periods. The health effect ranges from organ failure, gastrointestinal disorder, damage to the central nervous system, and subsequently death (Engwa et al., 2019; Zaynab et al., 2022). These health complications can be avoided by proper environmental monitoring and enforcement of regulations at all levels (Becker et al., 2013; Li et al., 2020). To date, there are no research findings on the study locations under consideration using chemometrics in addition to the health risk assessment approaches that will reveal the pollutants, precise sources, identify the target dominant toxic pollutant and the risk of consumption of water and the vegetables grown along getsi and tasta warki rivers in Kano.

2. MATERIALS AND METHODS

Study areas

Getsi River (12°2′N and 8°32′E) is a tributary of Jakara River as shown in Fig 1A which serves as the water source for many inhabitants (Lynch *et al*., 2001). It joins the latter and flows northeast direction almost across Kano metropolitan receiving discharges from industries including the popular and busy Kano abattoir. River Getsi carries effluents from Bompai industrial estates and formed a confluence with river Jakara which drains municipal wastewater from Kano's old city district.

River Tatsawarki (Fig IB) and its tributary are the main drains of the southern part of Kano. The river receives the entire wastewater from Sharada phase 1 industrial area, as well as wastewater from the residential areas of Tarauni, Gandun Albasa, Gyadi-Gyadi, Na'ibawa and Kumbotso (Bichi and Anyata, 1999).

Quality control

Analytical grade reagents were used in the analysis. Deionized water was used all through to avoid metal interference. The plastic wares were soaked in 15% HNO_3 (v/v) and rinsed twice with deionized water.

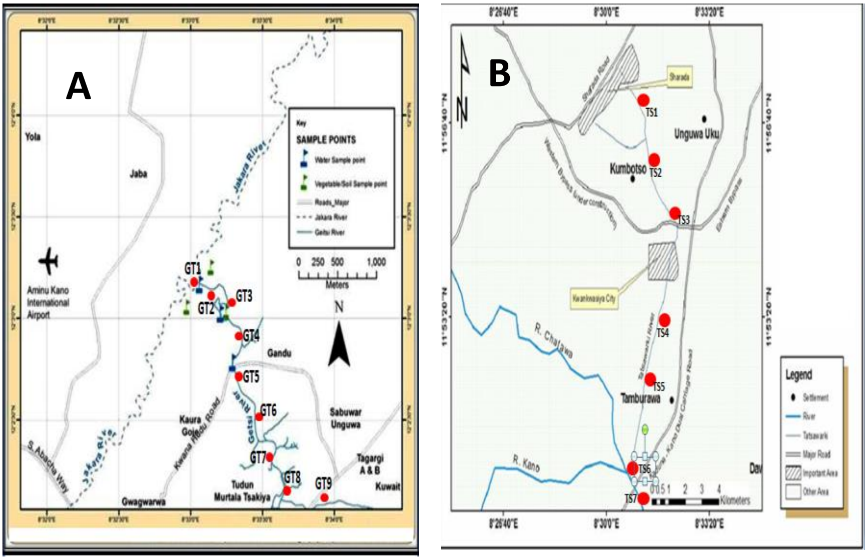

Fig 1: Map of the study areas showing the sampling locations along Getsi River (A) and Tatsa warki River (B) in Kano state

Sampling

Three water samples were collected from each sampling location between May and June 2022 and immediately preserved for the determination of heavy metal contents by the addition of a few drops of concentrated HNO_3. The water samples were then transported to the laboratory in pre-clean polyethylene for heavy metal analysis (Okyere, 2023). The average estimated distance of 100 m was observed between the sampling points to identify any possible variations (Yoshida et al., 2000, Deng et al., 2020), and labeled as GTW, GTP, TSW, and TSP for Getsi River water, Getsi vegetable, Tatsa warki River water, and Tatsa warki plant samples respectively. All possible sources of contamination were avoided during the sampling procedure.

