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INTEGRATED GEOSPATIAL ASSESSMENT AND GEOVISUALIZATION OF WATER AND SEDIMENT QUALITY IN AN ARTIFICIAL LAKE. INSIGHTS FROM SFERK, KLINA, KOSOVO

This study investigates the analysis of heavy metal content, as well as the physical and chemical properties of water and sediment in the artificial lake situated in Sferk, Klina, Kosovo. Sampling and analysis were conducted during the autumn of 2023. The inductively coupled plasma-optical emission spectrometry (ICP-OES) technique was employed to measure the levels of heavy metals. The contamination factors (*CF*) were calculated to evaluate the degree of heavy metal pollution. At the same time, the spatial interpolation technique (spatial resolution 1 m) in QGIS software was developed to spatially represent the distribution of heavy metals and other parameters across the study area. The results for water and sediment samples were compared with the WHO and EPA standards. The findings indicate significant variations in heavy metal concentrations, highlighting potential sources of contamination. *CF* calculations offer insights into pollution levels, assisting in identifying priority areas for remediation efforts, particularly in water samples. The comprehensive assessment provides valuable insights into the status of water and sediment quality in the artificial lake of Sferk, contributing to the understanding and management of environmental pollution and its impacts.

1. INTRODUCTION

Ecosystems, human health, and environmental quality are intricately linked to the management and control of water and sediment quality [1]. To increase water supply, the construction of artificial lakes is currently being undertaken. However, there are also

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other reasons for their constructions to enhance aquatic biodiversity and provide recreational opportunities, which play a vital role in sustaining these ecosystems [2]. Nevertheless, the proliferation of anthropogenic activities poses a significant threat to the integrity of these water bodies. As highlighted by Rajasekar et al. [3], with the escalation of industrial, agricultural, and urbanization processes, artificial lakes are increasingly susceptible to contamination. The distribution and total quantities of heavy metals in water and sediment need thorough investigation [4], as the dispersion of these trace elements presents a pressing concern for environmental management and pollution control efforts. Understanding the sources and concentrations of heavy metals is paramount [5] for implementing effective remediation strategies and safeguarding ecosystem health.

This study aims to investigate the levels of heavy metals in water and sediment samples collected from the artificial lake of Sferk, Klina, providing insights into the extent of contamination and potential risks to ecosystem health. By comparing the obtained results with international water quality standards and guidelines set forth by organizations like the World Health Organization (WHO) and the Environmental Protection Agency (EPA), this research will contribute to a better understanding of the status of water and sediment quality in the artificial lake of Sferk. Furthermore, Geographic Information System (GIS) mapping in this study seeks to spatially characterize the distribution of contaminants and identify potential sources of pollution [6,7]. Overall, this research underscores the importance of interdisciplinary approaches and scientific investigations in addressing complex environmental challenges and advancing our knowledge of water resource management and conservation practices in artificial lake systems.

2. MATERIALS AND METHODS

Study area. Kosovo has a continental climate characterized by pleasant summers (from 20 to 37 °C) and cold, snowy winters (from –10 to –26 °C). It is also divided into two big seasons: wet and dry. The dry season typically spans from March to September, while the wet season lasts until February [8]. For our study, we have chosen the artificial lake located in the village of Sferk, within the municipality of Klina, Kosovo. The artificial Lake of Sferk, also known as the Great Pit, is a prominent feature in the village of Sferk. Serving as a tourist attraction, the lake draws numerous visitors owing to its picturesque surroundings. Near this lake lies the bauxite mine, which commenced operations roughly six decades ago and ceased operations in 1990. Historical records estimate an annual bauxite production of approximately 100 000 tons from this mine [9].

Chemicals and sample digestion. For the metal analysis, we used standard solutions of high purity. For sediment analysis, a 2 g sample underwent digestion with 15 cm^3 of 69% HNO_3 followed by heating for 5 h at 130 °C until the volume was reduced to 2–3 cm^3.

The solution was filtered using the Whatman 41 filter paper. Its volume was adjusted to 100 cm^3 with deionized water.

