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Assessment of the environmental status of Vasileva Lake in the municipality of Gllogoc, Kosovo

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ABSTRACT

The research evaluated the health risks associated with specific heavy metals (Ni, Cr, Pb, Mn, Zn, Cu, Fe, As, Al, Co, Cd) in the surface water of Vasileva Lake, located in the Gllogoc municipality of Kosovo. Surface water and sediment samples were collected in June 2024 and analyzed using inductively coupled plasma optical emission spectrometry (ICP-OES), with results compared to World Health Organization (WHO) and Environmental Protection Agency (EPA) standards. The average concentrations of heavy metals (mg·dm^{-3}) in surface water samples were as follows; Zn (2.54), Ni (1.07), Fe (1.03), Mn (0.61), As (0.08), Pb (0.05), Cd (0.009) and Cu (2.41) have high concentration, while the sediment samples concentration is listed (mg·kg^{-1}) of; Fe (4.67), Zn (4.61), Ni (3.88), Cu (3.22), Pb (2.66), Cr (2.32), As (1.01) and Cd (0.207). The concentrations of contaminants in water samples were higher as compared to concentrations in sediment samples, which were very low. The decreasing trend of the metal levels in surface water and sediment were as follows: Zn > Ni> Fe >Mn >As >Pb >Cd > respectively Fe >Zn >Ni > Cu >Pb >Cr >As >Cd respectively. Correlation analysis indicated significant positive value indicating that the heavy metals were from same source and as well strong negative correlation indicating different source of heavy metals into the lake.

Keywords: surface water, heavy metals, risk assessment, Vasileva Lake.

INTRODUCTION

The pollution of surface water and its health problems caused by human activities (population growth, increasing waste and rapid industrialization) is a global issue. According to Zhou et al. (2020), anthropogenic activities in both rural and industrial zones place surface water bodies such as rivers, streams, dams, oceans, lakes etc., under threat of pollution from various sources.

As water holds great importance for people, it is also needed in socio-economic development. Li et al. (2020) states surface water is used to satisfy domestic, agricultural, and industrial water requirements throughout the world, especially in regions where surface water is lacking or polluted.

Groundwater and surface water in rural areas such as Vasileva Lake, municipality Gllogoc, are basic sources of drinking water for millions of the population (Demaku et al., 2023). But the rapid pace of industrialization and urbanization within the Gllogoc municipality has greatly affected the groundwater and surface water quality, hence heavy metal contamination is an urgent environmental pollution and health threat.

The aesthetic qualities of surface water and sediments have been compromised in the recent past as a result of human activities which include, littering, among other activities like fishing, runoff from farmlands, industrial effluents, leachate from dumpsites etc, which go on and around any water body. This action then brings in heavy metals and organic pollutants into the surface water lending less to its utility (Kabir et al., 2020).

Water and sediments heavy metal pollution have industrial discharge cycle, fertilizers, sheeted wire and turbine pipe corrosion and biomass burning as key drivers in their emission. Most of the industrial practices and agricultural practices with notable high doses of pesticides and fertilizers in agriculture and other chemical industrialized farming pose risks to the human health (Kabir et al., 2020).

Heavy metal deposits in water in this case is often released into the environment as water pollution is a common phenomenon and has been widely regarded as a problem of significant public interest due to its lethal characteristics, inability to break down, assistance in other toxins that amass over time, and constitution that endangers life underwater causing harm to the aquatic ecosystem (Kabir et al., 2020). They are naturally present in the rocks; however, a considerable proportion of heavy metals are emitted by human activities (Proshad et al., 2020). These are washed away into surface waters by rock degradation, and water waste, operational outputs and organic origins from fossil and petroleum materials that have not completed combustion (Proshad et al., 2020).

Chromium (III), copper, cobalt, iron, manganese, molybdenum, selenium, and zinc are types of metals which are tagged by the USEPA as essential, however, their concentration above normal thresholds become toxic to organisms; this is also same for aluminium, arsenic, cadmium, lead, mercury, silver and other non-essential metals.

The numerous uses and sources have led to their wide distribution, raising global concern over the possible impact on human health and the environment's (Zaynab et al., 2022). Heavy metals are ubiquitous and have associations with cancer, mutation, and malformation in aquatic life and humans. Pollutants lie in the water over the lake and in the lake sediments, and are taken up by fish and other aquatic animals in water and hence bio-concentration of such pollutants leading to biomagnification in the food web is possible (Zaynab et al., 2022). They find use in Vasileva Lake which is the main water supply for people residing near the said lake, who lacks access to clean drinking water, industrial activities, and irrigation farming activities done close to the lake, especially during the dry season (KAS, 2024).

