Düzce University Journal of Science and Technology
Düzce Üniversitesi Bilim ve Teknoloji Dergisi

14 (2), 2026, 396-408.
https://doi.org/10.29130/dubited.1744995

e-ISSN: 2148-2446
https://dergipark.org.tr/en/pub/dubited

Research Article

Heavy Metal Content and Water Quality Assessment of Kotum Stream

Çiğdem Özer[1*], Mehmet Cihan Aydın[2]

[1] Bitlis Eren University, Faculty of Arts and Sciences, Department of Chemistry, Bitlis, Türkiye.
ror.org/00mm4ys28

[2] Bitlis Eren University, Faculty of Engineering and Architecture, Department of Civil Engineering, Bitlis, Türkiye.
ror.org/00mm4ys28

*Corresponding author:
cozer@beu.edu.tr

Received: 17.07.2025
Revision: 24.01.2026
Accepted: 24.01.2026
Online: 19.04.2026

Abstract: Tatvan (Kotum) Stream is a water source formed by small branches fed from springs around Nemrut Mountain. The watershed is located in the high and rugged terrain of the Eastern Anatolian Plateau, where basaltic and andesitic rocks are common. Due to high snow cover in winter and rapid snowmelt in spring, seasonal changes are observed in the stream regime. Hydrologically, Tatvan Stream is one of the important tributaries flowing into Lake Van. The alluvium carried by the stream increases the flow rate in spring and contributes to delta formation around the lake. However, in recent years, increasing settlement and agricultural activities have threatened the water quality. This study examines heavy metals and other chemical parameters in water samples from Kotum Stream within the Lake Van Basin. Heavy Metal Pollution Index (HPI) and Metal Index (MI) were calculated to assess pollution levels. Additionally, other water quality parameters were evaluated and interpreted according to regulatory standards. The aim of the study is to provide a scientific basis for developing sustainable water management policies and environmental protection strategies for the region.

Keywords *Stream hydrology, Heavy metal, HPI, MI, Water quality*

I. INTRODUCTION

Freshwater resources are vital to the sustainability of life, and increasing population, industrial activities and agricultural practices are causing serious deterioration in water quality (Appiah-Opong et al., 2021). Surface and groundwater are under serious pressure from heavy metal pollution, increasing the need for environmental maintenance (Kar et al., 2008; Wongsasuluk et al., 2014). The presence of heavy metals in water not only disrupts the ecosystem balance, but also poses a direct threat to drinking water safety and public health (Al-Obaidi & Sarhat, 2022; Husain & Ali, 2024). This pollution, which poses serious risks to both the environment and human health, has led to the development of various indices for monitoring and evaluating water quality (Latif et al., 2025). Thanks to these methods, both the determination of pollutant sources and water quality assessment are based on a more scientific and sustainable approach (Gad et al., 2021; Hamahsaeed, 2024). Among these indices, Heavy Metal Pollution Index (HPI) and Metal Index (MI) are widely used in determining the drinkability level (Chaudhari et al., 2024; Jazza et al., 2022; Ojekunle et al., 2016) and general quality of water, and play a critical role in the evaluation of water resources in urban and rural areas, and in determining the effects of both seasonal changes and local pollution sources (Latif et al., 2025).

Extensive research in the literature shows that the presence of heavy metals in water resources is not only a local environmental issue but also a critical global challenge for environmental sustainability (Appiah-Opong et al., 2021; Hamidu et al., 2021; Ojekunle et al., 2016). Detailed analyses in river and lake systems highlight how seasonal changes and anthropogenic pressures increasingly affect water quality, threatening not only aquatic ecosystems but also biodiversity and public health (Mahapatra et al., 2020; Reza & Singh, 2010). Numerous studies emphasize that the rise in heavy metal concentrations in surface and groundwater can lead to long-term and often irreversible ecological damage (Appiah-Opong et al., 2021; Latif et al., 2025). This growing concern underscores the urgent need to move beyond academic assessments and to integrate heavy metal analyses and water quality indexes into concrete environmental management practices and sustainable policy frameworks (Khadija et al., 2021; Mahapatra et al., 2020).

This study aims to evaluate heavy metal contents through HPI and MI indices and support them with graphical presentations and analyzes the pollution status of a regional water source in the light of current findings in the literature. The aim of the research is to contribute to both national and international literature and to form the basis for the development of sustainable water management policies and environmental maintenance strategies in the relevant region.

Cite as: Özer, Ç., & Aydın, M. C. (2026). Heavy metal content and water quality assessment of Kotum Stream. *Düzce University Journal of Science and Technology, 14*(2), 396-408. https://www.doi.org/10.29130/dubited.1744995

This is an open access paper distributed under the terms and conditions of the Creative Commons Attribution-NonCommercial 4.0 International License.

II. MATERIAL AND METHOD

A. *Study Area and Sampling*

In this study, water samples were taken from a single fixed sampling point (n = 1) located in the nearest downstream section of the Kotum Stream just before it flows into Lake Van (38°28'45.84"N, 42°18'32.59"E). The chosen sampling point allows for consistent temporal monitoring because it carries the cumulative effects of inputs from the upstream, while also presenting a methodological limitation as it fails to capture spatial variability along the stream and therefore may miss local pollution sources in the upstream area.

Kotum Stream originates from spring-fed channels on the southern slopes of Nemrut Mountain and flows through a mixed land-use basin characterized by rangelands, scattered rural settlements, and small-scale agricultural fields. Potential pollution sources along the catchment include agricultural runoff (fertilizers and pesticides), domestic wastewater leakage from septic systems, and episodic inputs from roadside drainage, particularly during snowmelt and rainfall events. The basin is underlain predominantly by basaltic–andesitic volcanic rocks, which naturally influence ionic and trace-metal composition due to weathering processes (Oyan & Tolluoğlu, 2005). Hydrologically, Kotum Stream exhibits a snowmelt-dominated flow regime, with low winter discharge, sharp increases in March–May, and reduced baseflow in late summer, consistent with hydrological patterns reported for the Nemrut volcanic system and the Lake Van Basin(Coşkun, 2020; Üçler, 2022). The regional climate is continental with cold, snowy winters and dry summers; precipitation is concentrated in winter and spring, typically ranging from 700–900 mm annually (Climate-Data.org, 2025). These climatic and hydrological characteristics, combined with the basin's land-use structure, shape the spatial and temporal dynamics of heavy-metal transport and provide essential context for interpreting the seasonal water-quality variations observed in this study.

Sampling was performed once per month between July 2022 and June 2023, yielding a total of 12 individual sampling events. No composite samples were taken; each monthly sampling consisted of one grab sample collected under identical procedures. For seasonal evaluation, monthly samples were grouped as follows: summer (June–August), autumn (September–November), winter (December–February), and spring (March–May). In total, 12 water samples were analyzed for physicochemical parameters and heavy metals throughout the study period.

All sampling and preservation procedures were carried out in accordance with established international standards, including APHA Standard Methods for the Examination of Water and Wastewater Methods 3010 B, 3030 B, 3111/3120 (Baird et al., 2017). Water samples were collected as instantaneous samples in pre-acid-washed high-density polyethylene (HDPE) bottles, and the containers were rinsed three times with stream water before sampling. Immediately after collection, samples were stored in an insulated cooler at 4°C to minimize physicochemical changes. For heavy metal analysis, samples were acidified to pH < 2 with ultra-pure HNO_3 (65%, Merck) as recommended by APHA 3030 B. Following in-situ analyses at the sampling points, samples were brought to the Bitlis Eren University Environmental Problems Application and Research Center laboratory, acidified for heavy metal measurements, and stored under appropriate conditions for delivery to the Bitlis Eren University Science and Technology Application and Research Center.

