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Assessment of Heavy Metal Pollution of Çoruh River (Turkey)

Tamer AKKAN[1*], Tanju MUTLU[2]

Abstract

In this study, the pollution assessment of the water, total suspended solids, and sediment samples collected from the Çoruh River was carried out. For this purpose; aluminium, chromium, manganese, iron, cobalt, nickel, copper, zinc, cadmium, and lead were measured in these samples. The water and sediment quality indices were used for the evaluation of the obtained data. When water quality index values were evaluated, it was determined that the river was in the poor water quality class. According to enrichment factor, the Çoruh River sediments in this study are classified as deficiency to minimal enrichment for chromium and nickel, as moderate enrichment for manganese, iron, and cobalt, as significant enrichment for copper and zinc, as very high enrichment for cadmium and lead. Pollution loading index results also showed that the sediment quality deteriorated and it had a high metal load. It suggests that the reason for these pollution factors in the sediment is due to the mining activities in the region. As a result, it was determined that the water and sediment quality of the Çoruh River should be monitored with a regular monitoring program.

Keywords: Metal, Çoruh River, Risk assessment, Water quality, Sediment quality.

Çoruh Nehri'ndeki Ağır Metal Kirliliğinin Değerlendirilmesi

Öz

Bu çalışmada Çoruh Nehri'nden toplanan su, askıda katı madde ve sediment örneklerinin kirlilik değerlendirmesi yapılmıştır. Bu amaç için toplanan numunelerde alüminyum, krom, manganez, demir, kobalt, nikel, bakır, çinko, kadmiyum ve kurşun konsantrasyonları ölçülmüştür. Elde edilen verilerin değerlendirilmesinde su ve sediment kalite indeksleri kullanılmıştır. Su kalitesi indeks değerleri incelendiğinde nehrin kötü su kalitesi sınıfında olduğu belirlendi. Sediment zenginleştirme faktörüne göre krom ve nikel açısından düşük düzeyde zenginleşme, manganez, demir ve kobalt için değiştirilebilir derecede zenginleşme, bakır ve çinko için önemli derecede zenginleşme, kadmiyum ve kurşun için çok yüksek düzey zenginleşmeye tespit edilmiştir. Kirlilik yükleme indeksi sonuçları da sediment kalitesinin bozulduğunu ve yüksek metal yüküne sahip olduğunu göstermiştir. Sedimentteki bu kirlilik faktörlerinin nedeninin bölgedeki madencilik faaliyetlerinden kaynaklandığını düşünülmektedir. Sonuç olarak, Çoruh Nehri'nin su ve sediment kalitesinin düzenli bir izleme programı ile izlenmesi gerektiği belirlenmiştir.

Anahtar Kelimeler: Metal, Çoruh Nehri, Risk değerlendirmesi, Su kalitesi, Sediment kalitesi.

[1] Giresun University, Arts and Science Faculty, Biology Department, Giresun, Turkey, biyoloji@yahoo.com
[2] Recep Tayyip Erdoğan University, Environmental Protection and Control Department, Giresun, Turkey, tanju.mutlu@erdogan.edu.tr

[1]https://orcid.org/0000-0002-9866-4475 [2]https://orcid.org/0000-0001-6514-6914

[*]**Sorumlu Yazar/Corresponding Author**
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1. Introduction

Pollution of natural waters is a widespread problem worldwide due to its impact on human health and economic damage besides environmental damages (Marcovecchio et al., 2007). Heavy metals are among the most worrisome of these pollutants due to their environmental persistence, their tendency to accumulate in aquatic organisms and their high toxicity (Benzer et al. 2013; Yancheva et al. 2014; Gedik et al. 2019; Bayır and Mutlu, 2021).

Population, urbanization, industrialization, and agricultural practices can increase heavy metal levels by reaching aquatic ecosystems such as rivers, lakes, and seas (Abdel-Baki et al., 2011; Mutlu et al., 2018). Otherwise heavy metals are found in the natural structure of rocks and can accumulate in sediment because of decomposition of rocks (Wojciechowska et al., 2019; Mutlu et al., 2020).

Sediments, which play an active role in the transport processes of many nutrients and toxic chemicals, are preferred in determining the pollution model in aquatic ecosystems (Akkan et al., 2018). Besides, sediments can increase the level of heavy metals in the benthic organism through direct uptake in water and sediment due to natural or anthropogenic processes (Ho et al., 2010). Metals that are not biodegradable may pose a health risk to people consuming aquatic organisms due to bioaccumulation in the food web (Bahnasawy et al., 2011).

The aim of this study is to determine the origin and possible ecosystem effects of the existing pollutants in the water and sediment structure of the Çoruh River, which flows into the Black Sea from the Çoruh Basin, which is one of the most important basins of the southeastern Black Sea Region, through quality indexes.

2. Materials and Methods

2.1. Sampling Area

This study was carried out in the Çoruh River. Çoruh river is one of Turkey's most important river has a total length of 431 km. Turkey 410 km from the border 21 km to reach the Georgian border and flows into the Black Sea (Birici et al., 2017). Sediment and water samples (0-10 cm) were collected seasonally using grab sampler from four sites in Çoruh River between March 2019 and February 2020, as shown in Fig. 1.