Over the years, a number of researches have been carried out at Vasileva Lake. Yet, there are no documents on health risks associated with heavy metal poisoning at Vasileva Lake. Hence, the present study intends to carry out and evaluate health risk assessment of heavy metals in the water and sediment of Vasileva Lake in Gllogoc municipality, Kosovo state with specific aims: (i) to assess various parameters of the water and sediments, (ii) to evaluate quality of surface water and sediments against established standards such as the (WHO, 2017), (US-EPA, 2011).

MATERIALS AND METHODS

Study area

Gllogoci is a city in central Kosovo that is recognized for its thriving economic and industrial activities. Lake Vasileva is located between the Municipality of Gllogoc and that of Fushë Kosovo (Fig. 1), surrounded by green mountains, it is

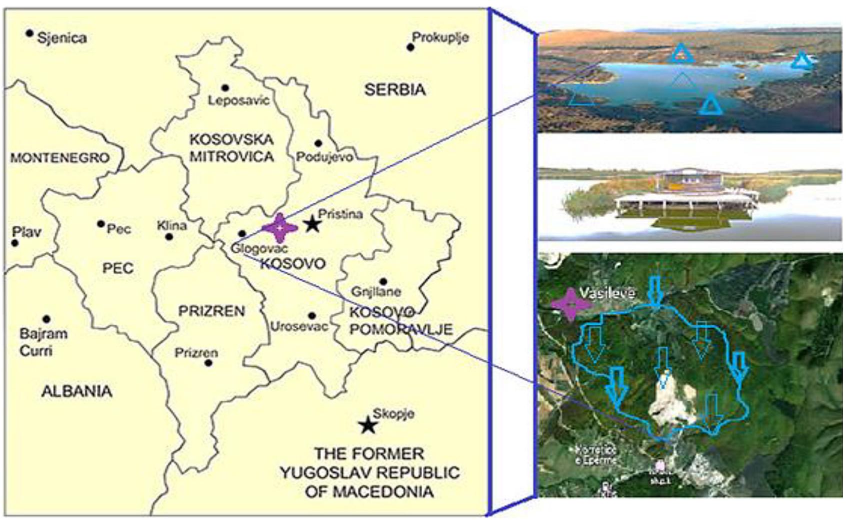

Figure 1. Map of Gllogoc indicating Vasileva Lake as the study area

part of the mountain of Gospoja that is located in a deep geographical position, and has an area of about 0.2 km² (about 20 ha) and with a depth of about 20 meters (KAS, 2024).

This lake is also rich in flora and fauna and very suitable for fishing. In this lake there are at least 5 species of wild geese, dozens of species of birds and several species of fish. Over time, a small island has been created in the lake, which is used by fishermen. The beautiful nature that this place offers with an impressive landscape, with just a little dedication and investment, makes this lake develop tourism throughout the summer season (KAS, 2024).

The area has two seasons: rainy (May–June) and dry (June–November). Human activities such as farming, industrial sewage discharge, trash discharge, textile washing, faces, and animal washing, as well as sand and gravel exploration, have a significant impact on Vasileva Lake.

Sample collection and preparation

Vasileva Lake, which was formed by mining and the excavation of minerals, was the site from which samples were obtained. Water samples were collected from three positions separated by five meters and were spiraled together to form a composite sample (Mohammad et al., 2022). A plastic bottle was submerged to a depth of one meter, and placed at a distance of five meters.

Water that was to be collected was minimized for the cleaning of the sterilized sampling bottle that was to be filled with water, which was the case at all of the sampling points. During the collection of sediment samples, the upper layer was scraped off using plastic spoons before the mixtures were moved to a pre-released 1000 ml polypropylene container.

The lid was then removed and the container was properly labelled before being taken to the laboratory for further analyses (Mohammad et al., 2022). Solutions for heavy metal analysis were prepared using distilled water and high analytical purity chemicals from three sample sites.

At June/2024, water and sediment samples were taken from the area surrounding the Vasileva Lake at seven distinct sampling positions, namely; M1-M2 which is located in the southern part along the line of Vasileva, M3-M4 at the eastern part along the line of Slatine, M5-M6 which is a section of the northern line coinciding with the village of Çiçavicë and M7 which is located in the center of Vasileva Lake, (see Figure 1-right side with arrows down, blue color; M1-M7).

Digestion of surface water and sediment samples

In June 2024, seven water samples were taken from each location in plastic containers that had been treated with acid. The samples were then transferred to the laboratory on ice.