B. *Analysis Methods*

B.1. Physicochemical Parameters

pH, temperature, dissolved oxygen (DO), and electrical conductivity (EC) measurements were performed in situ using a portable multiparameter instrument (Hach HQ40d Multimeter). Measurements were carried out as single-point measurements on samples taken approximately 20-30 cm below the water surface, following the procedures described in APHA Standard Methods (Methods 4500-H^+, 2550 B, 2510 B, and 4500-O) (Baird et al., 2017) and ISO 5667-6 (International Organization for Standardization, 2014) for river sampling. Instrument calibration was performed in situ using standard solutions recommended by the manufacturer prior to each sampling event.

For each monthly sampling event, field measurements were recorded once at a fixed sampling point located downstream of Kotum Creek, thus ensuring consistency across all samples.

Suspended solids (SS) content was determined in the laboratory using the gravimetric method according to APHA Method 2540 D (Total Suspended Solids, Dried at 103–105 °C). Samples were filtered through pre-weighed glass fiber filters, dried at 103–105 °C for 1 hour, cooled in a desiccator, and re-weighed to determine the mass of suspended solids (Rosado-Berrios & Bouldin, 2016; ASTM Committee D-19 on Water, 1960).

B.2. Metal Analysis

Water samples were filtered through 0.45 µm membrane filters immediately after collection, and stabilization was performed by adjusting the pH to <2 with ultrapure nitric acid (HNO_3), following APHA Method 3030 B (Baird et al., 2017) and ISO 5667-3(International Organization for Standardization, 2024) guidelines.

Digestion for total metal determination followed APHA Method 3010 B. Metal concentrations were quantified using

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) according to APHA Method 3125 (Metals by Inductively Coupled Plasma Mass Spectrometry). Instrument calibration, internal standardization, and quality-control procedures (blanks, duplicates, spikes, and SRM analyses) followed the QA/QC guidance outlined in APHA 2017 Standard Methods (Baird et al., 2017).

The selected metals (Na, Al, Fe, Zn, As, Cd, Co, Pb, Cr, Mn, Ni, Cu, Ca, Mg, K) were included in the analysis due to their hydrogeochemical relevance, ecological importance, and documented anthropogenic influence within volcanic and agricultural basins similar to the Kotum Stream catchment. Major ions such as Na, Ca, Mg, and K were analyzed because they represent fundamental indicators of water–rock interactions and reflect the geochemical signature of basaltic–andesitic terrains (Oyan & Tolluoğlu, 2005). Transition metals including Fe, Mn, Al, and Cu are known to be mobilized through weathering of volcanic lithologies, which dominate the Nemrut volcanic complex (Hayta & Firat, 2022). Trace elements such as Pb, Cd, Cr, Ni, Co, As, and Zn were selected because they are classified as priority pollutants in national and international drinking-water standards (Türk Standardları Enstitüsü, 1997; World Health Organization, 2022) and are frequently associated with agricultural runoff, septic leakage, vehicular emissions, and surface drainage (Hussain et al., 2025). Collectively, these metals provide a comprehensive representation of both natural geochemical processes and potential anthropogenic contamination sources affecting the stream.

It should be noted that Na, Ca, Mg, and K are not heavy metals, but rather major ions. To avoid conceptual ambiguity, these parameters have been evaluated under a separate category representing the overall ionic composition and water-rock interaction processes. In the heavy metal section, only trace and transition metals of ecological or regulatory importance (e.g., Fe, Mn, Al, Zn, As, Cd, Pb, Cr, Ni, Cu, Co) have been analyzed.

B.3. Heavy Metal Pollution Indexes

The Heavy Metal Pollution Index (HPI) and Metal Index (MI) were selected in this study because they provide complementary and well-established frameworks for assessing metal-related water quality in surface-water systems.

Heavy Metal Pollution Index (HPI); Heavy Metal Pollution Index (HPI) is an important indicator used to quantitatively assess heavy metal pollution in water resources. This index reflects the total impact of various heavy metals on water quality, allowing water to be classified in terms of drinkability and ecological suitability (Findik & Aras, 2023). HPI is a weighted index that integrates multiple metals into a single numerical value based on their relative importance and guideline limits, thereby enabling an overall evaluation of environmental quality and ecological suitability of water resources (Mahapatra et al., 2020; Reza & Singh, 2010). This index is particularly effective for comparing seasonal variations and identifying general pollution trends in rivers and lakes influenced by both natural geochemical processes and anthropogenic activities (Findik & Aras, 2023).

Equation 1 was used for HPI calculations.

$$HPI = \sum_{i=1}^{n} \left(\frac{W_i Q_i}{\sum W_i}\right) \quad (1)$$

where, Wi is weighting factor (1/Si), Qi (calculated using equation 2) is the sub-index of a heavy metal and n is the number of heavy metals measured.

$$Qi = \sum_{i=1}^{n} \frac{|Mi - Ii|}{(Si - Ii)} \quad (2)$$

where, Mi is measured metal concentration, Ii is ideal value (TS 266 standards) (Argun, 2025; Türk Standardları Enstitüsü, 1997), Si is standard limit value (Türk Standardları Enstitüsü, 1997; Mahapatra et al., 2020).

Metal Index (MI); It emphasizes the cumulative metal load relative to maximum allowable concentrations and is considered more sensitive to potential human health risks, especially when water resources are used or considered for drinking purposes (Badeenezhad et al., 2023). MI can indicate health-related concerns even when individual metal concentrations remain below regulatory thresholds, making it a valuable complement to HPI-based environmental assessments (Hamahsaeed, 2024). The equation 3 was used for MI calculations:

$$MI = \sum \frac{Ci}{(M.A.C.)} \quad (3)$$

where, Ci is measured metal concentration, MAC is the maximum allowable concentration (Badeenezhad et al., 2023).

For HPI and MI calculations, ideal values (Ii), standard values (Si), and maximum allowable concentrations (MAC) were defined separately for each metal, based on drinking water guideline limits. In line with common practice in surface water studies, ideal values for all trace metals were considered to be zero, while Si and MAC values were taken from internationally accepted drinking water guidelines. Only for Co metal, since there is no limit value specified in drinking water standards, the annual average limit value for rivers and lakes specified in the Turkish Surface Water Quality Regulation (TSWQR) (T.C. Çevre ve Şehircilik Bakanlığı, 2012) was used. All parameters used in the calculations are summarized in Table 1 along with their respective sources.

Table 1. Parameters used for HPI and MI calculations.

Metal	*Ii* (mg/L)	*Si* (mg/L)	*MAC* (mg/L)	Source
Al	0	2.0×10^{-1}	2.0×10^{-1}	TS 266 (Water Intended for Human Consumption: TS 266, Türk Standardları Enstitüsü, 1997)
Fe	0	2.0×10^{-1}	3.0×10^{-1}	
Mn	0	5.0×10^{-2}	1.0×10^{-1}	
Zn	0	5.0×10^{0}	3.0×10^{0}	
As	0	1.0×10^{-2}	1.0×10^{-2}	
Cd	0	5.0×10^{-3}	3.0×10^{-3}	
Pb	0	1.0×10^{-2}	1.0×10^{-2}	
Cr	0	5.0×10^{-2}	5.0×10^{-2}	
Ni	0	2.0×10^{-2}	7.0×10^{-2}	
Cu	0	2.0×10^{0}	2.0×10^{0}	
Co	0	3×10^{-4}	3×10^{-4}	TSWQR (T.C. Çevre ve Şehircilik Bakanlığı, 2012)

The parameters, threshold values, and interpretation criteria used in HPI and MI calculations are given in Table 2. The combined use of HPI and MI was specifically preferred for assessing metal-related pollution and associated ecological and human health risks, as these indices are designed to focus only on trace and potentially toxic metals. This eliminates the limitation of relying on a single index and allows for the simultaneous assessment of ecological water quality and human health risks. While general water quality indices such as the Weighted Arithmetic Water Quality Index (WAWQI) can provide an integrated assessment of physicochemical parameters, the primary objective of this study is to specifically assess metal-related pollution and associated environmental and health risks. Therefore, metal-focused indices (HPI and MI) were preferred over general indices to avoid dilution of metal-related effects by non-toxic major ions (Badeenezhad et al., 2023; Latif et al., 2025; Mahapatra et al., 2020; Reza & Singh, 2010).