The vegetable samples were collected in triplicate at each sampling location, placed in a clean polyethylene bag and transported to the laboratory.

Insitu Measurement

The selected physicochemical parameters in this study, electrical conductivity (EC), pH, dissolved oxygen (DO), and suspended solids (SS) were measured onsite by using a portable multi-parameter probe (PH-2603) and a suspended solid meter in which pH, EC and SS were analyzed. The DO concentration in the river water samples was measured using a portable DO meter (HI 9147).

Metal Analysis

The acidified river water samples were filtered and heated on a hot plate until the volume is reduced substantially to 20 ml. The digestate is filtered and analyzed using Atomic Absorption Spectrophotometer (Buck Scientific World 210VGP). The concentrations of Pb, Cd, Cr, Co and Mn were determined. Blank samples were used to allow for the blank corrections of metal concentration (Adebayo, 2017; Srikanth et al., 2013).

The vegetable samples were washed three times with deionized water, and air dried. It was later dried in the oven and ground using a clean mortar and pestle. About 5g of the powdered sample was ashed in a muffle furnace for 4 hrs at a temperature of 500 ℃, and the ash was transferred into a beaker with the addition of 20 ml conc HNO_3. It was heated, cooled and filtered. The filtrate was analyzed using Atomic Absorption Spectrophotometer (Buck Scientific World 210VGP).

Data Analysis

The statistical analysis for the dataset was carried out using MS Excel 2010 in which mean and standard deviation were calculated. In addition, one-way ANOVA was applied to the dataset to identify the variations in metal concentrations among the sampling locations and the results were reported at $p< 0.05$. Multivariate statistical analysis including PCA and LDA was carried out on the data set using JMP Pro SAS.

Metal Index

Metal index (MI) explains the water quality concerning the potential health effects due to concentration or levels of metals (Bakan et al. 2010). This is achieved by relating the measured concentrations with the standard permissible values expressed as shown in equation 1 (Tamasi and Cini 2004);

$$\mathrm{MI} = \sum \frac{\mathrm{C}}{\mathrm{MAC}} \quad (1)$$

where C is the observed metal concentration, MAC is the maximum permissible level of the chosen water quality guideline. The higher the ratio of C to MAC, the more deteriorated the quality of the water is, therefore, MI > 1 is a threshold of warning that signifies a potential threat and deteriorated quality of the water (Bakan et al. 2010; USEPA 1989).

Preliminary Health Risk Assessment

The average daily intake of the selected metals (ADI) was evaluated using equation 2 which gives the estimated average daily consumption of the metals into the human body in consideration of other risk parameters. The average adult daily intake of vegetable is 0.345 kg/person/day (Wang et al., 2005), and the average body weight of 61 kg (Koki et al., 2017) were used.

$$\mathrm{ADI} = \frac{C_x\ (\mathrm{mg/kg}) \times \mathrm{K}\ (\mathrm{kg/day})}{\mathrm{BW}\ (\mathrm{kg})} \quad (2)$$

Where C_x is the metal concentration in the vegetable, K is the daily intake conversion factor and BW is the average body weight.

3. RESULTS AND DISCUSSION

The results of the study showed a significant variation in metal concentrations and the physico-chemical parameters analyzed across the sampling locations for the two studied sites. The variations may be linked to differences in industrial activities, and other anthropogenic inputs.

River water quality

The quality of the river water is dependent on both heavy metals and physic-chemical parameters in comparison to the reference standards for drinking and irrigation purposes.

Heavy metals concentrations

Heavy metal concentrations in both Getsi and Tatsa warki rivers revealed considerable variations (Tables 1 and 2) with Getsi river recording the highest heavy metal concentrations. This is attributed to the more industrial activities along River Getsi with effluents discharged into the river water. As shown in Table 1, heavy metal concentrations above the maximum permissible limits set by WHO were detected at the downstream locations of River Getsi. This is bedause water carries both soluble and insoluble contaminants from far distance and accumulate or deposit at the river's tail end (Wang et al., 2012; Setia et al., 2020).