Before being subjected to a chemical examination, the water was kept at 4 °C. The heavy metal (loid) contents were assessed using an inductively coupled plasma-optical emission spectrometry, ICP-OES, Perkin Elmer, Optima 2100 DV, after a subsample of 20 ml of the collected water was filtered via 0.45 μm pore-spaced filters according to (EPA-Method 6010C, 2007). In the case of the sediment (seven samples), the samples were taken into acid-treated plastic containers, transported to the laboratory on ice, and then frozen until chemical analysis could be conducted in a Department of Chemistry laboratory.

The sediment samples were stored in preweighed, acid-washed polypropylene vials and dried for 24 hours at 60 °C. Thereafter, stones and coarse debris were removed from the samples by passing them through a 2-mm nylon sieve. 0.1 grams of each sediment sample was digested using eight milliliters of 68% nitric acid (HNO_3) and three milliliters of 40% hydrochloric acid (HCl) (EPA-Method 6010C, 2007).

Inductively coupled plasma optical emission spectrometry (ICP-OES) (Perkin Elmer, Optima 2100 DV) was used to determine the elemental contents after the digested sample was run through a membrane filter. The analysis was done in line with the (EPA-Method 6010C, 2007).

Analytical statistics

The heavy metal (loid)s concentrations were measured along with their average and standard deviations. Pollution indices, enrichment factor (EF), and geo accumulation index (Igeo) were used to determine the anthropogenic contribution to heavy metal (loid)s pollution in the sediments of Vasileva Lake. For the evaluation of the association between the examined parameters, correlation analysis was performed by the Pearson Correlation test (Hakanson, 1980; Muller, 1971; Tomlinson, 1980). Cluster analysis was also performed using multivariate statistical methods to evaluate the grouping and relationships among sampling points and metal (loid) concentrations.

Factor of enrichment (EF)

The amount and presence of contamination in the sediment were evaluated using EF (Hakanson, 1980; Muller, 1971; Tomlinson, 1980). EF is computed as follows:

$$EF = \frac{(Baseline\ Cx/BaselineFe)}{(Cx/Fe)} \quad (1)$$

where: *Cx* is the concentration of metal (loid) [20].

Background values for the metal (loid)s were used from Turekian and Wedepohl's average shale values (Turekian et al., 1961; Okey-Wokeh et al., 2021). Natural metal (loid) concentrations were taken into consideration by using the concentration of Fe as a reference point. Metal (loid) contamination have been successfully normalized using iron (Fe) (Okey-Wokeh et al., 2021). (EF < 2) deficient to minimal enrichment; (2 < EF < 5) moderate enrichment; (5 < EF < 20) considerable enrichment; (20 < EF < 40) very high enrichment; and (EF > 40) extremely high enrichment were the classifications into which EF values were utilized to evaluate the pollution of bottom sediment samples (Mirza et al., 2019).

Index of geo-accumulation (Igeo)

The Igeo index was used to gauge the level of metal (loid) pollution in the river sediments. Metal (loid)s contamination in soil and sediment fractions has been investigated worldwide using the Igeo (Liang et al., 2023). It considers both the effects of human activity and natural geological processes on metal (loid) contamination (Liang et al., 2023). The following formula determines the geo-accumulation index's value:

$$Igeo = log_2\left(\frac{C_x}{1.5 \times Bn}\right) \quad (2)$$

where: *Bn* is the geochemical background value of a specific metal (loid) in the shale [28], *Cx* is the concentration of the metal (loid) under study in the sediment, and the factor 1.5 is applied to allow for potential differences in the background values.

The geoaccumulation index is divided into seven classes (Liang et al., 2023). Class 0 (Igeo0), Class 1 (0Igeo1) uncontaminated to moderately contaminated, Class 2 (1Igeo2) moderately contaminated, Class 3 (2Igeo3) moderately to heavily contaminated, Class 4 (3Igeo4) highly contaminated, and Class 5 (4Igeo5) heavily to extremely contaminated are the classes that fall between uncontaminated and extremely polluted (Liang et al., 2023).