Table 2. Threshold values and interpretation criteria used for HPI and MI calculations.

Index and Threshold Value	Interpretation	Reference
HPI < 100	Low metal pollution / Good water quality	(Mahapatra et al., 2020; Reza & Singh, 2010)
HPI ≥ 100	Critical heavy metal pollution	
MI < 1	Water suitable for drinking	(Badeenezhad et al., 2023; Hamahsaeed, 2024)
MI ≥ 1	Water unsuitable for drinking	
MI > 6	Seriously affected	(Sarhat & Al-Obaidi, 2023)

III. RESULTS AND DISCUSSIONS

Descriptive statistics of the heavy metal concentrations measured in monthly samples collected from July 2022 to June 2023 at the closest sampling point of Kotum Stream to its discharge into Lake Van are presented in Table 3.

Table 3. Descriptive statistics for monthly heavy metal data (All values are in µg/L (n = 12 months of observation).

Metal	Mean	Standard Deviation (SD)	Min.	Max.
Al	353.27	441.20	50.99	1460.46
Cr	1.70	2.27	0.19	7.86
Mn	61.76	30.06	23.74	115.91
Fe	1237.58	515.16	849.42	2710.35
Co	0.58	0.29	0.37	1.28
Ni	3.40	1.50	2.19	6.77
Cu	3.72	2.90	1.70	9.60
Zn	19.43	24.79	4.30	83.33
As	0.97	0.38	0.40	1.57
Cd	0.037	0.039	0.009	0.124
Pb	1.02	1.11	0.28	4.02

Seasonal values obtained from the averages of these monthly measurements were used in descriptive statistics, and box plot visualizations were employed to present the effect of seasonality comparatively based on statistical findings.

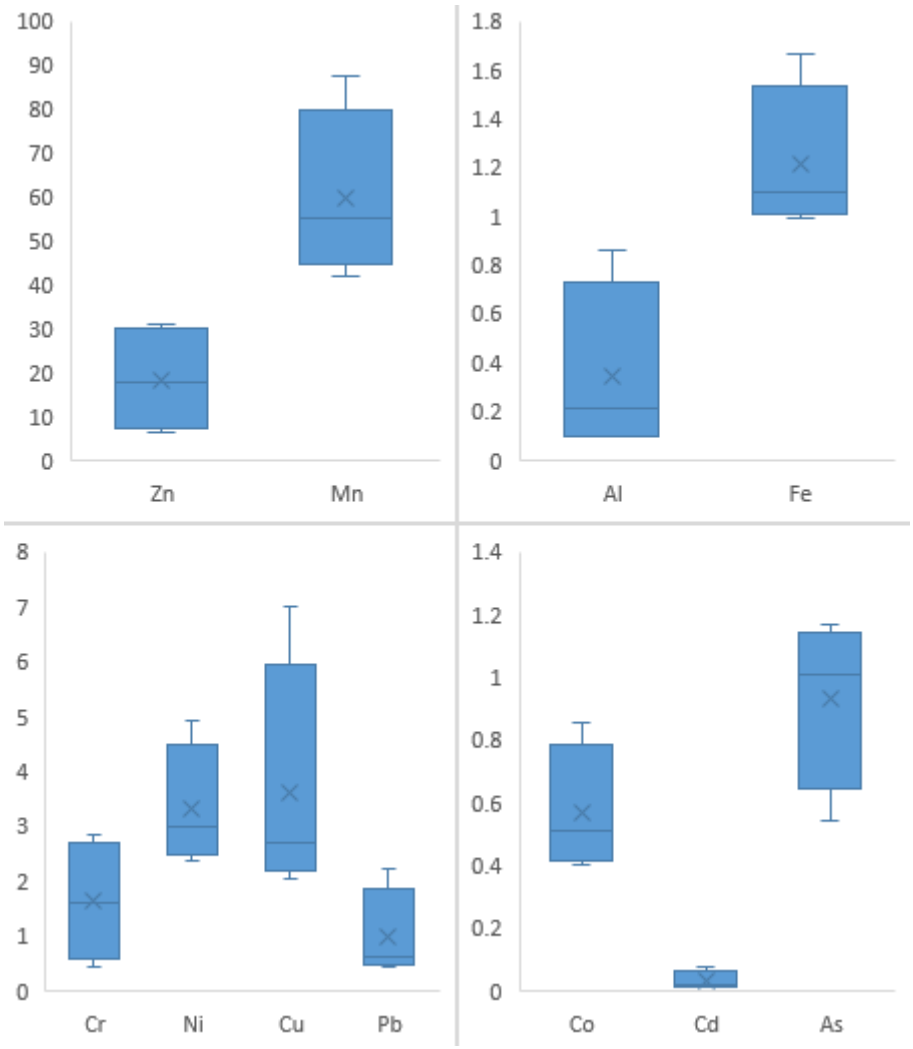


Figure 1. Seasonal variation of metal concentrations illustrated by box-plots.

Seasonal box plot visualizations (Figure 1) revealed significant differences in the interseasonal distribution of metal concentrations, demonstrating that the temporal dynamics of individual metals are not homogeneous. For example, Mn exhibited a much wider seasonal concentration range compared to Zn, showing high upper values suggesting increased mobilization or input in specific seasons. This type of seasonal variation in dissolved and particulate metals has been commonly reported in aquatic environments and is generally attributed to changes in hydrological conditions, flow, and biochemical processes throughout the year (Guo et al., 2022).

Similarly, Fe and Al showed significant interseasonal variability, with box plots showing significantly higher medians and wider interquartile ranges in specific seasons. This pattern is consistent with seasonal dynamics, where fluctuations in Fe and related elements are observed in response to river input and dilution effects associated with precipitation and seasonal runoff changes (Guo et al., 2022; Kır et al., 2007).

Trace elements such as Cu and Ni also show significant seasonal distribution, while Cr and Pb exhibit relatively narrower distributions. This suggests that Cu and Ni are more seasonally variable, possibly reflecting episodic sources or seasonally driven transport mechanisms.

As shows high median values and a wide distribution. This variability in As may be related to seasonal redox conditions, sediment–water interaction, or hydrochemical changes. Co exhibits moderate variation, while Cd shows limited seasonal fluctuation compared to other metals.

