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Original Research

Contamination and Ecological Risk Assessment of Heavy Metals in Surface Sediments of the Munzur Stream, Turkey

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Abstract

The aim of the present study is to determine the heavy metal concentrations in the surface sediment between 2019-2020 in Munzur Stream,Turkey. The impact of pollution level in the study area was evaluated by geoaccumulation index (Igeo), Contamination Factor (CF), enrichment factor (EF), pollution ecological risk (PER) index, and pollution load index (PLI). The average amount of heavy metals detected in sediment in the study in mg/kg was, in descending order, Fe>Al>Mn>Ni>Cr>Zn >Cu>Pb>Cd>Hg. The data evaluated by several statistical methods indicated that the metals with a positive relationship between them in the Pearson correlation analysis and the elements of the same factor in the factor analysis were mostly the same. The comparison of the results with the sediment quality criteria showed that only the mean value of Mn and Ni exceeded the values of PEL. Heavy metal levels in Munzur Stream sediment exposed to domestic and agricultural wastes, agricultural fertilizers and pesticides, and mines were not high enough to pose a threat to aquatic life.

Keywords: heavy metal sediment quality, river, toxicity

Introduction

Freshwater resources worldwide are affected by various factors resulting from intensive anthropogenic activities [1]. These lotic ecosystems are among the freshwater bodies most vulnerable to pollution being responsible for the transport of industrial and municipal effluents and the flow from agricultural areas [2-3]. In addition, pollution and anthropogenic activities directly affect the water body due to the settlement of rivers. In addition, pollution sources may be pointed or distributed throughout the region with a scattered flow regime. In addition, many environmental problems, leachate from mining areas, agricultural irrigation, sewage, and heavy metals from wastes are pollution to water bodies [4]. The wastewater treatment plants built to prevent pollution are economically unviable, lead to water quality degradation, and reduce biodiversity [5]. Due to their toxicity and bioaccumulation ability; heavy metals are considered one of the most persistent pollutants in aquatic ecosystems [6]. While most heavy metals are considered toxic at higher concentrations, some of them have effects, albeit minor, on aquatic life. The pathway through the food chain poses significant environmental and health risks to invertebrates, fish, and humans [7-9]. Heavy metal pollution resulting from

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socioeconomic and industrial activities in river systems is a major environmental problem worldwide [10-11].

In a river system, sediment acts as a source and sinks for waterborne heavy metal pollution [12]. Heavy metals combine with suspended fine-grained particles and sink toward sediment in an aquatic environment, which complicates the physical and chemical interactions [13-16]. Therefore, much attention has been paid to surface sediments [17]. Moreover, these compounds are less mobile in the water column than in sediment [18-22]. Therefore, analyses of river and sediments play an important role in the evaluation of contamination strategies in aquatic environments [23-24]. Various statistical tools such as cluster, correlation, and geostatistical analyzes are used in the evaluation of heavy metals in sediments [25-31].

The Munzur Stream joins the Mercan Stream, which originates from the Mercan Valley and extends into the Munzur Mountains at a distance of 5 km in the Ovacık district and flows rapidly southward through deep and narrow valleys in some places. The river starts at coordinates 39°40'83''K and 39°23'44''D and ends at coordinates 39°25'42''K and 39°48'01''D. It then flows first into the Uzunçayır Reservoir and then into the Keban Reservoir. Munzur Stream is the largest source of fresh water in Turkey, which is used for drinking water supply, and is located very close to the gold mine at its origin.

In the present study, the accumulation of heavy metals in the surface sediment of Munzur Stream was investigated. The above stream is extensively used for drinking water, agricultural fields and livestock. In the present work, the surface sediment of Munzur Stream was investigated using statistical methods to determine the sources of anthropogenic and natural pollutants and to evaluate the toxicity level. The study investigated and analyzed the spread of heavy metal pollution and contamination for the first time.

Material and Methods

Sample Location and Sampling

Field studies were conducted for 12 months with monthly sampling between February 2019 and January 2020. The study sampling sites are shown in Fig. 1. Station 1 is the sampling location at the upper end of the stream. Samples were collected at 9 different stations on Munzur Stream. An Ekman Dredge grab sampler (20 × 20 × 20 cm) was used to collect sediment samples from 0-10 cm depth at all stations. Samples were stored in polyethylene bags at -20ºC in a laboratory freezer to avoid deterioration of the sediment chemical structure.