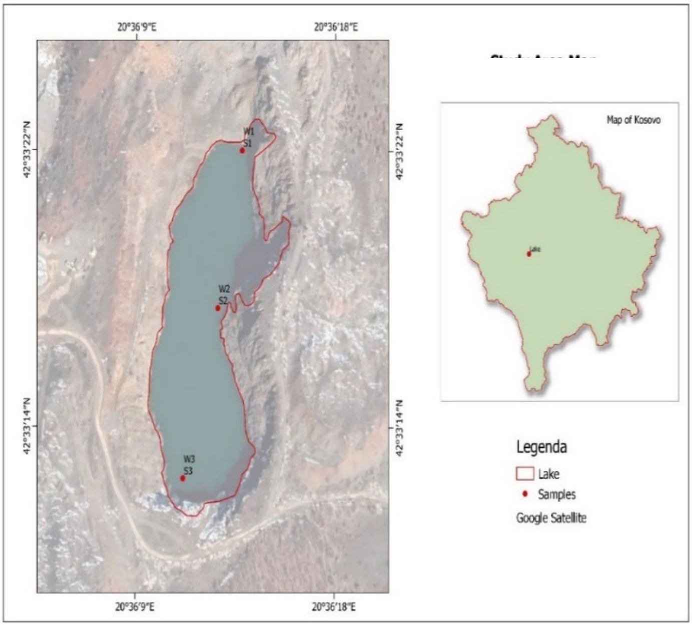

Fig. 1. Locations of the sampling points in the study area

Water samples were collected from three distinct sampling locations (Fig. 1), each yielding two water samples collected using glass bottles 2 dm^3 in volume. Before analysis, the samples underwent filtration to remove solid waste, then transferred into Teflon vessels. The samples were treated with 1 cm^3 of HCl and 5 cm^3 of HNO_3 before undergoing digestion in a microwave system. Their physical and chemical parameters were measured according to the specified standards described by Hendricks [10].

Instrumentation. Heavy metal (Pb, Zn, Cu, Cd, Ni, Cr, Mn and Fe) concentrations were measured with an inductively coupled plasma-optical emission spectrometry (ICP-OES) instrument. To ensure accuracy, each set of analytical samples underwent simultaneous processing with two spiked blanks and two method blanks. High-purity argon was employed for the ICP-OES spectrometer during the analysis.

Contamination factor (CF) is a metric employed to evaluate the contamination level of specific elements in environmental samples compared to a reference value [11].

$$CF = \frac{C_i}{B_i}$$

where C_i is the concentration of a metal, mg/kg or mg/dm^3, B_i its reference value, mg/kg or mg/dm^3. The classification of pollution degree according to the *CF* value is given in Table 1.

Table 1

Classification of the pollution degree according to *CF*

Degree	Range
Low	$CF < 1$
Moderate	$1 \leq CF < 3$
Considerable	$3 \leq CF < 6$
Very high	$CF \geq 6$

Geovisualization and geospatial analysis. To visualize spatially the *CF*, the Geographic Information System software (QGIS) was used. The geovisualization process was supported by the geospatial interpolation technique (Inverse Distance Weighted) in this software. The cartographic output was with 1 m spatial resolution. As well as an unsupervised methodology (Quantile) in QGIS was used to classify and interpret the thematic maps that represent the pollution level in the lake.

3. RESULTS AND DISCUSSION

Table 2 presents comprehensive data on the physicochemical properties of the water collected from the artificial lake in Sferk across three distinct sampling locations. The analysis of water samples revealed notable variations in physicochemical properties across different sampling locations. Water temperature ranged from 11.4 °C (W1) to 13.3 °C (W3), indicating a gradual increase. Dissolved oxygen (DO) decreases slightly from 8.8 mg/dm^3 (W1) to 7.8 mg/dm^3 (W3), suggesting potential oxygen depletion or organic pollution. Oxygen percentage varies (W1 116%, W2 94.5, W3 99%), reflecting fluctuations in oxygen saturation. Electrical conductivity (*EC*) increases from 389 to 425 µS/cm, indicating increased dissolved ion concentration. pH remains stable (6.68–6.98). Total dissolved solids (TDS) significantly increase from 198 mg/dm^3 (W1, W2) to 1224 mg/dm^3 (W3), indicating increased dissolved solids.

Chloride (Cl^-) ranges from 3.24 mg/dm^3 to 9.44 mg/dm^3, suggesting potential contamination sources. Chemical oxygen demand (COD) substantially increase from 33.6 mg/dm^3 (W1) to 74.2 mg/dm^3 (W3), indicating an increase in organic pollution. Biological oxygen demand (BOD) also increases significantly from 22.3 mg/dm^3 to 65.8 mg/dm^3, indicating higher biodegradable organic content. Total phosphorus (P_{tot}) shows minimal variation (from 0.154 to 0.169 mg/dm^3), suggesting stable nutrient levels with low eutrophication risk.