In general, observed seasonal patterns in metal concentrations reflect complex interactions between hydrological seasonality, physicochemical conditions, and metal-specific geochemical behavior. Seasonal variability in heavy metals is widely documented; some metals show higher concentrations during seasons of increased flow or water mixing, while others remain more stable due to their geochemical stability or lower mobility (Guo et al., 2022; Kır et al., 2007)

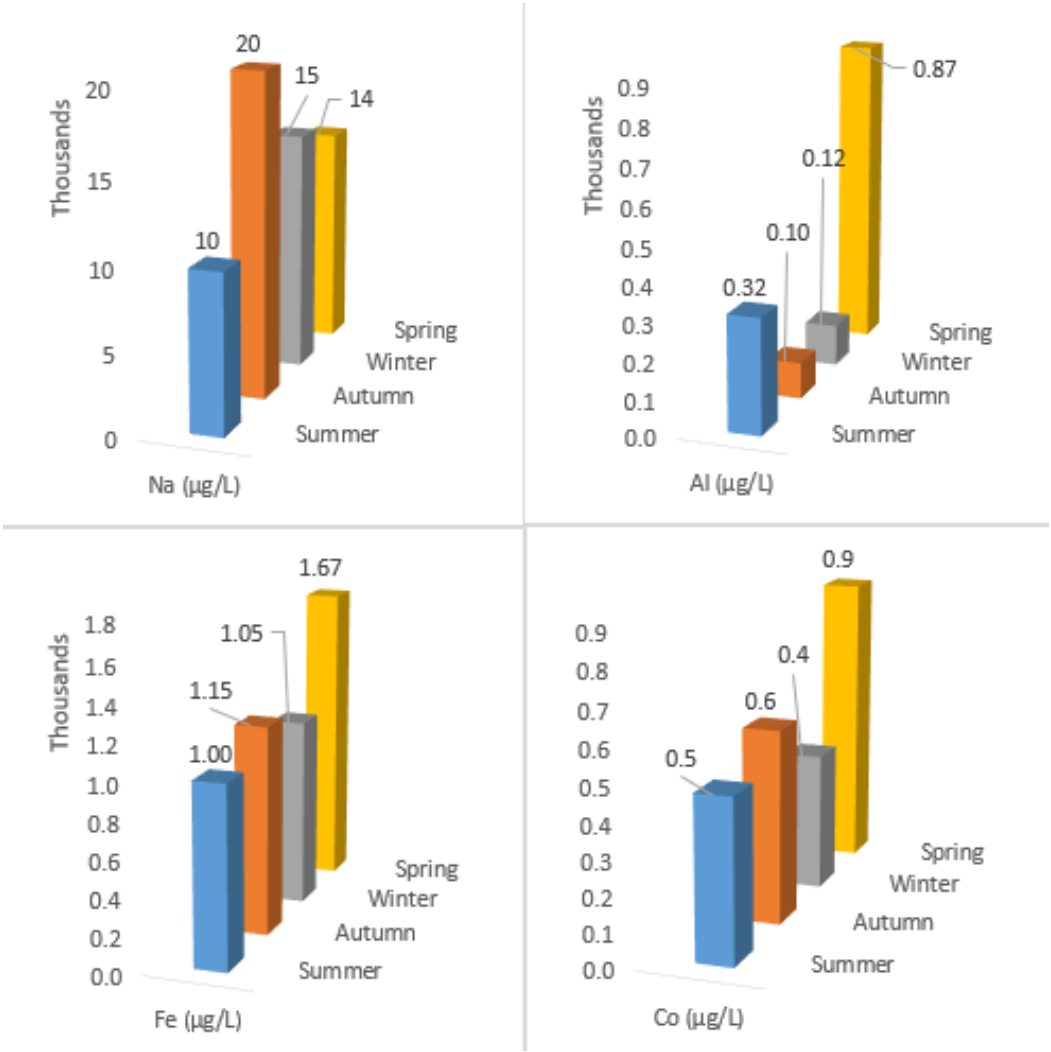


Figure 2. Seasonal Na, Al, Fe, Co changes.

As seen in Figure 2, the highest Na concentration was measured in the autumn season (20 000 µg/L) and the lowest in the summer (10 000 µg/L). This may be due to the end of agricultural activities in the autumn and the increase in the

saline content from surface runoff with drainage. The natural Na contribution from rocks with autumn precipitation in this region of Türkiye should not be forgotten because the data show that some rocks in the region are rich in sodium (Oyan & Tolluoğlu, 2005). Al concentration increased significantly in the spring (870 µg/L) and was measured lower than 320 µg/L in other seasons. It can be thought that melting snow and precipitation in the spring increased the Al level by washing the soil. The increase in Fe concentration observed in the spring may be due to surface runoff enriched with organic matter (increases Fe solubility) and the transport of iron oxides in the soil. Co was measured at the highest level in the spring with 0.9 µg/L and in the range of 0.3-0.6 µg/L in other seasons. In the spring, dissolved Co from the geological structure in the region (e.g. ultrabasic rocks) may have mixed into the water, and atmospheric precipitation (dust) may also be the reason for the increase in Co amount in this season.

Seasonal Cr, Mn, Ni, Cu changes of Kotum (Tatvan) Stream are given in Figure 3. The highest value for Cr was measured in the autumn season (2.9 µg/L), and the lowest value (0.5 µg/L) was measured in the winter season. It is thought that the probable Cr in the volcanic rocks was transported by seasonal erosion and surface flows in the autumn months. Starting from the summer season, Mn, which tends to increase in all seasons, reached its highest value of 88 µg/L in the spring. Since Mn is a metal that can be naturally dissolved from rocks, it is thought that the increase in the spring month is due to surface water flow and bottom sediment dissolution. It is thought that the Ni amount measured above the limit in the spring season may be due to the washing of ultramafic rocks with rich Ni content, agricultural activities in the region, especially the use of pesticides and fertilizers (Kahraman et al., 2012), and even waste leaking from septic tank systems. Cu, which reached a high value of 7.0 µg/L in spring, is estimated to be of both natural (mineralization, rock weathering) and anthropogenic (pesticides, fertilizer/pesticide residues carried by surface runoff from old mine sites) origin.