The heavy metals under consideration (Pb, Cd, Cr, Co and Mn) were found to be higher than the permissible limit of 0.01, 0.003, 0.05, 0.01, and 0.4 mg/l set for drinking at some locations (WHO 2011). This indicates pollution and the unsuitability of the water for human consumption. The high metal concentrations could be attributed to the industrial effluents from Bompai industrial estate and other anthropogenic activities along the river. For the consideration of the water for irrigation, only Cd concentration was found to be higher than 0.01 mg/l set by FAO at GTW8 and GTW9. It was reported that toxic metals at low concentrations may accumulate over time and be harmful to humans (Al Osman et al., 2019; Bharti and Sharma, 2022).

In comparison, the levels of heavy metals in Tatsa Warki River (Table 2) follow the same pattern of distribution as that of the Getsi River, but the concentrations are lower. The low metal concentrations observed at some locations of Tatsa warki River may be related to the less industrial activities. However, in some locations, all the heavy metals under consideration were higher than the maximum permissible limit for drinking purposes (WHO 2011), which makes the water unfit for human consumption. All the metals in river water have concentrations lower than the limit set for irrigation purposes (FAO 1992) except Mn which could be linked to the natural background concentration of Mn in the environment (Prisno et al., 2012).

Physico-chemical parameters

For the physicochemical parameters in River Getsi as shown in Table 1, the pH and EC at all the sampling locations were found to comply with the reference standards for drinking and irrigation purposes. But at some locations, the SS was found to be higher than 30 mg/l set for drinking water (WHO 2011). The slight deviation from the standard limit for the SS could be attributed to surface runoff and irrigation activities along the River and its tributaries (Fulazzaky et al., 2012). Eisma (2012) reported that farming and poultry activities in addition to the indiscriminate dumping of refuse introduce suspended matter into the water bodies. The DO levels at all the sampling locations along the River Getsi were found to be below the limit of 5 mg/l (WHO 2011), except for GTW8 with DO concentration of 5.4 mg/l. The very low DO values especially at the upstream locations may be linked to the deposition of waste, surface runoff, and the discharge of animal waste and blood from the abattoir (Jack et al., 2009; Johnbosco et al., 2009).

The levels of pH and EC in River Tatsa warki (Table 2) were found to be below the reference limits at all the sampling locations for both drinking and irrigation uses. However, the SS at TSW3 with 21.1 mg/l, and DO at all the sampling locations were not in conformity with the standard permissible values which indicates the presence of high levels of suspended particulate matter, and the dominance of organic matter in the water. Lindenschmidt et al., (2009) reported that depletion of DO in the water and the presence of particulate matter affects the survival of the aquatic organisms.

Table 1: Concentration of Heavy metals and physico-chemical parameters of water from River Getsi