Similar trends were observed for nitrate (NO_3^-) and total nitrogen (N_{tot}). NH_4^+ levels increase significantly from 0.011 mg/dm³ (W1) to 0.398 mg/dm³ (W3), indicating potential pollution. Nitrite (NO_2^-) remains relatively stable. N_{inorg} shows low values, suggesting minimal impact.

Table 2

Physical and chemical properties of water samples from the artificial lake in Sferk

Parameter	Sample			Parameter	Sample		
	W1	W2	W3		W1	W2	W3
Water temperature, °C	11.4	12.7	13.3	N_{inorg}, mg/dm³	0.185	0.269	0.284
DO, mg/dm³	8.8	8.7	7.8	SO_4^{2-}, mg/dm³	8.88	7.98	8.89
O_2, %	96	94.5	99	PO_4^{2-}, mg/dm³	0.076	0.089	0.095
EC at 19 °C, µS/cm	389	387	425	TOC, mg/dm³	9.8	16.8	28.65
pH	6.68	6.96	6.98	Color of water	–	transparent	
TDS, mg/dm³	198	198	1224	TSS, mg/dm³	21	19.9	55.3
Cl^-, mg/dm³	6.52	9.44	3.24	F^-, mg/dm³	0.8	0.7	0.6
COD, mg/dm³	33.6	65.3	74.2	TH, °dH	16.65	17.54	16.54
BOD, mg/dm³	22.3	31.2	65.8	Ca^{2+}, mg/dm³	99.6	99.5	121
P_{tot}, mg/dm³	0.165	0.154	0.169	Mg^{2+}, mg/dm³	19.63	17.8	18.6
NO_3^-, mg/dm³	0.8	0.9	0.7	Air temperature, °C	19	21	22
N_{tot}, mg/dm³	0.324	0.336	0.356	HCO_3^-, mg/dm³	465.32	624.55	695.32
NH_4^+, mg/dm³	0.011	0.084	0.398	TUR (NTU)	9.89	11.2	13.65
NO_2^-, mg/dm³	0.032	0.012	0.036	$KMnO_4$, mg/dm³	6.84	11.56	16.74

Sulfates remain within acceptable limits, indicating limited impact on water quality, like phosphates with low values. Total organic carbon (TOC) has significantly increased from 9.8 mg/dm³ to 28.65 mg/dm³, which can suggest higher levels of organic compounds, likely originating from agricultural runoff or wastewater discharge, posing a risk to water quality and ecosystem health. Total suspended solids (TSS) have considerably varied from low to high values. The content of fluorides suggests natural geological sources. Calcium and magnesium may reflect differences in geological. Bicarbonates start from the lowest value of 465.32 mg/dm³ (W1) to 695.32 mg/dm³ (W3). Turbidity (TUR) has higher levels in water samples than EPA recommends. The potassium permanganate index ($KMnO_4$) starts from 6.84 mg/dm³ (W1 to 16.74 mg/dm³ (W3).

The observed variations in water quality parameters highlight the complex interplay of natural and anthropogenic factors influencing the environmental health of the artificial lake in Sferk. Analyzing the content of heavy metals in water is also very crucial as these elements can pose significant risks to human health and the environment [12]. Heavy metal pollution in the water can result from various industrial activities [13, 14], mining operations [15], and urban runoff [16], leading to adverse impacts on aquatic ecosystems and public health [17, 18]. Therefore, monitoring and assessing heavy metal levels is essential for ensuring water quality and environmental sustainability [19]. The statistical data on heavy metal concentrations, including mean, standard error of the mean (SE mean), standard deviation (StDev), minimum, maximum, first quartile (Q1), third quartile (Q3), and median, across three distinct water sampling points, are presented in Table 3.