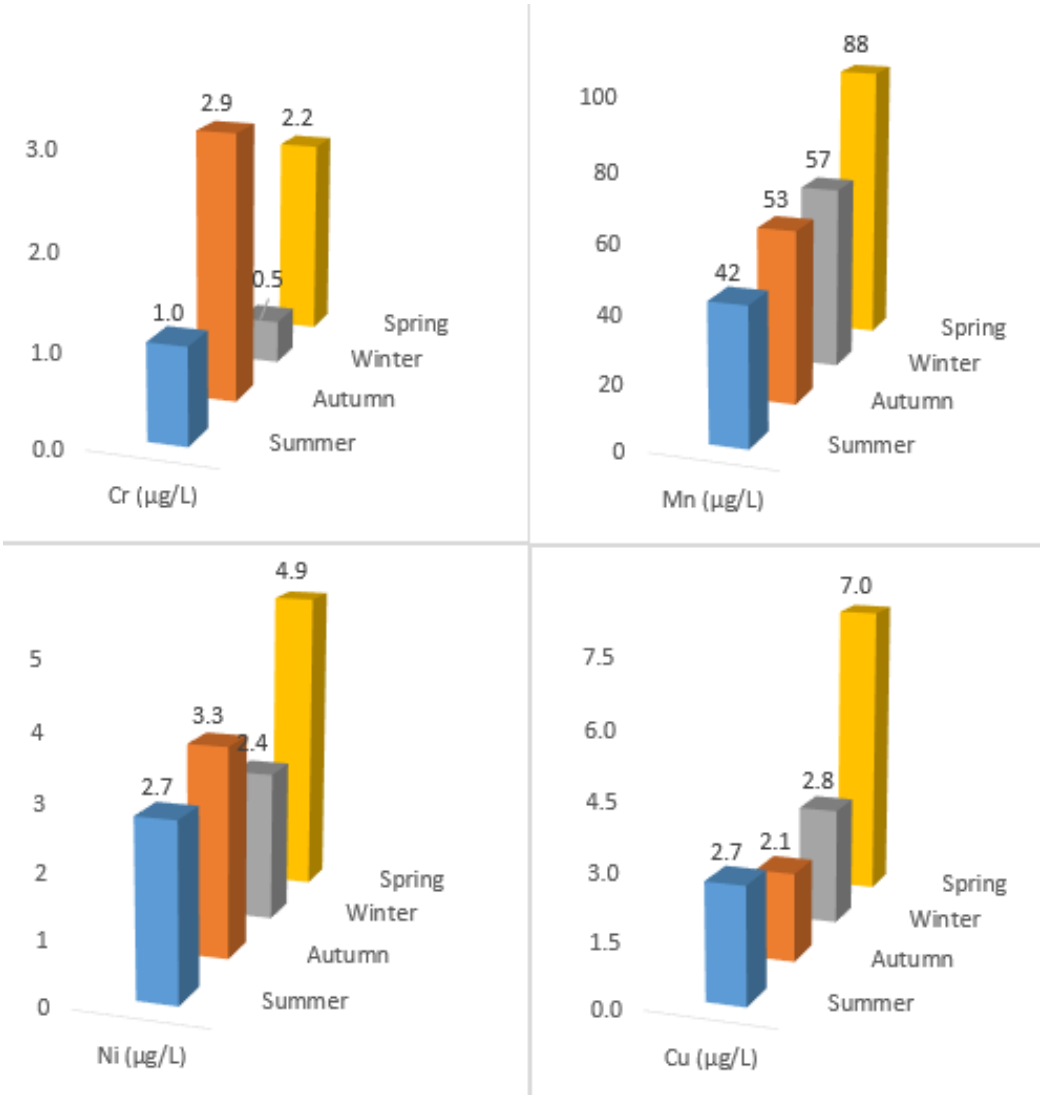


Figure 3. Seasonal Cr, Mn, Ni, Cu changes.

Figure 4 shows that Zn concentrations are significantly higher in autumn (31.3 µg/L) and spring (27.1 µg/L) seasons. Natural contribution from volcanic rocks in the region is possible. However, it is thought that the increases especially in autumn and spring are caused by agricultural activities or metallic wastes (e.g. galvanized pipes). As varied between 0.5-

1.2 µg/L in all seasons. Volcanic rocks in this region, especially thermal waters, are thought to be the source of As. The increase in Cd concentration, which is balanced in other seasons, observed in spring season can be interpreted as Cd accumulation caused by phosphate fertilizers used in agriculture. The increase in Pb amount observed in spring months is remarkable. The increase in these months can be interpreted as increased surface flow carrying Pb originating from vehicle emissions from road surfaces to water resources.

In Kotum Stream, pH values are on average 7.7 - 7.9 throughout the year, neutral - slightly basic. This is suitable for a natural surface water system to be healthy and lively (Ölmez & Saraç, 2009). The pH is at its lowest in February with 7.2, suggesting a slight increase in acidic load due to snowmelt and drainage.

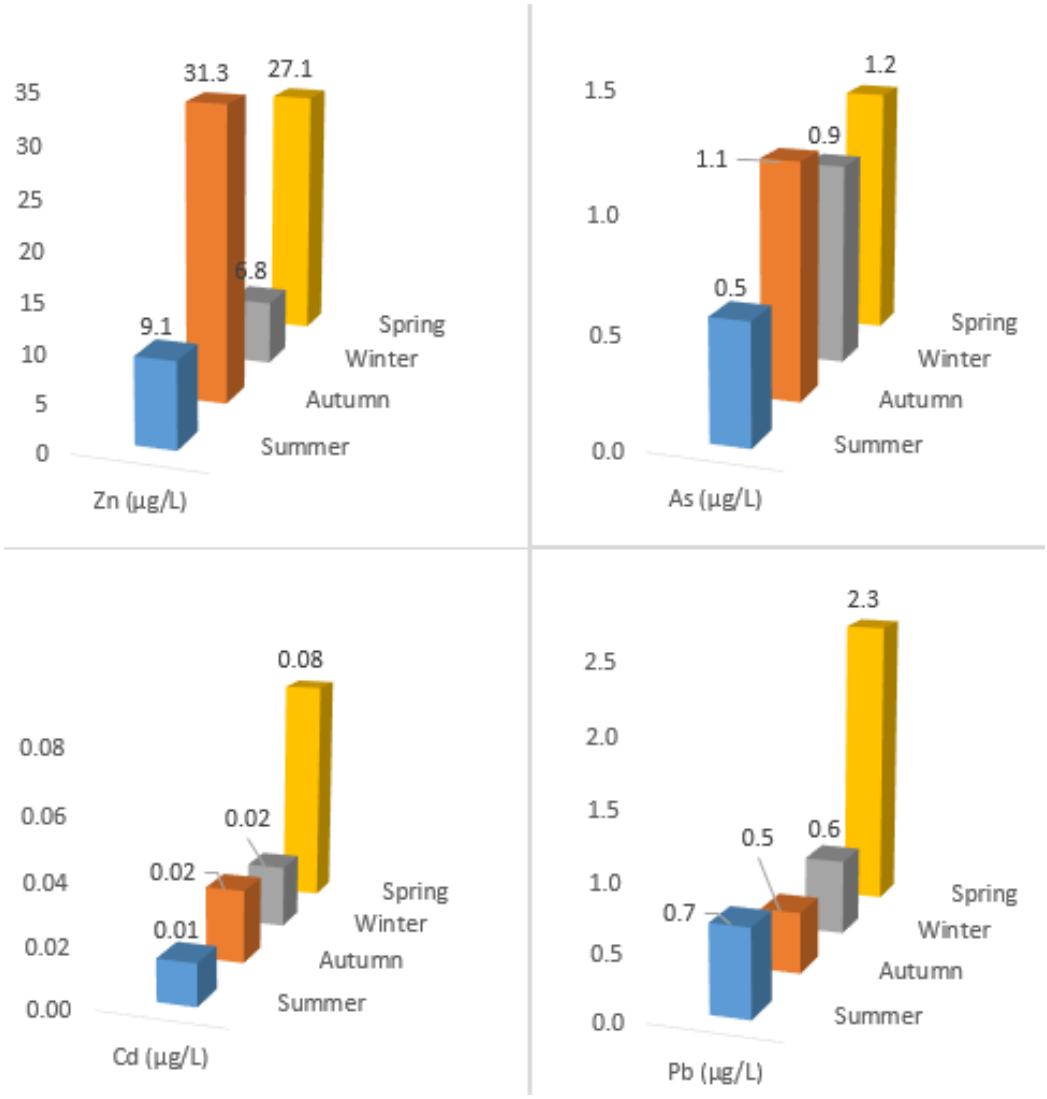


Figure 4. Seasonal Zn, As, Cd, Pb changes.

The dissolved oxygen, whose seasonal averages are given in Figure 5, is very high in February and January (8.9-9.2 mg/L), which is related to the high oxygen solubility of cold water. In March and April, O_2 has decreased significantly (5.4-5.6 mg/L). The O_2 level should not fall below 5 mg/L, where it is only approached the lower limit in March. This can be related to the increase in water temperature and oxygen consumption by melted organic matter loads (Nacar et al., 2020).