Sample	GTW1	GTW2	GTW3	GTW4	GTW5	GTW6	GTW7	GTW8	GTW9	WHO	FAO
Pb	0.003 ± 0.001	0.001 ± 0.0005	0.007 ± 0.001	0.054 ± 0.004	0.062 ± 0.005	0.047 ± 0.002	0.056 ± 0.0035	0.034 ± 0.0025	0.051 ± 0.004	0.01	5.0
Cd	0.0023 ± 0.00026	0.0041 ± 0.00021	0.0017 ± 0.0002	0.0024 ± 0.00025	0.0041 ± 0.0006	0.0039 ± 0.0002	0.001 ± 0.0016	0.0335 ± 0.0065	0.0269 ± 0.0003	0.003	0.01
Cr	0.016 ± 0.0015	0.008 ± 0.0016	0.062 ± 0.007	0.037 ± 0.0015	0.064 ± 0.0032	0.029 ± 0.0091	0.078 ± 0.019	0.054 ± 0.017	0.044 ± 0.007	0.05	0.1
Co	ND	0.004 ± 0.0012	0.009 ± 0.0025	0.002 ± 0.0015	0.026 ± 0.009	0.041 ± 0.010	0.013 ± 0.002	0.036 ± 0.0032	0.028 ± 0.0025	0.01	0.05
Mn	0.267 ± 0.0049	0.181 ± 0.0081	0.476 ± 0.0056	0.262 ± 0.0137	0.362 ± 0.0163	0.513 ± 0.074	0.414 ± 0.042	0.231 ± 0.0472	0.246 ± 0.0325	0.4	0.2
pH	7.2±0.1	7.8±0.3	8.4±0.5	7.9±0.4	8.9±0.2	8.1±0.3	6.5±0.1	6.9±0.4	7.8±0.2	6.5-8.5	6-9
EC	56.4±0.6	71.2±0.3	47.3±0.1	61.8±0.2	107.1±0.4	78.2±0.1	95.8±0.5	66.7±0.1	71.4±0.1	1000	2250
SS	31.5±0.3	26.3±0.7	21.1±0.5	26.7±0.4	44±1	27.2±0.6	32.8±0.3	28.3±0.4	25.1±0.5	30	-
DO	1.5±0.4	2.3±0.8	2.8±1.0	1.9±0.6	3.0±1.9	3.8±1.6	3.3±1.4	5.4±2.0	4.9±2.8	5	-

EC in µs/cm, pH (No unit), SS, DO and heavy metals in mg/L, ND = Not detected

Table 2: Concentration of Heavy metals and physico-chemical parameters of water from River Tatsa warki

Sample	TSW1	TSW2	TSW3	TSW4	TSW5	TSW6	TSW7	WHO	FAO
Pb	0.012 ± 0.0035	0.005 ± 0.0003	0.009 ± 0.001	0.017 ± 0.005	0.042 ± 0.001	0.038 ± 0.003	0.056 ± 0.003	0.01	5.0
Cd	0.0014 ± 0.0003	0.0032 ± 0.00026	0.0041 ± 0.0010	0.0022 ± 0.00036	0.0037 ± 0.0006	0.0046 ± 0.00045	0.001 ± 0.0016	0.003	0.01
Cr	0.027 ± 0.0025	0.001 ± 0.0016	0.058 ± 0.0013	0.026 ± 0.0015	0.044 ± 0.004	0.019 ± 0.0091	0.056 ± 0.019	0.05	0.1
Co	0.002 ± 0.001	0.004 ± 0.0015	0.006 ± 0.0025	0.002 ± 0.0015	0.031 ± 0.009	0.029 ± 0.010	0.013 ± 0.002	0.01	0.05
Mn	0.167 ± 0.011	0.261 ± 0.020	0.365 ± 0.012	0.212 ± 0.027	0.468 ± 0.015	0.471 ± 0.009	0.312 ± 0.066	0.4	0.2
pH	8.2±0.3	7.1±0.1	6.7±0.3	7.5±0.2	8.4±0.5	8.1±0.7	8.4±0.1	6.5-8.5	6-9
EC	105.2±0.6	86.7±0.5	97.5±0.1	91.8±0.2	86.2±0.3	108.2±0.3	95.8±0.5	1000	2250
SS	47.5±0.1	39.3±0.2	21.1±0.5	37.4±0.5	59±1	67.5±0.8	35.2±0.3	30	-
DO	2.4±0.2	1.8±0.5	4.6±2.0	3.9±0.7	3.1±1.2	4.8±1.2	4.2±1.5	5	-

EC in µs/cm, pH (No unit), SS, DO and heavy metals in mg/L, ND = Not detected

Table 3: Levels of heavy metals in plants cultivated along River Getsi (mg/kg)