Table 3

Statistical summary of heavy metal concentrations in water samples in the artificial lake of Sferk [mg/dm^3]

Variable	Mean	SE mean	StDev	Minimum	Q1	Median	Q3	Maximum	WHO[a]
Pb	0.482	0.230	0.399	0.101	0.101	0.448	0.896	0.896	0.01
Zn	0.1670	0.0225	0.0389	0.1230	0.1230	0.1810	0.1970	0.1970	3
Cu	0.2530	0.0612	0.1059	0.1320	0.1320	0.2980	0.3290	0.3290	2
Cd	0.0487	0.0223	0.0386	0.0120	0.0120	0.0450	0.0890	0.0890	0.003
Ni	1.638	0.153	0.265	1.365	1.365	1.654	1.895	1.895	0.02
Cr	0.8497	0.0946	0.1638	0.6680	0.6680	0.8950	0.9860	0.9860	0.05
Mn	0.435	0.170	0.295	0.101	0.101	0.546	0.658	0.658	0.4
Fe	1.803	0.126	0.217	1.564	1.564	1.856	1.989	1.989	0.3

[a]WHO – in drinking water.

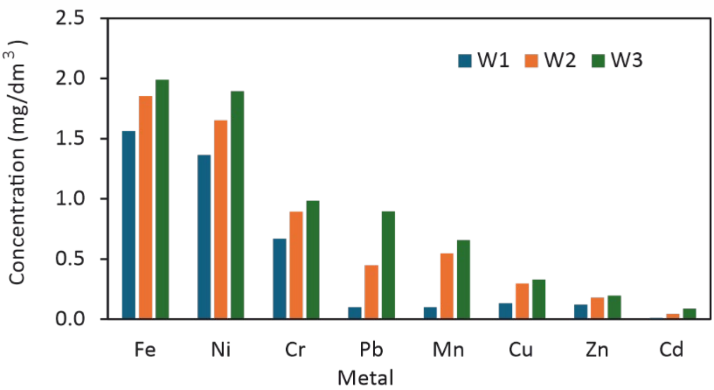

Fig. 2. Concentration of heavy metals in water of the artificial lake in Sferk in the sampling sites W1, W2 and W3

Figure 2 illustrates the concentration of Pb, Zn, Cu, Cd, Ni, Cr, Mn, and Fe at each sampling point. Significant variations in concentration levels can be observed. Lead concentrations, ranging from 0.101 mg/dm^3 to 0.896 mg/dm^3, surpassed the WHO recommendation of 0.01 mg/dm^3 in all sampling points. Interventions may be necessary to address these elevated levels and ensure public health safety. Zinc concentrations in our samples remain well below the WHO-recommended limit of 3 mg/dm^3, with values at W1 of 0.123, W2 of 0.181, and W3 of 0.197 mg/dm^3. However the copper concentrations are within WHO limits, continuous monitoring is advised to maintain levels below the maximum allowable threshold of 2 mg/dm^3 (from 0.132 mg/dm^3 to 0.329 mg/ dm^3).

Cadmium concentrations exceed the WHO guideline of 0.003 mg/dm^3 at all sampling points (0.012 (W1), 0.045 W2), and 0.089 mg/dm^3 (W3)), indicating potential health hazards. Immediate actions should be taken to minimize associated risks. Nickel concentrations also exceed the WHO standard of 0.02 mg/dm^3 at all sampling points (1.365 (W1), 1.654 (W2), and 1.895 (W3)), suggesting potential health risks. Smart strategies are necessary to mitigate nickel levels and protect public health.

Chromium concentrations are within WHO limits, albeit slightly elevated in all samples. Regular monitoring is advisable to prevent potential health risks associated with chromium exposure. Higher manganese concentrations have been detected recently in Kosovo, particularly in Pristina's drinking water. Samples from the artificial lake of Sferk exhibit even higher concentrations: 0.101 (W1), 0.546 (W2), and 0.658 mg/dm^3 (W3), exceeding the WHO recommendation of 0.4 mg/dm^3. Continuous monitoring is advisable to prevent potential health risks associated with manganese exposure. Iron concentrations range from 1.564 mg/dm^3 in sampling point W1 to 1.989 mg/dm^3 in sampling point W3.

Table 4

Statistical summary of heavy metal concentrations in sediment samples in the artificial lake of Sferk [mg/kg]

Variable	Mean	SE mean	StDev	Minimum	*Q*1	Median	Q3	Maximum	EPA[a]
Pb	6.15	1.19	2.06	4.06	4.06	6.19	8.19	8.19	<40
Zn	5.24	1.19	2.06	3.17	3.17	5.25	7.29	7.29	<90
Cu	3.376	0.884	1.531	2.041	2.041	3.039	5.047	5.047	<25
Cd	2.657	0.893	1.547	1.321	1.321	2.298	4.352	4.352	<5
Ni	32.74	7.99	13.85	17.46	17.46	36.30	44.45	44.45	<20
Cr	13.40	1.44	2.50	11.10	11.10	13.04	16.05	16.05	<25
Mn	4.63	1.24	2.15	2.67	2.67	4.29	6.93	6.93	750
Fe	60.89	7.62	13.20	48.40	48.40	59.59	74.70	74.70	

[a]EPA recommended values for environmental risk.