Surface sediment core samples cut into 5-cm-thick slices were placed in Petri dishes, dried at 60ºC for 24 hours, and crushed to powder in a mortar. Metal analyses were performed using an ICP-MS instrument at Bureau Veritas Analytical Labs, Canada. Reference material, duplicate measurements and blank sample measurements were performed to test the validity and reliability of the metal analyses (Table 1). EF, CF, I_{geo} were used to detect metal deposits of anthropogenic origin.

Analytical Methods

$$EF= \left[\frac{Cn\ sample}{CAl\ sample}\right] / \left[\frac{Bn\ Background}{B\ Al\ background}\right]$$

Here, as before, Cn is the aluminum concentration, Bn is the background metal, B_{Al} is the background Al. The results obtained were evaluated as follows: EF<2 deficiency to minimal enrichment, EF = 2-5 moderate enrichment, EF = 5-20 significant enrichment, EF = 20-40 very high enrichment and EF>40 extremely high enrichment [32].

CF was calculated this formula

$$CF = \frac{Metal\ concetration}{metal\ background\ value}$$

The obtained results were evaluated as follows: CF<1 low contamination, 1≤CF<3 moderate contamination, 3≤CF<6 contamination and CF>6 very high contaminations [33].

Ecological Risk Index

I_{geo} is an ecological risk index that evaluates the level of pollution caused by metals and whether the source is based on natural or anthropogenic effects. I_{geo} calculations were performed Müller Method [34].

Thus: $I_{geo} = \log 2 \left[\frac{Cn}{1.5Bn}\right]$

Where Cn corresponds to the amount of metal measured and Bn corresponds to the value of the continental crust of the metal. The values obtained were evaluated as follows: $I_{geo} \leq 0$ not contaminate, $0<I_{geo}<1$ uncontaminated to moderately contaminated, $1<I_{geo}<2$ moderately contaminated, $2<I_{geo}<3$ moderately contaminated, $4<I_{geo}<5$ strongly contaminated to extremely contaminated, $I_{geo} \geq 5$ extremely contaminated [35].

PLI was used to calculate the quality of the sediments based on their metal values [36] as follows: PLI = $(CF1 \times CF1 ... CFn)^{1/n}$

CF stands for the contamination factor and n for the number of elements used. The normal PLI value in the sediment was determined and this value indicates that there is no contamination, but the risk of contamination increases when the value of 1 is exceeded [37]. The Potential Ecological Risk Index (PER) was also used to evaluate the toxicity of metals in the sediment