Sample	GTP1	GTP2	GTP3	GTP4	GTP5	GTP6	GTP7	GTP8	GTP9	WHO
Pb	0.6±0.2	0.2±0.01	1.4±0.05	10.8±1.9	12.4±1.1	9.4±0.8	11.2±1.4	6.8±0.7	10.2±1.9	2.0
Cd	0.46±0.1	0.82±0.01	0.34±0.02	0.48±0.1	0.82±0.04	0.78±0.2	0.2±0.06	6.7±0.01	5.38±0.72	0.02
Cr	3.2±0.8	1.6±0.4	12.4±5.2	7.4±1.4	12.8±2.1	5.8±0.9	15.6±3.7	10.8±1.6	8.8±2.4	1.3
Co	0.2±0.02	0.8±0.1	1.8±0.2	0.4±0.1	5.2±0.9	8.2±1.5	2.6±0.8	7.2±0.5	5.6±1.6	0.1
Mn	23.6±0.6	12.9±0.3	15.8±1.3	14.9±1.1	16.5±0.6	17.8±1.2	10.9±0.3	18.9±0.7	17.3±2.4	0.42-6.64

Table 4: Levels of heavy metals in plants cultivated along River Tatsa warki (mg/kg)

	TSP1	TSP2	TSP3	TSP4	TSP5	TSP6	TSP7	WHO
Pb	2.4±0.3	1.0±0.2	1.8±0.3	3.4±0.8	8.4±1.3	7.6±0.6	11.2±1.7	2.0
Cd	2.8±0.1	0.64±0.1	0.82±0.07	0.44±0.05	0.74±0.03	0.92±0.14	0.2±0.15	0.02
Cr	5.4±1.2	0.3±0.1	11.6±0.6	5.2±1.1	8.8±1.4	3.8±0.53	11.2±1.7	1.3
Co	0.4±0.1	0.8±0.05	1.2±0.1	0.4±0.01	6.2±0.7	5.8±1.2	2.6±0.2	0.1
Mn	13.3±2.4	15.6±0.4	10.9±1.6	14.5±2.1	19.3±0.3	12.9±0.8	16.7±2.1	0.42-6.64

Levels of heavy metals in plants

The levels of heavy metals in vegetables cultivated along River Getsi and Tasta warki vary considerably as shown in Tables 3 and 4 respectively. The concentrations were found to be higher than safe limits for all the metals under consideration (FAO/WHO 2007), except for Pb at GTP2 and GTP3, TSP2 and TSP3 for Getsi and Tatsa warki Rivers respectively. This is an indication of contamination of the vegetables with heavy metals which may reach toxic levels. The soil in which the plants are grown and cultivated is contaminated with heavy metals over time. Several research findings reported that soil can accumulate very high concentrations of toxic heavy metals for decades, and release it to the plants via an absorption process, and can also be washed away to the environment by surface runoff (Kumar et al., 1995; Yaashikaa et al., 2022).

Metal Index

The status of the water quality of River Getsi and Tatsa warki are listed in Tables 5 and 6 respectively. The results revealed a significant variation across the sampling points which reflect differences in the anthropogenic inputs and the subsequent pollution of the river water. Several literature findings indicate that elevated concentrations of Pb, Cd and Cr are mostly associated with industrial activities which are discharged into rivers and lakes (Kamala-Kannan et al., 2008; Iqbal and Shah, 2013; Jiang et al., 2022). Therefore, the level of water contamination is directly related to the industrial related activities along the river bank.

As shown in Table 5, Pb, Cd, Cr and Co have MI > 1 in most of the sampling locations of Getsi River indicating contamination of the water with toxic metals thereby making it unfit for human consumption. Singh and Kalamdhad (2011) reported that consuming heavy metals even at lower concentrations in water or food substances could lead to poisoning or even death. Mn was also noted to exhibit MI > 1 which could be of health concern even considering the natural background concentration of Mn in the earth's crust (Koki et al., 2020).

For the Tatsa warki River, the same trend was observed with the Getsi River in terms of Pb, Cd, Cr, and Co as shown in Table 6. The observed MI values were of health concern but lower in magnitude than River Getsi. This can be explained by less industrial and other anthropogenic activities along the river.