The sediment also serves as a very good indicator of water quality [20]. Sediment provides valuable information about long-term pollution and the potential risks posed by contaminants to aquatic ecosystems and human health [21]. It also serves as a sink for various pollutants [22] including heavy metals, pesticides, and organic compounds, which can accumulate over time [23, 24]. Table 4 shows statistical data on heavy metal concentrations, including mean, standard error of the mean (SE mean), standard deviation (StDev), minimum, maximum, first quartile (Q1), third quartile (Q3), and median, across three distinct sediment sampling points. Figure 3 illustrates the concentration of heavy metals (mg/kg) in three sediment sampling points for Pb, Zn, Cu, Cd, Ni, Cr, Mn, and Fe. The sampling points are identified by the labels S1, S2, and S3.

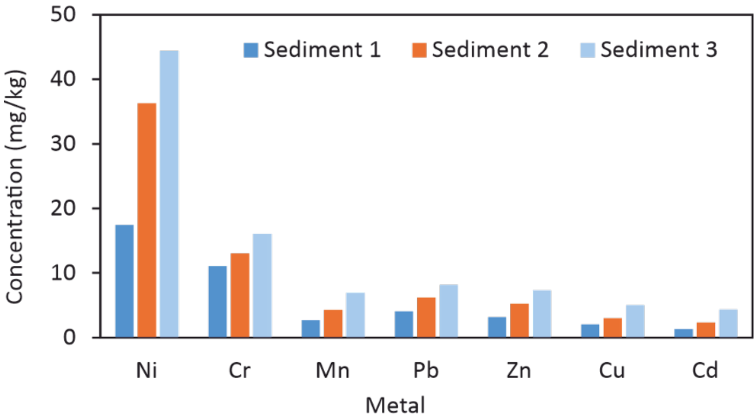

Fig. 3. Concentrations of heavy metals in the sediment of artificial lake in Sferk in the sampling sites S1, S2 and S3

Lead concentrations in the sediment samples range from 4.063 (S1) to 8.188 mg/kg (S3), all falling well below the EPA recommended limit of less than 40 mg/kg. Similarly, zinc concentrations also remain below the EPA recommended limit of <90 mg/kg, with values ranging from 3.175 (S1) to 7.289 mg/kg (S3), indicating minimal zinc contamination in the sediments. Copper concentrations vary from 2.041 (S1) to 5.047 mg/kg (S3), all below the EPA recommended limit of <25 mg/kg, suggesting low copper contamination in the sediments as well. Concentrations of cadmium vary from 1.321 (S1) to 4.352 mg/kg (S3). While these values are below the EPA recommended limit of <5 mg/kg, they are closer to the limit, suggesting potential cadmium contamination in the sediments.

Nickel concentrations exceed the EPA recommended limit of <20 mg/kg. They range from 17.456 (S1) to 44.453 mg/kg (S3) indicating significant nickel contamination in the sediments, requiring attention and remediation. Chromium and manganese concentrations observed in the sediment samples did not exceed the maximum allowable limits as per EPA recommendations. Chromium concentrations range from 11.099 mg/kg (S1) to 16.051 mg/kg (S3), all below the EPA recommended threshold of <25 mg/kg, indicating low to moderate levels of chromium contamination in the sediments. Similarly, manganese concentrations range from 2.6725 mg/kg (S1) to 6.933 mg/kg (S3), suggesting manganese contamination levels are within acceptable limits. The spatial distribution of metal concentrations at the sampling points provides information for identifying priority areas for environmental monitoring and management. By understanding the relationships between metal contamination levels and sampling locations, stakeholders can develop targeted mitigation strategies to address sources of pollution and minimize the potential risks to human health and ecosystem integrity.

To demonstrate the distribution and similarity of elements in water and sediment samples, the following dendrograms (Figs. 4 and 5) were utilized.