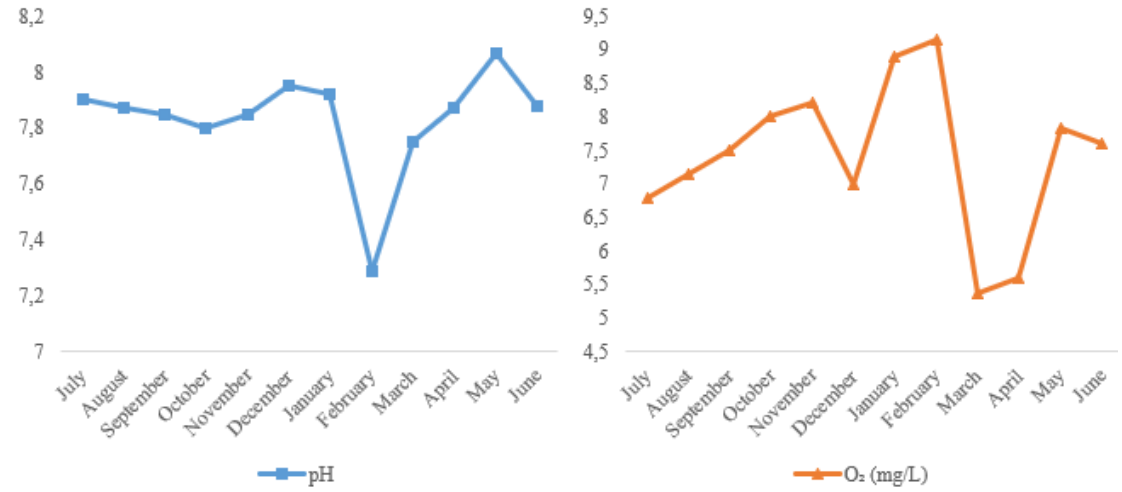


Figure 5. Seasonal pH and O2 changes.

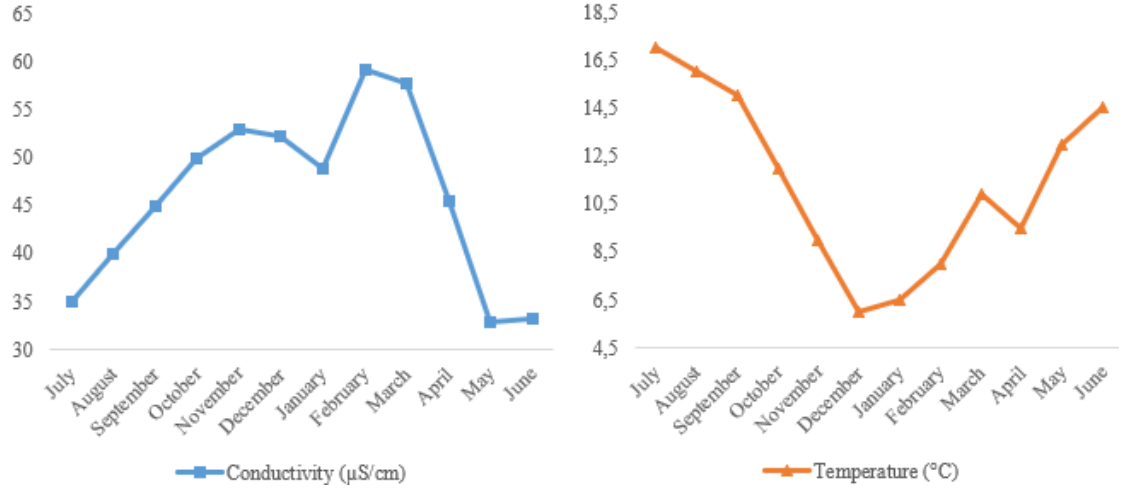


Figure 6. Seasonal temperature and conductivity changes.

As Figure 6 also indicates, water temperature is highest in summer and lowest in winter, as expected seasonally. Temperature values in summer ranged between 14.5–18°C, indicating that surface waters are warming due to the effect of sunshine duration and air temperature. Temperature gradually decreased in autumn (Sep–Nov) and dropped to 9°C in November. This shows that water temperature regularly decreases with the cooling of the weather. Temperature decreased to minimum levels (6–8°C) in winter (Dec–Feb). During this period, sunshine is low, evaporation is low, and stream volume is more stable. Temperature increased again with spring (Mar–May). 10.9°C was measured in March and 13°C in May, signaling a transition to summer.

The highest conductivity was observed in February and March. This may indicate the effect of dissolved minerals coming with melting snow water. From April onwards, the conductivity decreased rapidly (45.5 → 32.8 µS/cm); this shows that the ionic charge decreased with the dilution of the water. The range of 50–60 µS/cm indicates a very low salinity level (Korkmaz, 2025); therefore, it is possible to say that the Kotum Stream has an oligotrophic (nutrient-poor) character.

Table 4. Evaluation table for HPI and MI values across seasons.

Season	HPI Value	HPI Interpretation	MI Value	MI Interpretation
Summer	138	> 100 → Heavy metal pollution is at high levels, and water quality has severely deteriorated, with levels exceeding acceptable limits.	9	> 6 → Water is highly unsuitable for drinking; very high metal load; seriously affected
Autumn	165		10	
Winter	119		9	
Spring	253		18	

Table 4 presents the Heavy Metal Pollution Index (HPI) and Metal Index (MI) values calculated to assess the seasonal level of heavy metal pollution. These assessments were conducted in two stages to observe how a single metal exceeding the limit affects the results. HPI values, which were below the limit in all seasons, rose above the limit with the inclusion of Co metal in the assessment. MI values, while initially above the threshold, increased slightly, particularly in spring, with the addition of Co metal. This reveals that integrated pollution indices are significantly affected not only by high concentrations of metals but also by the cumulative effects of trace elements (Bhateria & Jain, 2016; Kır et al., 2007).

The widely accepted HPI threshold of 100 in the literature indicates that exceeding this threshold in all seasons shows that water quality is at risk in terms of heavy metal pollution (Bhateria & Jain, 2016; Sarhat & Al-Obaidi, 2023). The particularly high HPI value determined in the spring season (253) reveals that metal inputs and transport processes are more intense during this period. Increased rainfall, surface runoff, and strengthened sediment-water interaction in the spring are considered the main factors that increase the transport of heavy metals into the aquatic environment (Guo et al., 2022).

The MI results also showed a seasonal distribution consistent with the HPI. The significant increase in the MI value, especially in the spring, indicates that the total metal load increases during this period and that the water is not highly suitable for drinking purposes. Previous studies have highlighted that MI is an effective indicator for holistically assessing multiple metal pollution (Giri & Singh, 2014; Kır et al., 2007).

The increase observed in both HPI and MI values with the addition of Co metal to the analysis demonstrates that Co alone can significantly contribute to the total pollution load even if not present in high concentrations. This finding is consistent with previous studies arguing that trace metals should not be disregarded in integrated pollution indices (Bhateria & Jain, 2016; Li & Zhang, 2010).

Overall, the results reveal a significant seasonality in heavy metal pollution in the studied aquatic environment, with spring being the most critical period for both HPI and MI. The relatively lower index values obtained in winter can be attributed to weakened hydrodynamic conditions and limited metal transport (Güldiren & Tekin-Özan, 2017; Guo et al., 2022).

IV. CONCLUSION

In this study, the heavy metal concentrations and physicochemical parameters of the Kotum (Tatvan) Stream, measured over a one-year monitoring period, were evaluated seasonally; the level of heavy metal pollution was examined using a holistic approach with HPI and MI indices. The results clearly show that the distribution of heavy metals in the stream system is not homogeneous throughout the year, but rather exhibits significant seasonal variability.

A large portion of the metal concentrations reached their maximum values, especially during the spring. This increase observed in metals such as Al, Fe, Mn, Co, Cd, Pb, Cu, and Ni is associated with increased surface runoff due to snowmelt, strengthening of sediment-water interaction, and natural and anthropogenic inputs transported from the basin as a whole. In the autumn, relative increases were detected in Zn, Na, and Cr concentrations, which can be explained by surface transport after agricultural activities and geogenic contributions. Winter is generally the period with the lowest metal concentrations, which is consistent with low flow conditions and the dominance of dilution effects.

Comparative statistical findings presented by box-plot graphs have shown that metals behave seasonally not only in terms of average values but also in terms of distribution width and extreme values. This reveals that metal transport and accumulation processes are sensitive to hydraulic conditions and the geochemical properties of the metal.