Assessing risk from consumption of vegetables

The ADI for the consumption of the vegetables cultivated at the studied sites is shown in Tables 7 and 8. The results revealed that ADI for the metals varies considerably among the sampling locations. The ADI of Pb, Cd, Co, and Mn were found to be within the tolerable limits set by WHO/FAO except for Cr at GTP3, GTP5, GTP7, and GTP8. This finding indicates that inhabitants or consumers of the vegetables ingest high levels of Cr which could be of health concern (Sun et al., 2015). Cr toxicity to humans may involve irritation of the gastrointestinal tissues, and lead to cardiovascular collapse (Pversi and Moreira, 2020). Similarly, only Cr was found to exceed the ADI value at TSP3 and TSP7 in River Tatsa warki, this signifies that Cr is a metal of concern in this study. In addition to the industries, other sources of Cr may include the combustion of fuel and sewage sludge (Choppala et al., 2013).

Table 5: Metal index of the water samples from River Getsi

Sample	GTW1	GTW2	GTW3	GTW4	GTW5	GTW6	GTW7	GTW8	GTW9
Pb	0.3	0.1	0.7	5.4	0.01	4.7	5.6	3.4	5.1
Cd	0.76	1.36	0.56	0.8	1.36	1.3	0.33	11.16	8.96
Cr	0.32	0.16	1.24	0.74	1.28	0.58	1.56	1.08	0.88
Co	-	0.4	0.9	0.2	2.6	4.1	1.3	3.6	2.8
Mn	0.66	0.45	1.19	0.65	0.90	1.28	1.03	0.57	0.62

Table 6: Metal index of the water samples from River Tatsa warki

Samples	TSW1	TSW2	TSW3	TSW4	TSW5	TSW6	TSW7
Pb	1.2	0.5	0.9	1.7	4.2	3.8	5.6
Cd	0.46	1.07	1.37	0.73	1.23	1.53	0.33
Cr	0.54	0.02	1.16	0.52	0.88	0.38	1.12
Co	0.2	0.4	0.6	0.2	3.1	2.9	1.3
Mn	0.42	0.65	0.91	0.53	1.17	1.18	0.78

Table 7: Average Daily Intake of the selected heavy metals in plants harvested along River Getsi (mg/kg/day)

Sample	GTP1	GTP2	GTP3	GTP4	GTP5	GTP6	GTP7	GTP8	GTP9	WHO/FAO
Pb	0.0034	0.0011	0.0079	0.061	0.07	0.053	0.063	0.038	0.057	0.214
Cd	0.0026	0.0046	0.0019	0.0027	0.0046	0.0044	0.0011	0.0039	0.0078	0.060
Cr	0.0026	0.009	0.070	0.041	0.072	0.032	0.088	0.061	0.049	0.05-0.2
Co	0.0011	0.0045	0.010	0.0022	0.029	0.046	0.014	0.04	0.0316	0.005-0.06
Mn	0.133	0.073	0.089	0.084	0.093	0.101	0.062	0.106	0.097	1.8-2.3

Table 8: Average Daily Intake of the selected heavy metals in plants harvested along River Tatsa warki (mg/kg/day)

Sample	TSP1	TSP2	TSP3	TSP4	TSP5	TSP6	TSP7	WHO/FAO
Pb	0.013	0.056	0.01	0.019	0.047	0.043	0.063	0.214
Cd	0.015	0.0036	0.0046	0.0025	0.0024	0.0052	0.0011	0.060
Cr	0.0305	0.0017	0.0656	0.0029	0.0498	0.0215	0.0633	0.05-0.2
Co	0.0023	0.0045	0.0068	0.0023	0.0351	0.0328	0.0147	0.005-0.06
Mn	0.0752	0.0882	0.0616	0.082	0.1091	0.0729	0.0944	1.8-2.3

Multivariate analysis

Multivariate statistical models are essential in understanding and monitoring the environmental influence on surface water quality such as Rivers. In this study, the results of PCA and LDA identified the distribution, variations, and classifications of the water samples among the sampling sites.