RESULTS AND DISCUSSION

Concentration of heavy metal (loid)s in surface water and sediment samples

Heavy metal concentrations in surface water and sediment are presented in Tables 1 and 2 in mg·dm^{-3} and mg·kg^{-1}, respectively. The values

Table 1. Average and standard deviation of heavy metal concentrations in water samples (mg·dm^{-3}) across sampling locations with who standards

Elements	Sampling locations														WHO standards
	M1		M2		M3		M4		M5		M6		M7		
	Stdv	Average	Stdv	Average	Stdv	Average	Stdv	Average	Stdv	Average	Stdv	Average	Stdv	Average	
Ni	0.02	1.07	0.02	1.03	0.12	0.97	0.02	1.06	0.07	1.05	0.06	1.03	0.07	1.01	0.02
Cr	0.03	0.05	0.02	0.05	0.02	0.08	0.01	0.05	0.01	0.06	0.01	0.07	0.43	0.39	0.05
Pb	0.01	0.05	0.02	0.04	0.01	0.03	0.01	0.02	0.01	0.05	0.01	0.03	0.01	0.04	0.01
Mn	0.09	0.57	0.03	0.58	0.03	0.54	0.07	0.58	0.02	0.58	0.04	0.55	0.07	0.56	0.4
Cd	0.04	0.04	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.003
Cu	0.25	2.47	0.07	2.35	0.05	2.29	0.03	2.24	0.08	2.20	0.03	2.34	0.05	2.35	2
Fe	0.04	1.04	0.02	1.03	0.08	1.00	0.07	0.95	0.06	0.86	0.02	0.97	0.08	0.97	0.3
As	0.01	0.08	0.02	0.06	0.02	0.08	0.02	0.07	0.01	0.04	0.01	0.05	0.01	0.06	0.01
Zn	0.08	2.51	0.05	2.06	0.12	2.07	0.10	2.12	0.04	1.88	0.40	1.68	0.04	2.30	3
Al	0.01	0.02	0.01	0.01	0.00	0.01	0.04	0.07	0.00	0.01	0.00	0.01	0.00	0.01	0.2
Co	0.01	0.03	0.01	0.01	0.00	0.01	0.05	0.07	0.00	0.01	0.00	0.01	0.00	0.01	0.01

reported where applicable are the average concentrations with calculated standard deviations (StDev) of replicate measurements. All the metals studied were detected in the water samples.

In the water samples, the high concentrations were As (0.08), Cd (0.009), Mn (0.61), Pb (0.05), Ni (1.07), Fe (1.03), Cu (2.41), and Cr (0.09), while the relatively low ones were Al (0.01), Zn (2.54), and Co (0.01). Among these, Fe, Ni, Cr, Pb, Mn, Cd, Cu, and As were above the thresholds recommended by WHO, which could pose health or ecological risks (WHO, 2008). In contrast, Zn, Co, and Al values were within the range of acceptable limits, reflecting no potential risk of those elements.

Even though Co, Al, and Zn remained within WHO limits, the point should not be ignored that even their trace quantities have the potential to adversely affect aquatic biota because of nutrient enrichment or toxicological effects (Mohammad et al., 2022). Elevated concentrations of Ni, Pb, Fe, Mn, Cu, and As at several sites (e.g., M1 and M7) highlight localized pollution, likely attributable to anthropogenic activities such as agricultural runoff, industrial discharge, or urban contributions. These findings align with previous studies comparing rural lakes and artificial reservoirs in Kosovo (Demaku et al., 2022).

M1 and M7 revealed a much higher level of contamination compared to all other sites, while in the case of the mentioned sites, high concentrations of lead, nickel, iron, copper, manganese, arsenic, cadmium, and chromium were measured, which can be indicative of proximity to pollution sources. Sites M2-M6 showed lower concentrations, perhaps due to lesser anthropogenic influence or increased natural attenuation.

However, metal concentration variation among sites needs further analysis. Sediment sampling, bioavailability studies, and source apportionment should be conducted in an integrated analysis to validate the levels of pollution and to accurately identify their sources. Heavy metal concentrations in Vasileva Lake were significantly higher when compared with rural lakes but still lower than the levels measured in industrial lakes of Kosovo (Demaku et al., 2022). This indicates that natural geological inputs and local human activities have dual roles in determining contamination patterns.

The heavy metal concentrations are of ecological importance. Nickel (1.07 $mg \cdot dm^{-3}$), chromium (0.09 $mg \cdot dm^{-3}$), and manganese (0.61 $mg \cdot dm^{-3}$) showed higher values above the threshold limit set by WHO, thus being harmful to aquatic ecosystems. Even though Co, Al, and Zn showed values below the limit, the synergistic effect of these metals with other metals may cause adverse environmental impacts.

Meanwhile, the concentrations of metal (loid) s in sediment samples showed significant range with sites and, indeed, have been detected more that was not even shown in the analyzed water samples (Table 2).