Heavy Metal Pollution Index (HPI) results showed that the threshold value exceeded 100 in all seasons with the inclusion of Co metal in the analysis. This finding reveals that trace metals such as Co, even when measured at low concentrations, can make a significant contribution to the total pollution load in weighted index calculations. The highest HPI value was determined in the spring period, supporting the decisive role of seasonal transport processes on heavy metal pollution.

Metal Index (MI) results were above 6 in all seasons, and significantly higher in spring. This indicates that Kotum Stream water is unsuitable for drinking water use and that the total metal load poses serious risks to human health. The combined evaluation of HPI and MI results clearly shows that some conditions considered acceptable from an ecosystem perspective may not be equally safe for human health.

In terms of physicochemical parameters, pH, temperature, dissolved oxygen, and conductivity values generally fall within the limits typical of a natural stream system, indicating that Kotum Stream maintains its oligotrophic character. However, despite this positive picture, the pollution levels revealed by the heavy metal indices show that evaluating water quality solely with basic parameters may be insufficient.

In conclusion, it has been determined that heavy metal pollution in Kotum Stream is significantly seasonal, with the spring period being a critical monitoring period. Therefore, it is of great importance that water quality monitoring studies

in the basin be conducted with at least seasonal resolution; and that special measures be planned for snowmelt and high flow periods. Furthermore, the inclusion of trace metals, such as Co, which are often overlooked in most studies, in index calculations increases the accuracy and sensitivity of water quality assessments. The findings provide a scientific basis for sustainable water management, pollution control, and public health protection for Kotum Stream and similar basins.

DECLARATIONS

Acknowledgements: This work is supported by Bitlis Eren University Scientific Research Projects Coordinatorship within the scope of Independent Scientific Research Project (Project No. 2022.06).

Author Contributions: Conceptualization, M.C.A.; Methodology, Ç.Ö.; Validation, Ç.Ö.; Investigation, Ç.Ö. and M.C.A.; Resources, Ç.Ö.; Data Curation, Ç.Ö; Writing—Original Draft, Ç.Ö.; Writing—Review & Editing, Ç.Ö. and M.C.A.; Visualization, Ç.Ö.; Project administration, Ç.Ö. and M.C.A.; All authors have read and approved the final version of the manuscript.

Conflict of Interest: The authors declare no conflict of interest.

Supporting Institutions: This work is supported by Bitlis Eren University Scientific Research Projects Coordinatorship within the scope of Independent Scientific Research Project (Project No. 2022.06).

Ethical Approval: This study does not involve human or animal participants. All procedures followed scientific and ethical principles, and all referenced studies are appropriately cited.

Plagiarism Statement: This article has been evaluated for plagiarism and no instances of plagiarism were detected.

Use of AI Tools: The authors declare that no Artificial Intelligence (AI) tools were used in the creation of this article.

REFERENCES

Al-Obaidi, B. S., & Sarhat, A. R. (2022). Assessment of Darbandikhan Reservoir's water for different purposes by using (WQI), (HPI) and (MI) indices. *IOP Conference Series: Earth and Environmental Science*, *1120*(1), Article 012014. https://doi.org/10.1088/1755-1315/1120/1/012014

Appiah-Opong, R., Ofori, A., Ofosuhene, M., Ofori-Attah, E., Nunoo, F. K. E., Tuffour, I., Gordon, C., Arhinful, D. K., Nyarko, A. K., & Fosu-Mensah, B. Y. (2021). Heavy metals concentration and pollution index (HPI) in drinking water along the southwest coast of Ghana. *Applied Water Science*, *11*(3), Article 57. https://doi.org/10.1007/s13201-021-01386-5

Argun, Y. A. (2025). Examination of heavy metal concentrations and their interaction with anthropogenic sources in Ermenek Dam Lake (Turquoise Lake). *Environmental Geochemistry and Health*, *47*(2), Article 58. https://doi.org/10.1007/s10653-025-02367-2

Badeenezhad, A., Soleimani, H., Shahsavani, S., Parseh, I., Mohammadpour, A., Azadbakht, O., Javanmardi, P., Faraji, H., & Babakrpur Nalosi, K. (2023). Comprehensive health risk analysis of heavy metal pollution using water quality indices and Monte Carlo simulation in R software. *Scientific Reports*, *13*(1), Article 15817. https://doi.org/10.1038/s41598-023-43161-3

Baird, R. B., Eaton, A. D., & Rice, E. W. (2017). *Standard methods for the examination of water and wastewater* (23rd Ed.). American Public Health Association, American Water Works Association, Water Environment Federation.

Bhateria, R., & Jain, D. (2016). Water quality assessment of lake water: A review. *Sustainable Water Resources Management*, *2*(2), 161–173. https://doi.org/10.1007/S40899-015-0014-7

Chaudhari, M., Chotaliya, R., Ali, G., Pandya, A., & Shrivastav, P. (2024). Assessment of heavy metal contamination in the groundwater of Gujarat, India using the Heavy Metal Pollution Index. *Environmental Research and Technology*, *7*(3), 471–488. https://doi.org/10.35208/ERT.1433696

Coşkun, S. (2020). Trend analysis of precipitation in Van Lake closed basin. *Journal of Engineering Sciences and Design*, *8*(2), 521–532. https://doi.org/10.21923/JESD.685420

Findik, Ö., & Aras, S. (2023). Application of the metal pollution indices on surface waters for assessment of environmental risk: a case study for Damsa reservoir (Cappadocia, Türkiye). *International Journal of Environmental Science and Technology*, *20*(2), 1689–1698. https://doi.org/10.1007/s13762-022-04102-1

Gad, M., El-Safa, M. M. A., Farouk, M., Hussein, H., Alnemari, A. M., Elsayed, S., Khalifa, M. M., Moghanm, F. S., Eid, E. M., & Saleh, A. H. (2021). Integration of water quality indices and multivariate modeling for assessing surface water quality in Qaroun Lake, Egypt. *Water*, *13*(16), Article 2258. https://doi.org/10.3390/W13162258

Giri, S., & Singh, A. K. (2014). Assessment of surface water quality using heavy metal pollution index in Subarnarekha River, India. *Water Quality, Exposure and Health*, *5*(4), 173–182. https://doi.org/10.1007/S12403-013-0106-2

Güldiren, O., & Tekin-Özan, S. (2017). The seasonal variations of some heavy metals in water and sediment of Seyhan Dam Lake (Adana). *Journal of Yalvaç Academy*, *2*(1), 99–111.

Guo, W., Zou, J., Liu, S., Chen, X., Kong, X., Zhang, H., & Xu, T. (2022). Seasonal and spatial variation in dissolved heavy metals in Liaodong Bay, China. *International Journal of Environmental Research and Public Health*, *19*(1), Article 608. https://doi.org/10.3390/IJERPH19010608

Hamahsaeed, M. A. (2024). The using heavy metals pollution index (HPI) and metal index (MI) for Assessing quality of drinking water in Bardarash-Akre basin in Duhok governorate northern Iraq: Using heavy metals pollution index (HPI) for assessment quality of drinking water in Bardarash-Akre basin in Duhok governorate north Iraq. *Tikrit Journal of Pure Science*, *29*(2), 30–44. https://doi.org/10.25130/tjps.v29i2.1592

Hamidu, H., Halilu, F. B., Yerima, K. M., Garba, L. M., Suleiman, A. A., Kankara, A. I., & Abdullahi, I. M. (2021). Heavy metals pollution indexing, geospatial and statistical approaches of groundwater within Challawa and Sharada industrial areas, Kano City, North-Western Nigeria. *SN Applied Sciences*, *3*(7), Article 690. https://doi.org/10.1007/s42452-021-04662-w