PCA

PCA was carried out to show the distribution of parameters in the studied areas, in which their variability in water samples was analyzed. The principal components (PCs) with relevance in the result interpretation are (eigenvalues > 1) which explain the largest variations in the entire data set up to 52%. The plot of PC1 against PC2 contained important information and therefore primarily considered (Alberto et al., 2001; Juahir et al., 2011). PC1 and PC2 respectively account for 38.8% and18.8% of the total variation of the water quality in the Getsi and Tatsa warki rivers. The loadings of PC1 contain positively correlated parameters comprising Pb, Cr, Co, Mn, and DO as the major contributors as shown in Figure 2 with a clear separation in the red ribbon. The finding of the PCA in this study is similar to the metal index and ADI that identified heavy metal pollution in the water samples under consideration which may be linked with industrial and other anthropogenic activities (Bradl, 2005; Razzak et al., 2022). PC2 has high positive loadings for pH, EC and SS which are parameters related to suspended organic matter and domestic effluent discharges (Mustapha et al., 2013; Yan et al., 2022). Therefore, the score on PC2 that is identified in the blue ribbon is related to the sampling points from the Tatsa warki river.

LDA

LDA was applied to predict the important parameters that distinguish Getsi from Tatsa warki Rivers. This is achieved by identifying the most significant and dominant parameters in the studied sites**.** As shown in Figure 3, the water samples from the Getsi River are separated from Tatsa warki River in the direction of Canonical 1. The result shows that Co, Cd, Cr, and Pb are particularly associated with Getsi River, while Do, SS, Mn, pH and EC are associated with Tatsa warki River.

The findings of LDA in this study confirm that Getsi River is contaminated with heavy metals which agree with the results of PCA. Anthropogenic activities around the rivers are linked to water contamination with toxic metals which may affect the health of the inhabitants (Flora, 2014).

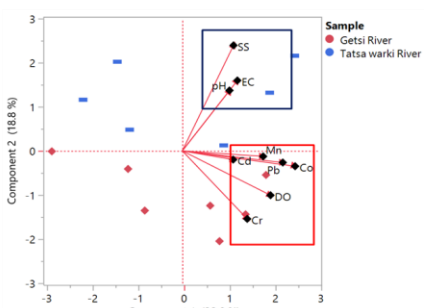

Fig 2: PCA bi-plot of heavy metals and physic-chemical parameters from Getsi and Tatsa warki Rivers

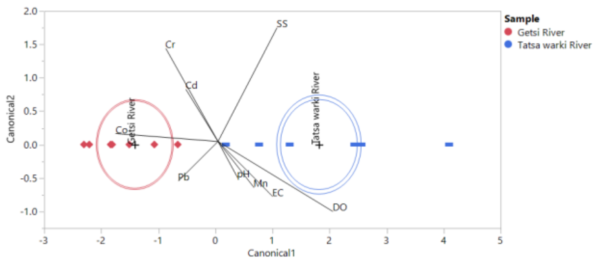

Fig 3: Canonical plot for the discrimination of water samples from Getsi and Tatsa warki Rivers

4. CONCLUSION

This work identified contamination of River Getsi and Tatsa warki with toxic metals with significant variations in the degree of heavy metal pollution and physico-chemical parameters at the different sampling locations. The vegetable samples were also found to be contaminated with heavy metals indicating long-term pollution of the soil and may reach toxic levels after consumption. The results demonstrated that industrial activities near the rivers contributed to the metal pollution of the water. The results of multivariate statistical analyses identified toxic metals and physico-chemical parameters as the key variables that discriminate the sampling locations. This finding reaffirmed that major variations in the water quality were associated with anthropogenic inputs which renders the water unfit for human consumption. This research finding therefore suggests the need for the regulatory agencies to closely and frequently monitor the industrial activities, and ensure proper treatment of effluents before discharge to the environment.

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