Several previous studies reported concentrations of metals in sediments of several orders higher than in overlying waters (Lawal et al., 2021). This is in agreement with the present observation, as seen in Table 2, that the majority of heavy metal (loid)s occurred at much higher concentrations in sediment samples compared to the water samples. This agrees well with the fact that the greater amount of heavy metal (loid) s in aquatic systems finally settle in bottom sediments. The causes for such accumulations are believed to be related to adsorption, precipitation, and sedimentation.

Table 2 summarizes heavy metals present in sediment samples of Vasileva Lake, together with EPA criteria levels for acceptable concentrations of each metal (loid)s in sediments.

Thus, among the changes that took place for sample sites in general, it was able to establish the trend of its concentrations for these metal (loid)s. There is greater contamination of this sediment on localized areas, potentially due to rampant anthropogenic activities around Vasileva Lake-from industrial and agricultural runoff. Coupled with it, such a contamination may involve an increased flow from the lake whose flow heavily rests on the weather conditions-preprecipitation events.

Therefore, in rainy seasons, the discharge of a lake increases significantly, improving the transportation of sediments along with contaminants of heavy metals from upstream to the downstream zone, thus increasing the concentrations within sediment deposits (Rima et al., 2021).

According to EPA, 1991, cadmium concentrations in the sediments of Vasileva Lake were well below the heavily polluted threshold of 6 $mg \cdot kg^{-1}$, with an average of 0.11 $mg \cdot kg^{-1}$ and a standard deviation of 0.01 $mg \cdot kg^{-1}$, thus indicating a very low contamination risk.

The lead concentrations were below the EPA threshold of < 40 $mg \cdot kg^{-1}$ with a mean of 2.47 $mg \cdot kg^{-1}$ and a standard deviation of 0.17 $mg \cdot kg^{-1}$,

Table 2. Average and standard deviation of heavy metal concentrations in sediment samples (mg·kg^{-1}) across sampling locations with epa standards

Element	Sampling locations														
	L1		L2		L3		L4		L5		L6		L7		Epa_ Standard
	Avg	Stdv	Avg	Stdv	Avg	Stdv	Avg	Stdv	Avg	Stdv	Avg	Stdv	Avg	Stdv	
Ni	3.81	0.64	3.06	0.38	3.09	0.71	3.10	0.19	3.10	0.28	3.09	0.15	3.88	0.33	< 20
Cr	2.32	0.24	2.11	0.15	2.28	0.44	2.07	0.13	2.26	0.34	2.31	0.20	2.29	0.21	< 25
Pb	2.66	0.47	2.16	0.10	2.36	0.30	2.35	0.57	2.47	0.17	2.55	0.17	2.61	0.23	< 40
Mn	1.89	0.10	1.86	0.08	1.68	0.10	1.59	0.07	1.82	0.08	1.66	0.22	1.79	0.24	750.00
Cd	0.11	0.01	0.10	0.01	0.09	0.00	0.10	0.01	0.10	0.01	0.09	0.00	0.21	0.01	-
Cu	3.22	0.18	2.98	0.76	2.99	0.42	2.89	0.22	2.87	0.17	2.69	0.21	3.11	0.23	< 25
Fe	4.33	0.10	4.22	0.14	4.11	0.19	4.08	0.42	3.89	0.06	3.97	0.20	4.67	0.50	25.00
As	0.98	0.14	0.88	0.04	0.84	0.12	0.67	0.05	0.46	0.05	0.75	0.04	1.01	0.00	-
Zn	4.86	0.12	4.89	0.08	4.87	0.34	3.98	0.19	3.89	0.38	3.98	0.45	4.61	0.18	< 90
Al	0.19	0.01	0.08	0.00	0.06	0.00	0.06	0.00	0.01	0.00	0.11	0.01	0.17	0.02	-
Co	0.21	0.03	0.18	0.01	0.14	0.01	0.16	0.01	0.19	0.01	0.20	0.02	0.21	0.02	-

confirming sediments being non-polluted with respect to lead. In the same manner, nickel concentrations, which averaged 3.10 mg·kg^{-1} with a standard deviation of 0.33 mg·kg^{-1}, were below the EPA chronic criterion < 20 mg·kg^{-1}.

Hence, a very low risk of nickel-related environmental impacts. Iron concentrations were also less than the EPA chronic criterion of < 25 mg·kg^{-1}, hence posing minimal risk with an average of 4.11 mg·kg^{-1} and a standard deviation of 0.19 mg·kg^{-1}. Chromium levels also fell below EPA standards with an average of 2.28 mg·kg^{-1} and a standard deviation of 0.21 mg·kg^{-1}, hence presenting a minimal contamination risk.