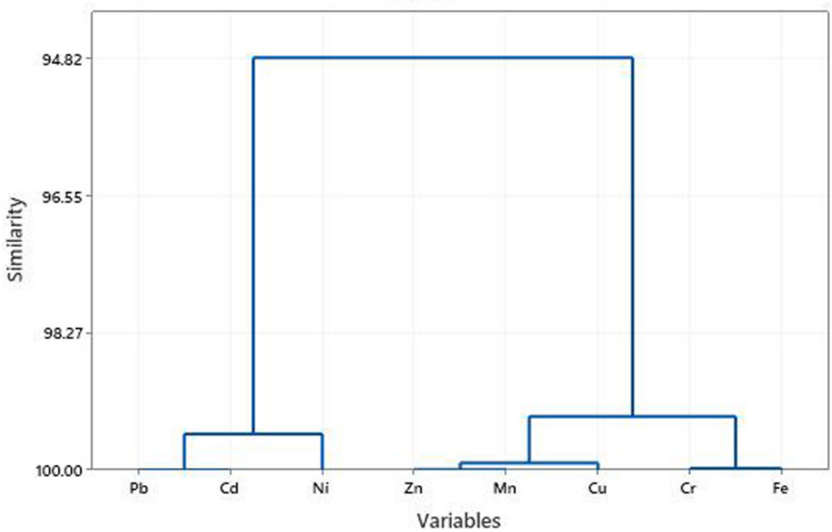

Fig. 4. Dendrogram distribution of heavy metals in water sampling sites

At the first sampling point (W1), relatively lower metal concentrations are observed across all elements compared to the other two (W2 and W3). This suggests that W1 may be situated in an area with limited anthropogenic activities or reduced inputs from sources of metal pollution. In contrast, sampling points W2 and W3 exhibit higher metal concentrations, indicating potential contamination from nearby anthropogenic activities or pollution sources. Higher concentrations of lead (Pb), zinc (Zn), copper (Cu), and cadmium (Cd) at W2 and W3 suggest inputs from industrial processes, urban runoff, or other anthropogenic sources. Additionally, the presence of nickel (Ni), chromium (Cr), and manganese (Mn) at higher levels further underscores the influence of industrial or urban pollution sources in these areas. In the case of sediment, the first sampling point recorded lower concentrations of heavy metals compared to the other two. This suggests that sampling point S1 is situated in an area with less human activity or reduced influence from sources of metal pollution.

All the elements occurred in moderate to high amounts at sampling site S2, including nickel, chromium, and manganese. The high concentrations of these metals may be from bauxite mining activities in the vicinity [25]. Also, attention should be paid to the presence of cadmium at S2 since this element is frequently used in industrial operations and can provide serious health hazards to humans [26].

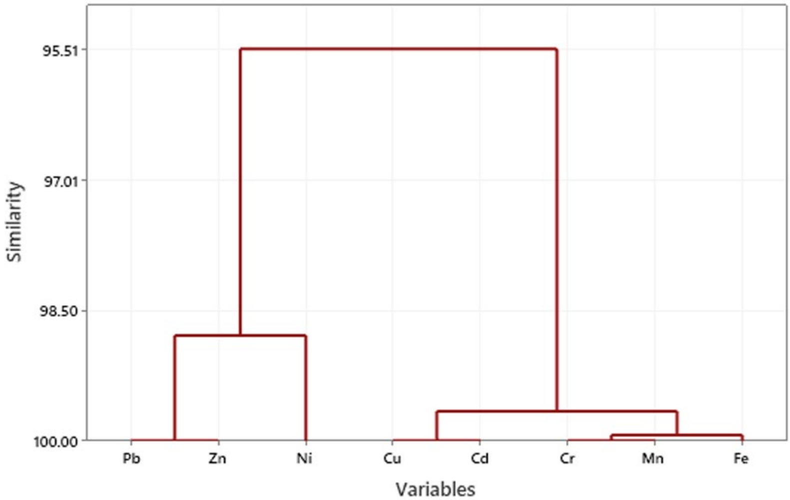

Fig. 5. Dendrogram distribution of heavy metals in sediment sampling sites

In contrast, sampling point S3 exhibits the highest metal concentrations among the three, indicating potentially significant pollution sources in the vicinity. The elevated levels of lead, zinc, copper, and cadmium suggest inputs from industrial activities [27] urban runoff, or other anthropogenic sources. Additionally, the high concentrations of nickel, chromium, and manganese at S3 further indicate the influence of industrial or urban pollution sources in this area.