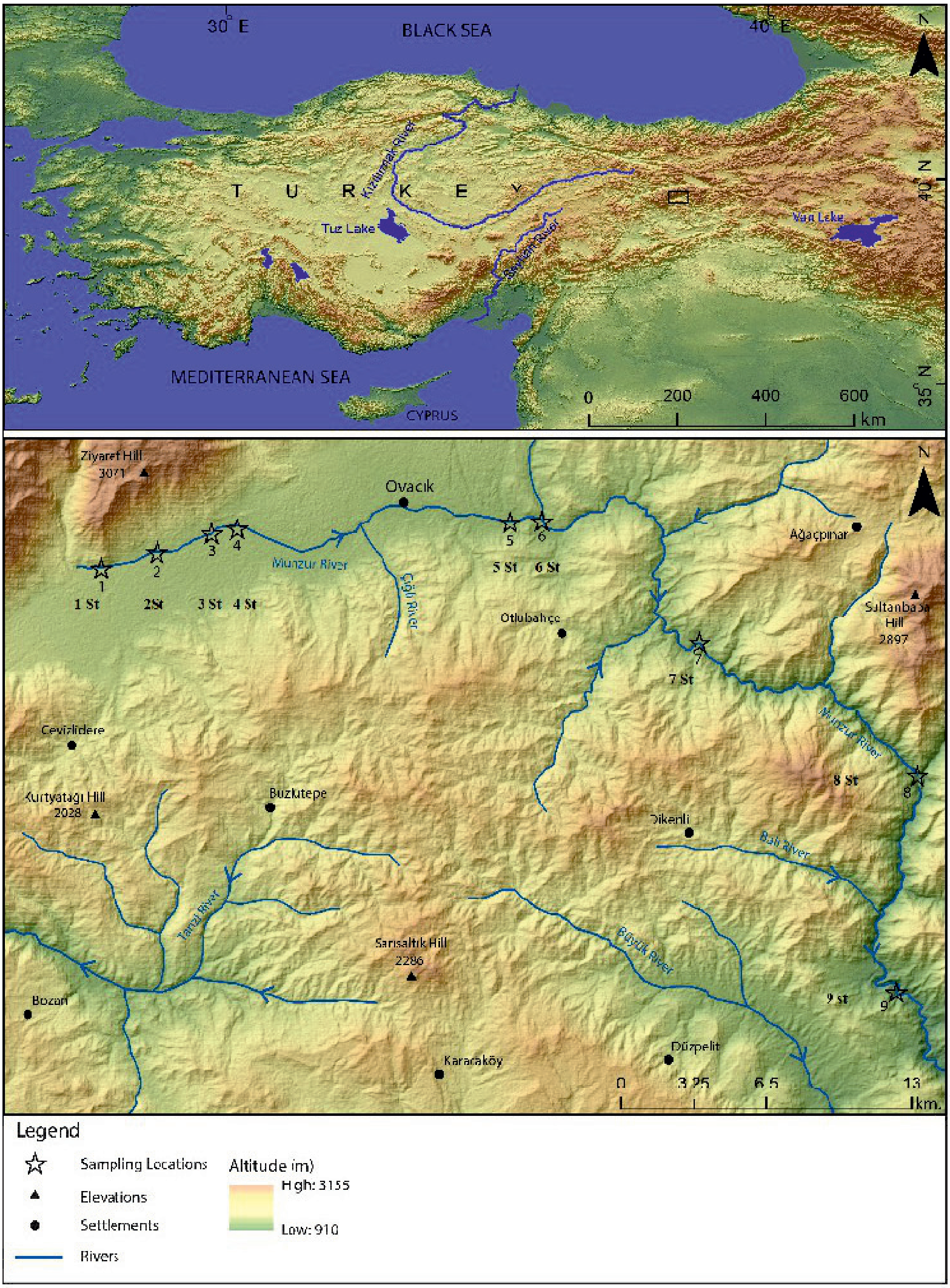

Fig. 1. The location of stations on Munzur River.

[38]. The formula PER for a single heavy metal is as follows:

$$PER = \sum E_f^i$$

Statistical Analysis

Differences between stations and months were analyzed using analysis of variance. The one-way test ANOVA and Pearson's correlation test were used to determine the relationships between the variables used

Table 1. Concentrations of heavy metal (mg/kg dry weight)sediments of Munzur Stream.

St. Num (St)	1	2	3	4	5	6	7	8	9
Cu	33.25	22.75	31.00	32.50	18.75	21.25	21.25	4.50	23.00
Pb	50.75	27.25	108.25	15.75	19.75	20.25	19.00	9.75	17.00
Zn	77.50	71.25	53.00	29.75	39.25	34.50	35.50	17.50	30.00
Ni	116.2	71.25	97.75	243.5	555.0	62.00	376.5	21.50	462.5
Mn	982.5	542.5	657.5	555	717.5	607.5	527.5	133.0	607.7
Fe	179471	125858	111178	126132	76949	131182	169703	22973	71006
As	2.3	2.6	2.2	2.0	2.2	2.4	2.8	1.51	2.1
Cd	3.09	1.99	1.76	1.23	1.58	1.20	1.29	0.92	1.25
Cr	128.8	68.3	107.8	169.3	315.0	79.8	195.0	3.0	221.0
Hg	0.028	0.024	0.026	0.027	0.034	0.019	0.002	0.002	0.02

in the data sets. Principal component analysis was performed using Statgraphics to evaluate the sources of trace elements in the sediment cores. Cluster analysis (CA) using Ward's method with Euclidean distances was applied to group sampling sites and similar features.