Factors of enrichment and geo-accumulation index

The analysis of heavy metal content in sediments is vital for evaluating environmental health. A detailed examination of each element offers valuable insights into potential risks and ensures compliance with regulatory standards. Figure 2 depicts the enrichment factor (EF) values across seven sampling locations (L1–L7) in Vasileva Lake, indicating varying levels of metal (loid)s accumulation in sediments. This analysis helps identify the influence of anthropogenic and natural sources of contamination.

EF values for metal(loid)s were computed to evidence the degree of sediment contamination and their potential sources of pollution. Figure 2 shows the highest values of EF calculated for As (1.01 mg·kg^{-1}), Fe (4.67 mg·kg^{-1}), Cu (3.22 mg·kg^{-1}), Ni (3.88 mg·kg^{-1}), Cd (0.207 mg·kg^{-1}), and Zn (4.89 mg·kg^{-1}). The spatial distribution of EF values points out the variability between sites. For instance, L7 showed elevated EF values for As, Fe, Ni, and Cd, suggesting localized pollution from industrial or agricultural sources upstream (Tian et al., 2020). L2 exhibited the highest EF for Zn, potentially indicating runoff from urban or vehicular activities (Jaskuła et al., 2022).

On the other hand, the lower EF values of Cr, Pb, Cu, and Mn at stations L2 to L6 reveal a weaker influence of human activities in this area, which corroborates with the proximity to less disturbed parts of the lake.

Figure 3 illustrates the geo-accumulation indexes of the studied metal (loid)s. Calculated Igeo values presented Fe and Ni to be moderately contaminated, as Igeo was > 0 at some sites, such as L7, indicating industrial wastes (Tian et al., 2020). However, the Igeo values for As, Cu, Cd, Cr, Al, Co, Mn, Pb, and Zn were less than at most sites, indicating a negligible level of contamination, hence posing minimal risks from these elements. The high Igeo values of Fe and Ni at L7 could be due to anthropogenic sources such as industrial discharges. These findings point out the need for mitigation trategies at specific areas.

The Pearson correlation analysis of heavy metals in water samples from Vasileva Lake reveals key relationships that indicate shared sources and geochemical behaviors.

A strong positive correlation between Ni and Mn (r = 0.773) suggests common anthropogenic origins, such as industrial runoff, while Fe

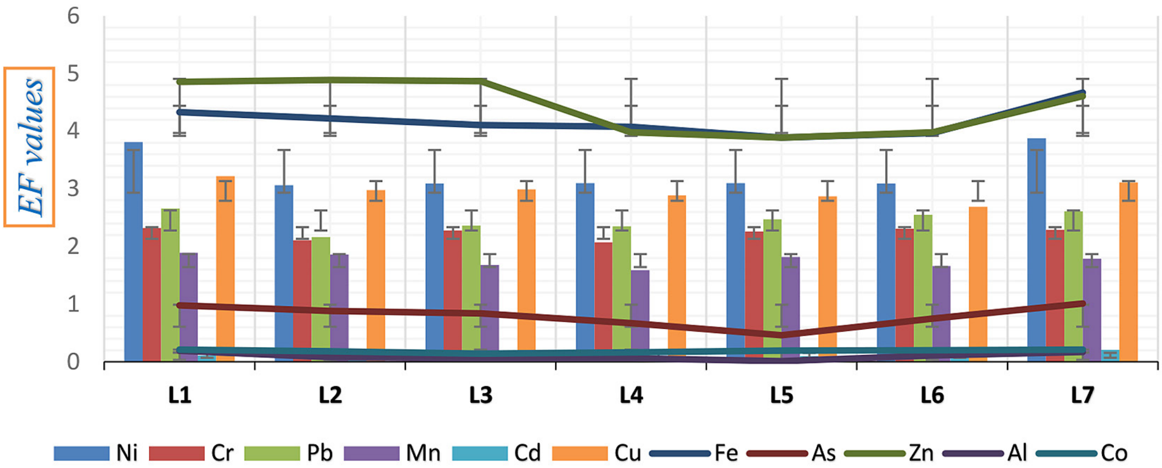

Figure 2. The enrichment factor (EF) values of metal (loid)s in the sediment of the Vasileva Lake