4. VISUALIZATION AND GEOSPATIAL ANALYSIS

In our analysis of pollution distribution, we utilized geostatistical spatial interpolation techniques within the QGIS software platform. This enabled us to create maps that illustrate the spatial distribution of pollution more effectively. Specifically, we developed a thematic map to visually represent the pollution levels within the Artificial Lake in Klina, Sferk. This visualization was based on the CF, which was derived from measurements of water and sediment quality at multiple sampling points throughout the lake.

By integrating this dataset, our objective was to offer a comprehensive assessment of pollution dynamics within the lake environment. This methodology serves as a vital component of our quantitative monitoring and assessment strategy, facilitating the identification and mitigation of potential environmental concerns more efficiently. These findings are further illustrated by the QGIS maps presented in Fig. 6 for water samples and Fig. 7 for sediment samples.

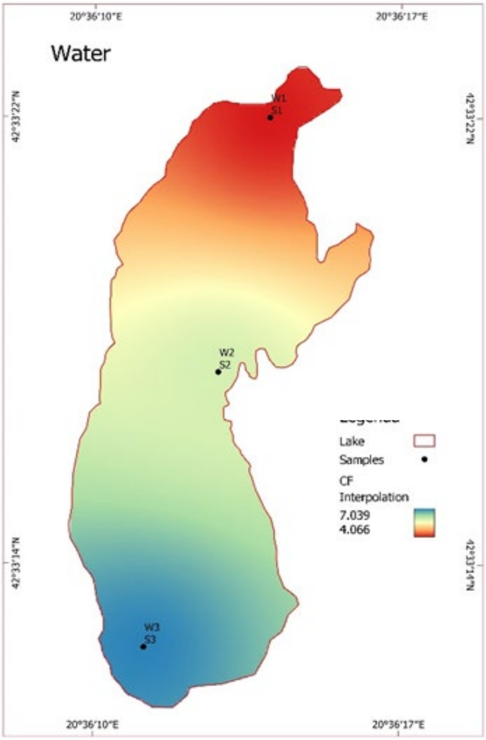

Fig. 6. Thematic map of water based on the *CF* index

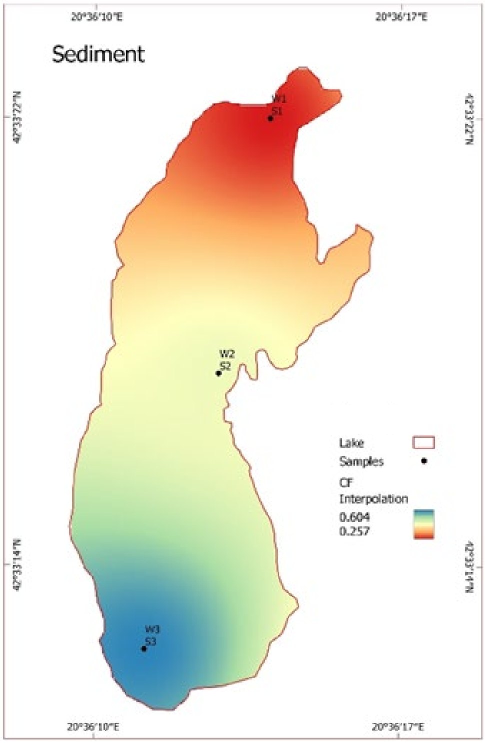

Fig. 7. Thematic map of sediment based on the *CF* index

Referring to the thematic map based on the *CF* index, the entire area of water in the artificial lake in Sferk Klina falls from a considerable degree of pollution to a high degree of pollution category (Table 1). It means the *CF* between 4.066 and 7.039.

5. CONCLUSION

Based on the findings including geospatial analysis and geovisualization with a spatial resolution of contamination level, there are notable discrepancies in the concentrations of heavy metals observed across various sampling points within the artificial lake of Sferk. The concentration of lead in water is higher than the guidelines set by the WHO at all sampling points, signalling potential health concerns for living organisms and the environment in general. Similarly, concentrations of cadmium and nickel in water exceed the standards set by the WHO, presenting potential risks. The concentrations of zinc and copper in water samples remain within the limits set by the WHO. The concentration of chromium remains within the limits set by the WHO. In sediment samples, higher heavy metal concentrations compared to those of the EPA have not been recorded.

The increased concentrations of heavy metals in water highlight the importance of ongoing monitoring and management efforts to safeguard water quality and ecosystem health. Addressing the sources and pathways of heavy metal contamination in both water and sediment is crucial for toning down potential risks to human health and the environment.

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