Results and Discussion

The environmental data are important to determine the degree of pollution and to interpret the geochemical data. Table 1 shows the heavy metal distribution values by station. The average abundance of metals (mg/kg) was in the following order: Mn>Ni>Cr>Zn>Pb>Cu>As>Cd>Hg. The highest values for the metals Cu, Zn, Mn, Cd and Hg were found in station 1. The highest values for Fe and Pb, and Cr and As were found at station 3 and station 5, respectively. The highest value for Ni was observed at station 7. Comparison of metal concentrations in the sediment with background values showed that the surface was moderately contaminated except for Cr, Mn, Ni, and Cu at station 8. While the Pb concentration at station 3 was considered highly polluted, no pollution was observed at the other stations [38-39] (Table 1).

The annual average of Mn in sediments collected monthly from the station in Munzur Stream was 592 (mg/kg). The highest value of 982 (mg/kg) was recorded at station 1 (Table 1). In addition, the sediment quality criteria (460 (mg/kg)) given by [40] 1993 were not exceeded only at station 6.

In addition, the mean value of the element Ni was 222.97 (mg/kg). The corresponding lowest value was found at station 7 with 21.50 (mg/kg) and the highest value at station 5 with 555 (mg/kg).

Iron (Fe) is the most abundant element in the earth's crust, amounting to an average value of 47000 (mg/kg) [41]. Similarly, in the present study, Fe was the most abundant element in the sediment, with an average value of 104373 (mg/kg). The minimum Fe value was 22973 (mg/kg) at the eight station, and the maximum value was 17941 (mg/kg) at the one station. Based on these data, it could be ensured that the observed river sediment level did not pose a threat to the aquatic ecosystems.

Copper (Cu) is an important micronutrient for aquatic life in freshwater and sediments; however, in high concentrations it causes toxicity. Cu is naturally released into the environment by volcanic eruptions and decomposition of plants, but also by human activities, municipal and industrial effluents. Cu is sparingly soluble in water, but is readily adsorbed and eventually accumulates in sediments. The amount of Cu accumulated in sediments reflects the degree of water pollution [42]. The average annual amount of copper (Cu) observed in the present study was 23.14 (mg/kg). The lowest value was found to be 4.50 (mg/kg) at station 7 and the highest value was 33.25 (mg/kg) at station.

The average annual amount of zinc (Zn) in sediment was 43.14 (mg/kg). The maximum value was found to be 77.50 (mg/kg) at station 1 and the minimum value was 17.50 (mg/kg) at station 7. These values were significantly lower than the naturally found zinc value (100 (mg/kg) in the sediment [43]. It can be concluded that the sediments of the basin were not exposed to Zn contamination.

The element cadmium (Cd) is not essential for living organisms, causes genetic and environmental toxicity in animals, and impairs plant growth. Generally, it is released into the environment by power plants, metal industry, geological weathering, atmospheric precipitation, phosphate fertilizers, burned solid wastes, and toxic wastes from industrial plants and sewage system [44, 45]. The annual average of the amount of Cd detected in river sediment was 1.59 (mg/kg). The lowest value was found to be 0.92 (mg/kg) at station 7 and the highest value was 3.09 (mg/kg) at station 1.

Similarly, lead (Pb), another toxic element that is not essential to living things, spreads naturally and through human activities in the environment. The main sources of lead release include vehicle exhaust, volcanoes, airborne soil particles, forest fires, solid waste incineration, industrial waste, lead-based dyes, and pesticides [43]. The natural Pb concentration in the Earth's crust varies between 15 and 20 (mg/kg) [43]. The annual average of Pb detected in the sediment was 22.44 (mg/kg), with the exception of Station 2. The Pb levels measured in the current study were similar to the average value in the Earth's crust. Overall, the Pb levels detected in the river sediment did not pose a threat to the aquatic ecosystem.

Ecological Risk Index

Igeo was used for heavy metal measurement. The study area varied between I-geo grades, metals, and stations for sediment. Pb, Zn, As, Cr, Cd, Hg, Cu, Fe, and Al were found to be uncontaminated, while Ni was found to be moderately contaminated and Mn was found to be highly contaminated (Fig. 2). All of these metals remained as background levels in the sediment of the study area. In studies conducted at Stations 4, 5, and 7, Ni and Mn transitioned from moderately polluted to heavily pollute. Several studies reported the use of quality assessment methods to evaluate sediment pollution levels [46-49].