Hayta, S., & Firat, E. (2022). Determination of heavy metal concentrations and soil samples of Betula pendula and Populus tremula in Nemrut Crater Lake. *International Journal of Secondary Metabolite*, *9*(4), 504–512. https://doi.org/10.21448/IJSM.1082781

Husain, S., & Ali, G. (2024). Groundwater quality assessment with respect to heavy metal content by using heavy metal pollution index (HPI) of Moradabad district, Uttar Pradesh, India. *International Journal of Environment and Climate Change*, *14*(6), 476–491. https://doi.org/10.9734/IJECC/2024/V14I64245

Hussain, F., Ahmed, S., Muhammad Zaigham Abbas Naqvi, S., Awais, M., Zhang, Y., Zhang, H., Raghavan, V., Zang, Y., Zhao, G., & Hu, J. (2025). Agricultural non-point source pollution: Comprehensive analysis of sources and assessment methods. *Agriculture*, *15*(5), Article 531. https://doi.org/10.3390/AGRICULTURE15050531

International Organization for Standardization (ISO). (2024). *ISO 5667-3:2024: Water quality — sampling — part 3: preservation and handling of water samples.* https://www.iso.org/standard/82273.html

International Organization for Standardization (ISO). (2014). *ISO 5667-6:2014: Water quality — sampling — part 6: guidance on sampling of rivers and streams.* https://www.iso.org/standard/55451.html

Jazza, S. H., Najim, S. S., & Adnan, M. A. (2022). Using heavy metals pollution index (HPI) for assessment quality of drinking water in Maysan province in southern east in Iraq. *Egyptian Journal of Chemistry*, *65*(2), 703–709. https://doi.org/10.21608/EJCHEM.2021.89658.4295

Kahraman, T., Alemdar, S., Alişarlı, M., & Ağaoğlu, S. (2012). Heavy metal levels of drinking water in Bitlis province. *Eurasian Journal of Veterinary Sciences*, *28*(3), 164-171.

Kar, D., Sur, P., Mandal, S. K., Saha, T., & Kole, R. K. (2008). Assessment of heavy metal pollution in surface water. *International Journal of Environmental Science and Technology*, *5*(1), 119–124. https://doi.org/10.1007/BF03326004

Khadija, D., Hicham, A., Rida, A., Hicham, E., Nordine, N., & Najlaa, F. (2021). Surface water quality assessment in the semi-arid area by a combination of heavy metal pollution indices and statistical approaches for sustainable management. *Environmental Challenges*, *5*, Article 100230. https://doi.org/10.1016/J.ENVC.2021.100230

Kır, İ., Özan, S. T., & Tuncay, Y. (2007). The seasonal variations of some heavy metals in Kovada Lake's water and sediment. *Ege Journal of Fisheries and Aquatic Sciences*, *24*(1), 155–158.

Korkmaz, P. (2025). *Determination of irrigation water quality of Mustafakemalpaşa Stream* [Master's thesis, Bursa Uludağ University]. https://uu245-102.uludag.edu.tr/bitstreams/e07d766d-1c88-4b19-b9b8-9343317ca5fc/download

Latif, M., Nasim, I., Ahmad, M., Nawaz, R., Tahir, A., Irshad, M. A., Al-Mutairi, A. A., Irfan, A., Al-Hussain, S. A., & Zaki, M. E. A. (2025). Human health risk assessment of drinking water using heavy metal pollution index: a GIS-based investigation in mega city. *Applied Water Science*, *15*(1), Article 12. https://doi.org/10.1007/S13201-024-02341-W

Li, S., & Zhang, Q. (2010). Risk assessment and seasonal variations of dissolved trace elements and heavy metals in the Upper Han River, China. *Journal of Hazardous Materials*, *181*(1–3), 1051–1058. https://doi.org/10.1016/J.JHAZMAT.2010.05.120

Mahapatra, S. R., Venugopal, T., Shanmugasundaram, A., Giridharan, L., & Jayaprakash, M. (2020). Heavy metal index and geographical information system (GIS) approach to study heavy metal contamination: A case study of north Chennai groundwater. *Applied Water Science*, *10*(12), Article 238. https://doi.org/10.1007/s13201-020-01321-0

Nacar, S., Mete, B., & Bayram, A. (2020). Estimation of daily dissolved oxygen concentration using multivariate adaptive regression splines methods. *Uludağ University Journal of the Faculty of Engineering*, *25*(3), 1479–1498. https://doi.org/10.17482/uumfd.750518

Ojekunle, O. Z., Ojekunle, O. V., Adeyemi, A. A., Taiwo, A. G., Sangowusi, O. R., Taiwo, A. M., & Adekitan, A. A. (2016). Evaluation of surface water quality indices and ecological risk assessment for heavy metals in scrap yard neighbourhood. *SpringerPlus*, *5*(1), Article 560. https://doi.org/10.1186/S40064-016-2158-9

Oyan, V., & Tolluoğlu, A. Ü. (2005). Na-Feldspar-rich leucogranitic rocks in the Bitlis Massif (Yolcular Metamorphic): A potential source for feldspar. *Journal of the Earth Sciences Application and Research Centre of Hacettepe University*, *26*(3), 1–11.

Ölmez, M., & Saraç, D. (2009). Su ürünleri için pH'nın önemi. *Ziraat Mühendisliği*, (353), 12–17.

Reza, R., & Singh, G. (2010). Heavy metal contamination and its indexing approach for river water. *International Journal of Environmental Science and Technology*, *7*(4), 785–792. https://doi.org/10.1007/BF03326187

Rosado-Berrios, C. A., & Bouldin, J. L. (2016). Turbidity and total suspended solids on the lower Cache River watershed, AR. *Bulletin of Environmental Contamination and Toxicology*, *96*(6), 738–743. https://doi.org/10.1007/S00128-016-1793-8

Sarhat, A. R., & Al-Obaidi, B. S. (2023). Assessment of heavy metal pollution in Sirwan River by heavy metal pollution index (HPI) and metal index (MI). *Water Conservation Science and Engineering*, *8*(1), Article 12. https://doi.org/10.1007/S41101-023-00187-Y

ASTM Committee D-19 on Water. (1960). Standard methods of test for suspended and dissolved matter (suspended and dissolved solids) in industrial water and industrial wastewater (D 1069–58). In *Manual on industrial water and industrial wastewater* (pp. 1–14). ASTM International. https://doi.org/10.1520/STP48540S

T.C. Çevre ve Şehircilik Bakanlığı. (2012). *Yerüstü su kalitesi yönetmeliği*. https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=16806&MevzuatTur=7&MevzuatTertip=5

Climate-Data.org. (2025). *Tatvan climate: weather Tatvan & temperature by month*. Retrieved December 11, 2025, from https://en.climate-data.org/asia/turkey/bitlis/tatvan-15386/

Turkish State Meteorological Service (MGM). (n.d.). Forecast cities. Retrieved December 11, 2025, from https://www.mgm.gov.tr/eng/forecast-cities.aspx

Türk Standardları Enstitüsü (TSE). (1997). *TS 266: Water intended for human consumption*. https://intweb.tse.org.tr/standard/standard

Üçler, N. (2022). Trend analysis of meteorological variables in the Lake Van Basin, Turkey. *Kocaeli Journal of Science and Engineering*, *5*(2), 194–204. https://doi.org/10.34088/KOJOSE.1104351

Wongsasuluk, P., Chotpantarat, S., Siriwong, W. & Robson, M. (2014). Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. *Environmental Geochemistry and Health*, *36*(1), 169–182. https://doi.org/10.1007/s10653-013-9537-8

World Health Organization. (2022). *Guidelines for drinking-water quality* (4th ed.). World Health Organization. https://www.who.int/publications/i/item/9789240045064