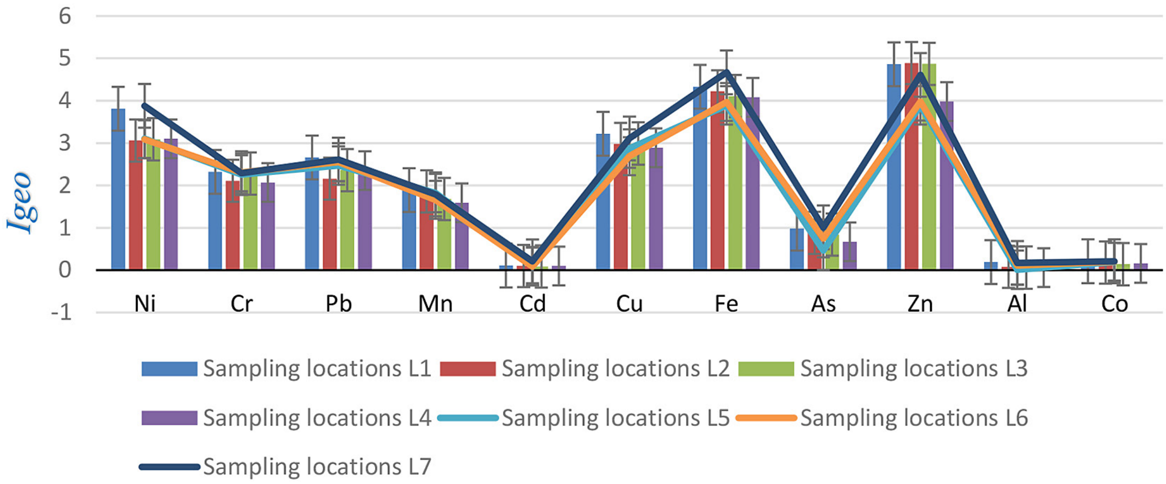

Figure 3. The geo-accumulation index (Igeo) of heavy metal (loid)s in the sediment of the Vasileva Lake

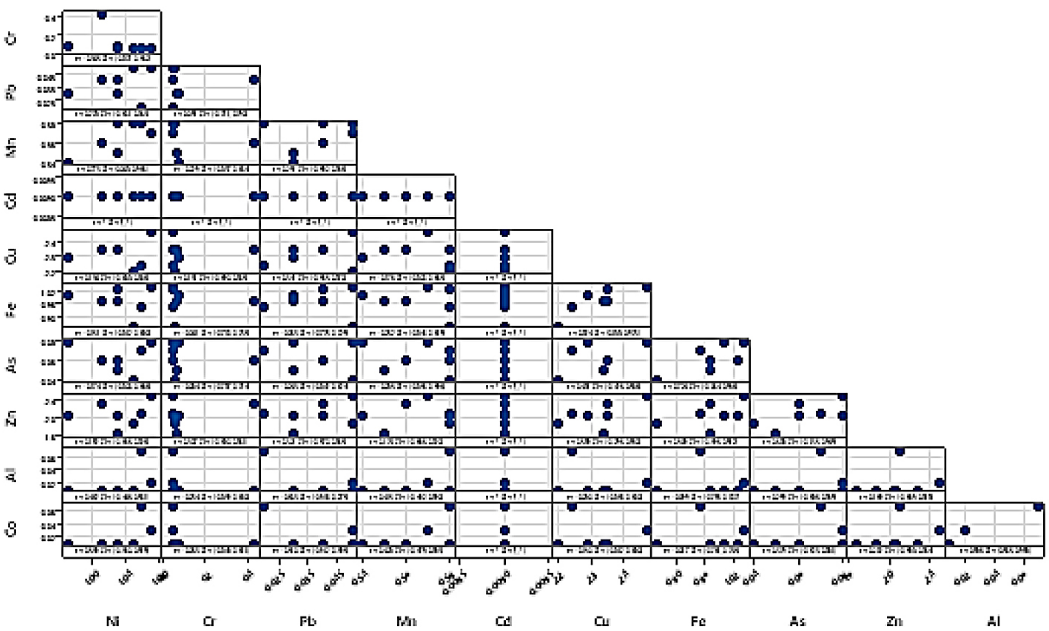

Figure 4. Matrix plot of pairwise correlations for heavy metal concentrations in water samples