Enrichment Factor

The enrichment factor is crucial for identifying the origin of metal sources. The method allows the identification of the heavy metal source, whether it is anthropogenic or natural. Table 2 shows the EF values for Munzur Stream.

The enrichment factor is important to determine the heavy metal source. The method indicates whether the heavy metal sources are natural or anthropogenic. The EF values in descending order are as follows: Mn>Ni>Cu>Fe>Cr>Zn>Pb>As>Cd≥ Hg. According to the calculations, only nickel and manganese behaved differently from the other elements. Nickel was moderately loaded and manganese was moderately loaded. The other elements showed no effect on the flux. While Mn showed strong enrichment characteristics except for station 8, Ni was 5.7 and showed strong enrichment characteristics. The first element is wastewater without domestic treatment, and the second is from agricultural fertilizers. The second is the source of heavy metals and is anthropogenic.

The EF value is used to evaluate the possible origin of elements [50-52]. It is used in the assignment to natural or anthropogenic sources for element abundance. The EF values between 0.05 and 1.5 indicate a natural origin of the metals and the EF value >1.5 indicates an anthropogenic origin [53-55].

Manganese contamination was detected at all stations. It was probably transferred from underground water sources by dissolution of manganese-bearing rock. It could also be caused by disproportionate use of fertilizers in agriculture. Nickel pollution originated from metallurgical industry, chemical industry, metal refining, waste incineration, and oil burning. The study area is a coal, oil, gas and mining area. The mining sector and the structure of natural sources could contribute to the high nickel concentration in this region.

Pollution Load Index

CF value is the index used to evaluate the metal source and is listed in descending order as follows: Cr>Ni>Fe>Pb>Cd>As>Mn>Cu>Zn>Hg. According to the CF values, the elements Cu, Zn, Mn and As showed low contamination. Pb showed moderate contamination in station 2. The average values indicate that the values of all elements are below 1, except Pb (Table 3). Similar results were obtained for the Zarrin Gol River and the Tijan River [56].

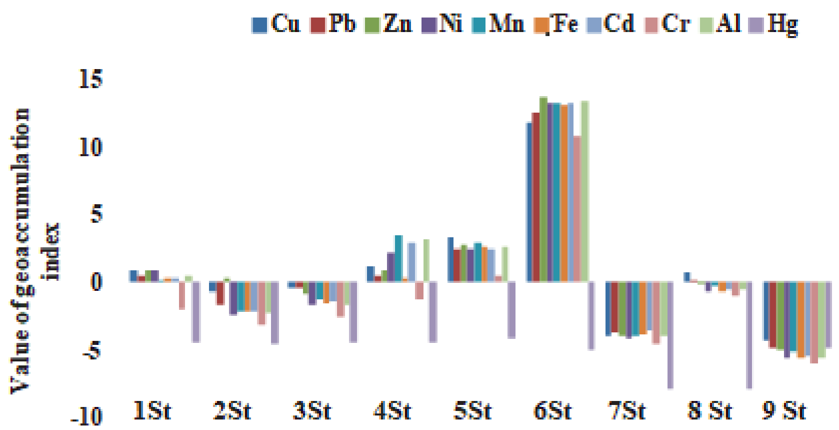

Fig. 2. The Igeo index values for the sediments of all studied sites in the Munzur River.

Table 2. Enrichment Factor (EF) values of measured heavy metals in the Munzur Stream.

Station Number	1	2	3	4	5	6	7	8	9	Mean
Cu	1.92	1.31	1.79	1.88	1.08	1.23	1.23	0.26	1.33	1.34
Pb	0.58	0.31	1.24	0.18	0.22	0.23	0.21	0.11	0.19	0.37
Zn	0.77	0.71	0.53	0.29	0.39	0.34	0.35	0.17	0.30	0.43
Ni	2.23	1.37	1.87	4.67	10.6	1.19	7.23	0.41	8.88	4.28
Mn	10.1	5.58	6.76	5.70	7.38	6.25	5.42	1.36	6.25	6.09
Fe	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
As	0.06	0.07	0.06	0.05	0.06	0.06	0.07	0.04	0.05	0.06
Cr	1.60	1.03	0.91	0.64	0.82	0.62	0.67	0.47	0.65	0.83
Cd	0.05	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.03
Hg	0.04	0.04	0.04	0.04	0.05	0.03	0.00	0.00	0.03	0.03

Table 3. Contamination Factor (CF) and Pollution Load Index ((PLI) values measured heavy metals.

Station Number	1	2	3	4	5	6	7	8	9	Mean
Cu	0.73	0.50	0.68	0.72	0.41	0.47	0.47	0.10	0.51	0.51
Pb	2.53	1.36	5.41	0.78	0.98	1.01	0.95	0.48	0.85	1.59
Zn	0.81	0.75	0.55	0.31	0.41	0.36	0.37	0.18	0.31	0.45
Ni	1.15	1.05	1.43	3.58	8.16	0.91	5.53	0.31	6.80	3.27
Mn	1.15	0.63	0.77	0.65	0.84	0.71	0.62	0.15	0.71	0.69
Fe	1.00	1.63	3.61	2.76	2.67	2.36	2.68	0.48	2.79	2.22
As	1.25	1.41	1.23	1.08	1.19	1.30	1.56	0.80	1.16	1.22
Cr	5.45	9.95	8.80	6.15	7.9	6.05	6.45	4.60	6.25	6.83
Cd	1.45	0.75	1.19	1.88	3.50	0.88	2.16	0.03	2.45	1.58
Hg	0.07	0.06	0.06	0.06	0.08	0.04	0.00	0.00	0.00	0.05
PLI	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.01

Table 3 shows the pollution index values (PLI) for heavy metals. The values of PLI ranged from 0.000-0.002 and the calculated mean value was 0.001. The lowest PLI value was observed at station 1, while station 4 had the highest value. At all stations, these index values were <1. The concentration of these elements at the stations was lower than the background values and, therefore, was classified as not contaminated. The distribution of metals depends not only on their source, but also on the hydro-mechanical flow of the water. The values of PLI indicate a moderately contaminated river system (Table 3). The integrated index was calculated to be easily understood. However, the weakness of the ecotoxic potential of each metal is the overlooked drawback.

Potential Ecological Risk

Table 4 illustrates the potential ecological risk values for each heavy metal. According to the analysis, the order was Cr>Ni>As>Pb>Cd>Cu>Hg>Zn. Under ambient conditions, the PER value was in the low risk group, except for the mean Cr value. However, samples with an average PER Cr value in the sediment reaching a peak value of 238.25 probably have a higher risk and relatively broader distribution than other metals. The high Cr content observed in the surface sediment samples in the present study could be due to different geological factors, main source agricultural activities, wastewater discharges, and mines. The assessment of ecological and health risks in sampling areas is generally quite complex. Various factors such as organic material, hydrological factors, and topography play an important role [57]. It could be related to sediment

Table 4. Potential Ecological Risk (PER) indices for single metal (and PER for heavy metals).

Station Number	Potential Cu	Ecoloical Pb	Risk Zn	İndices Ni	for As	Heavy Cr	Metal Cd	E_f^i Hg	PER
1	3.69	12.68	0.81	8.54	12.50	463.5	2.86	2.80	507.4
2	2.52	6.81	0.75	5.27	14.16	298.5	1.51	2.40	331.9
3	3.44	27.06	0.55	7.18	12.36	264.0	2.39	2.60	319.6
4	3.61	3.93	0.31	17.90	10.83	184.5	3.76	2.70	227.5
5	2.08	4.93	0.43	40.80	11.94	237.0	7.00	3.40	307.5
6	2.36	5.06	0.36	4.55	13.05	180	1.77	1.90	209.0
7	2.36	4.75	0.37	27.68	15.69	193.5	4.33	0.25	248.9
8	0.55	2.43	0.31	1.58	8.05	138.0	0.06	0.25	151.0
9	2.55	4.25	0.18	34.00	11.66	187.5	4.91	2.00	247.2
Mean	2.57	7.99	0.45	16.39	12.55	238.5	3.17	2.03	283.3

particles attracting metals in water and precipitation of high molecular weight metals at the bottom. Removal of the metal Cr caused the PER value of all metals to be below 70 (Table 4). However, the addition of Cr increased PER. The value was over 500, especially at the 1st station. Station 8 was the cleanest area.