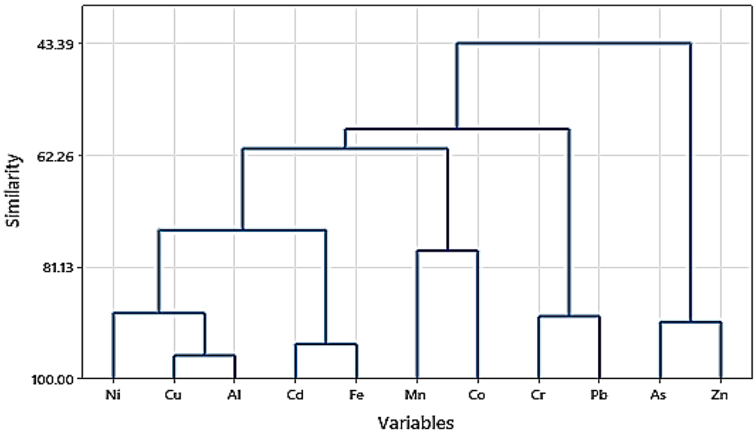

Figure 5. The dendrogram of the distribution of heavy metals in sediment of the Vasileva Lake

and Cu (r = 0.824) indicate related industrial or geochemical processes. Similarly, As and Fe (r = 0.724) highlight potential co-deposition, and the near-perfect correlation between Co and Al (r = 0.986) suggests shared geological or anthropogenic inputs.

While the moderate correlation-for example, Zn-As (r = 0.688)-indicates partial overlap in sources, negative correlation, such as Al-Pb (r = -0.603), has indicated distinct origins. Poor relationships, for instance, Cr-Ni with a correlation coefficient of -0.345, depict independent pathways. The missing data on Cd limits any conclusion. This result has emphasized the need for a targeted mitigation of the sources of those metals which are correlated and further study to address the data gaps and spatial variability. Different behaviors of pollutants require different strategies in order to manage contamination effectively.

To determine the likely sources of possibly harmful element pollution at Vasileva Lake, multivariate statistics were employed. Dendrogram analysis is critical for interpreting and understanding environmental samples, as it provides a clear and systematic method for clustering and visualizing complex data (Liang et al., 2023) (Fig. 5).

Therefore, dendrogram analysis is an indispensable tool for making sense of environmental datasets, guiding effective interventions, and enhancing our comprehension of ecological systems (Yongo et al., 2023). Dendrogram showing a hierarchical clustering of the trace metals using the complete linkage and correlation coefficient distance (Fig. 4).

It divides variables by similarity of behaviour or origin, offering insights into potential relationships and sources. Mn and Co make a very closely related cluster and merge early in the hierarchy. These may either come from natural geochemical processes or from mining.

Then, that cluster extends to Cr, Pb, As, and Zn, which divides further into two subclusters: Cr and Pb are probably urban runoff or vehicular emissions, and then As and Zn, which share a strong correlation and may have either anthropogenic or natural sources.

At higher levels of clustering, there is a grouping such that (Ni, Cu, Al) is merged with (Cd, Fe) at a resemblance of almost 62.26% on effect of similarity-high, showing a median relationship of these clusters. However, those for (Mn, Co) and (Cr, Pb, As, Zn) were joined at a very low resemblance of about 43.39%, signifying a weaker relationship between these larger groups.

The analysis shows a reflection on trace metals with significant values of correlation and venue sources associated with them, such as industrial activities and agricultural as well as geological processes in nature.

Distinction between clusters infers a difference in sources or behaviour with regard to environment. These findings would be very crucial in formulating monitoring strategies and mitigation measures which are group specific for effective management of trace metal contamination.

CONCLUSIONS

In this case study, the findings indicate that if consuming Vasileva Lake water directly can pose risks to consumers due to elevated levels of certain heavy metals (Pb, Fe, Ni, Cd, As, Cr, Cu and Mn) surpassing WHO limits.

The environmental analysis conducted on the water concludes that, for most of the metals specified by standards, the concentrations of heavy metal contaminants in these environmental components are above the allowed limits the maximum allowed limits, WHO limits.

Whereas, the environmental analysis conducted on sediment, concludes that, for most of the metals specified by standards, the concentrations of heavy metal contaminants in these environmental, components are below the maximum allowed limits, according to EPA limits.

These encouraging results imply that the locations under study must demonstrate adherence to recognized environmental norms, easing worries about heavy metal contamination. Continuous monitoring and adherence to environmental regulations will be crucial to ensure the sustained health and integrity of these ecosystems.

As a result, it is noted that human activity has increased the amount of heavy metal (loid) pollution in this research region. The main source of this pollution is the leaching of metals from various sources, including trash dumps, the manure of animals and poultry, and runoff from agricultural areas. High flow also occurs during the hot season, when dissolved oxygen levels are low and an anaerobic environment prevails. This causes heavy metals (loids)s to be released from the bottom sediment into the water column above, which can alter the concentration of metals in the sediment and water.

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