PCA analysis identified heavy metal sources in the sediments and supported PCA (Table 5). The rotated space illustrated the plots showing the relationships between the heavy metals in relation to the four principal components PCA revealed three principal components whose eigenvalues accounted for 91.52% of the total variance (Table 6). Cu, Zn, Mn Cd, Al PC1 reprensenting 46.85% of the total variance are positife charged. Because Al, Cu, Zn,Cd, Mn values indicated enrichment in the sediments, the heavy metal combinations in the first component indicated sediment sources. The component indicated that the metal originated from natural sources, including source rock and mineral weathering. The second component accounted for 21.69% of the total variance and had high positive charges of Ni (0.54) and Cr (0.53). Thus, Ni and Cr could be derived from anthropogenic sources. The third principal component represented 13.54% of the total variance, with As (0.49) and Fe showing a positive charge. n PC4, Pb showed strong negative load. The PCA results showed small (positive or negative) charges, indicating a weak correlation. The results showed that edaphic factors (dissolution of minerals in rock/soil), anthropogenic factors (domestic waste/wastewater and nutrients), and climatic factors are effective on water quality.

The cluster analysis suggests that the heavy metal elements consist of two main groups (Fig. 3). The first group consisted of Cu, Mn, and Al formed a group, while Zn and Cd formed another group. Also, Hg, As, and Pb form a group on their own. In the second group, Ni, Cr, and Fe form a group. Overall, they were divided into two groups, especially Cr and Cu, Zn and Cd, Mn and Al pollution come from the same source.

The cluster analysis shows that the stations consist of two main groups. The first group consisted of the 1st group, while II, III, IV, V, VI, VII VIII, IX formed another group. Also IV, IX, V, VII formed a separate group. In the second group, III, VI, and VIII form one group (Fig. 4).

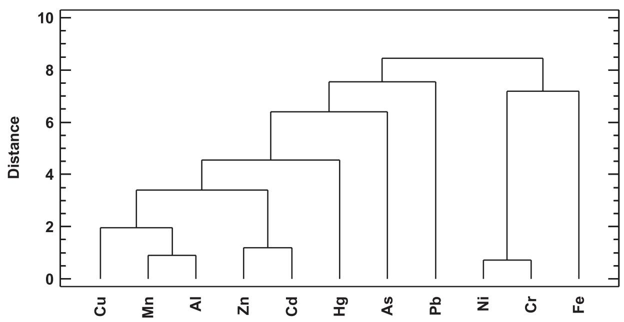

Fig. 3. Cluster analysis between heavy metal concentrations.

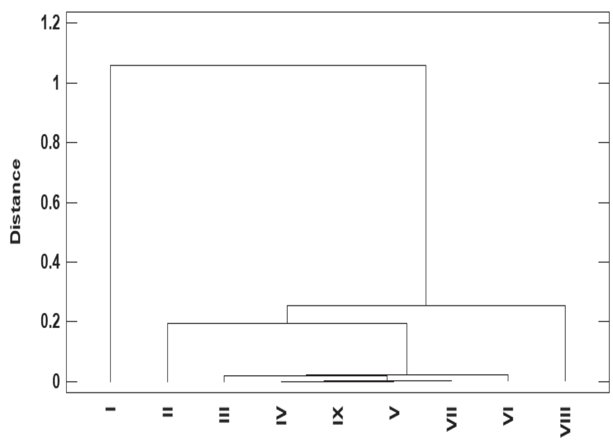

Fig. 4. Cluster analysis between stations.

Table 5. Pearson's correlation coefficient of heavy metal concentrations of sediments in Munzur Stream.

	Cu	Pb	Zn	Ni	Mn	Fe	As	Cd	Cr	Al	Hg	PER	PLI
Cu	1												
Pb	0.52	1											
Zn	0.5746*	0.5032*	1										
Ni	0.0336	-0.2980	-0.2691	1									
Mn	0.7813**	0.4071	0.6922	0.2370	1								
Fe	0.4718	0.3832	-0.1358	0.4769	0.2612	1							
As	0.4015	0.1109	0.5088	0.1748	0.4734	0.3393	1						
Cr	0.5845*	0.4590	0.9261**	-0.1788	0.7869**	-0.2444	0.3254	1					
Cd	0.2605	-0.1352	-0.0829	0.9550**	0.4697	0.5510	0.2607	0.0164**	1				
Al	0.8774**	0.4499	0.7174	0.0852	0.9432**	0.2859	0.6003	0.7679**	0.3109	1			
Hg	0.6301*	0.3420	0.5019	0.2069	0.7150**	0.3270	0.0749	0.5116	0.4336	0.5506	1		
PER	0.6352*	0.4826	0.9069	-0.0264	0.8526**	-0.1100	0.3761	0.9852**	0.1738	0.8149**	0.5722	1	
PLI	0.1133	-0.3611	-0.3089	0.2742	-0.0025	-0.1522	-0.6198	-0.0653	0.2798	-0.1034	0.2644	-0.0552	1

Table 6. Varimax rotated component matrix for some analyzed variable.

	Components			
	PC1	PC2	PC3	PC4
Cu	0.34	0.08	-0.07	-0.28
Pb	0.23	-0.16	0.19	-0.55
Zn	0.34	-0.25	-0.05	0.14
Ni	0.03	0.54	0.00	0.25
Mn	0.38	0.10	-0.07	0.07
Fe	0.10	0.38	0.40	-0.42
As	0.22	0.03	0.49	0.40
Cd	0.34	-0.21	-0.20	0.16
Cr	0.12	0.53	-0.02	0.18
Al	0.38	0.02	0.03	0.04
PER	0.36	0.36	-0.17	0.16
PLI	-0.05	0.23	-0.63	-0.13
Eigenvalues	6.09	2.82	1.76	1.22
% of variance	46.85	21.69	13.54	9.42
Cumulative	46.85	68.54	82.09	91.52

Heavy metals in sediments originate from various sources such as atmospheric bedrock, ore deposits, abrasion and erosion in industrial environments, and agricultural wastes [58]. Living organisms absorb it either directly through water uptake [59] or indirectly through the food chain as bioaccumulation. Crops grown on soils irrigated with contaminated water have high concentrations of heavy metals [60]. Recently, numerous types of research have focused on the pollution level and particulate heavy metal sources in rivers worldwide [61-64]. So far, the results have shown that most heavy metals are polluted to very different degrees in different rivers. Currently, heavy metals are a critical issue in aquatic ecosystems due to their persistence, environmental toxicity, and bioaccumulation.

The sources of heavy metals may be natural (atmosphere and soil structure) or anthropogenic (mines, untreated industrial water, and agricultural activities). Especially in environments where the various anthropogenic activities and the rapid increase in pollution from industrial wastes are still causing serious problems, and where treatment systems are not functioning properly or are lacking, it is important [65-66].

Conclusions

In recent times, Munzur Stream has been affected by human activities such as flood control measures, gold mining, agricultural activities, fertilization, pesticide use, and untreated household waste from the district and surrounding villages. This study is the first to identify potential sources of metals in the sediment of the basin to determine pollution levels, categorize potential ecological risks, and generate data for future studies. The basin is a headwater river that provides drinking water throughout Turkey. The average amount of heavy metals detected in sediment in the study in mg/kg was, in descending order, Fe>Mn>Ni>Cr>Pb>Zn>Cu>Cd>Hg. The data evaluated by several statistical methods indicated that the metals with a positive relationship between them in the Pearson correlation analysis and the elements of the same factor in the factor analysis were mostly the same. These phenomena could be explained by the possible emanation of metals from similar pollution sources. The comparison of the results with the sediment quality criteria showed that only the mean value of Mn and Ni exceeded the values of PEL. Heavy metal levels in Munzur Stream sediment exposed to domestic and agricultural wastes, agricultural fertilizers and pesticides, and mines were not high enough to pose a threat to aquatic life. However, the continued increase in these loads could have a negative impact on the water and sediment quality of the stream. In the present study, multivariate analyzes such as correlation analysis, CA, and PCA were conducted to determine the distribution of heavy metal sources in the sediments. The correlation analysis among heavy metals showed that the pollution sources for Cu, Cr, Ni, and Fe were common or showed the same geochemical behavior. The CA and PCA openly showed that these heavy metals belonged to the same clusters and components, indicating strong correlations. Moreover, their combination indicates anthropogenic sources for these heavy metals.

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Conflict of Interest

The authors declare no conflict of interest.

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