Figure 1. Sampling area (Google maps)

2.2. Analysis

Heavy metal analysis: The water samples were immediately transported to the laboratory and filtered through acid treated Millipore HA filters (0.45 µm) using a vacuum. These samples were stored in darkness at 4 °C up until analysis (APHA, 1998). Total Suspended Solids (TSS) samples were obtained by filtering (Millipore HA filters, 0.45 µm) from 1 L of river water. TSS and sediment samples were prepared with a preliminary digesting process via a CEM MARS-5 model microwave instrument. Heavy metal determinations of all the samples were carried out using an ICP-MS-Bruker 820-MS (Alam et al., 2001). The reference materials were used to check the accuracy and reliability of the method. Metal contents were expressed in terms of ppb.

Water quality index: This study water quality index (WQI), which is considered to be a powerful tool that can present a comprehensive picture of river water quality, determined according to Meng et al. (2016). WQI reflects the integrated impact of different water quality (Wang et al., 2013). It is calculated as follows:

$$WQI = \sum[\left(Wi\ x\ \left(\frac{Ci}{Si}\right)\right]x\ 100 \quad (1)$$

wi: represents the weight attributed to each parameter *i* and is assigned on the basis of the eigenvalues for each principal component and factor loading for each parameter from the PCA results and represents the relative importance of each individual water quality parameter for drinking purposes.

Ci: is the trace element concentration in water samples, and *Si* is the Chinese Drinking Water Guideline (GB 5749-2006) for each trace element. Five classifications were presented based on the calculated WQI values: 0 ≤ WQI < 50 indicates excellent water quality, 50 ≤ WQI < 100 indicates good water quality, 100 ≤WQI < 200 indicates poor water quality, 200 ≤WQI < 300 indicates very poor water quality, and WQI >300 represents water that is unsuitable for drinking (Meng et al., 2016).

Enrichment factor (EF) and Pollution Loading Index (PLI): Enrichment factor (EF) and pollution loading index (PLI) are a useful indicator reflecting the status of environmental contamination (Helz et al., 1985; Sinex and Helz, 1981; Trefry and Presley, 1976; Woitke et al., 2003). In calculating the normalized enrichment factors (EF), the original Salomons and Förstner (1984) equation was substituted in the present study by Al. To evaluate a possible anthropogenic origin of the metals, the enrichment factor (EF), and pollution loading index (PLI) were calculated for the metal concentration obtained in surface sediments.(Ozseker et al., 2013). The EF and PLI are calculated based on the following presented equation:

$$EF = M_x \; X \; Al_b / \; M_b \; X \; Al_x \qquad (2)$$

where M_x and Al_x are the sediment sample contents of the heavy metal and Al. Also, M_b and Al_b are their levels in a suitable background or baseline reference material (Abrahim & Parker, 2008; Salomons & Förstner, 1984).

$$PLI = (CF_1 \; X \; CF_2 \; X \; CF_3 \; X \; \dots X \; CF_n \;)^{1/n} \qquad (3)$$

$$CF = C_M \; / \; C_B \qquad (4)$$

where CM is metal concentration, CB is background concentration of the same metal (Ozseker et al., 2013).

Health Risk Assessment: In human health risk assessment, two methods of carcinogenic and non-carcinogenic can be used to predict health problems that may arise as a result of exposure to chemicals (Kamunda et al., 2016). The target hazard quotient (THQ) equation is used in the risk assessment of non-carcinogenic effects, and if the THQ value is below 1, it means that the adverse effect on human health is negligible. Conversely, if THQ or TTHQ is greater than or equal to 1, there is a potential health risk (Zheng et al., 2007; Mutlu, 2021). THQ was calculated using the equation presented by Chien et al., (2002)

$$THQ = \frac{E_F \times E_D \times W_I \times C}{RfD \times A_{Tn}} \times 10^{-3} \quad (5)$$

where; THQ is target hazard quotient; EF is the exposure frequency (365 days/year); ED is exposure duration (70 years); WI, water intake is the ratio of water intake to body weight in day (mL/kg/day) according to the EPA's predictions; C is the metal concentration (mg/L); RfD is the oral reference dose for a heavy metal (mg/kg/day), RfD for Cr, Mn, Ni, Zn, Cu, Co, Pb, and Cd are 0.003, 0.14, 0.02, 0.3, 0.005, 0.0003, 0.002, and 0.0005 mg/kg/day, respectively (EPA, 2018); and ATn is the average time for non-carcinogens (assuming 70 years).

Statistical Analysis: Statistical analysis of data was carried out using SPSS statistical package programs. Descriptive statistical analysis including One-way ANOVA was done, with a significance of 0.01 and 0.05. Important differences in the mean values were tested using Tukey's multiple range test. Moreover, relationships among the considered variables were tested using Pearson's correlation. Multivariate analyses of the dam lake data set were performed using Principal component analyses (PCA) and cluster analysis (CA). All of the statistical calculations were performed using SPSS 17.0 for Windows.

3. Findings and Discussion

The range of Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb in the water samples were 56.68-308.70, 0.16-1.89, 20.17-58.69, 316.04-596.99, 1.39-2.40, 33.34-78.99, 2.11-15.68, 12.56-22.98, 0.06-0.50, and 1.35-5.12 µg/L, respectively (Table 1). The highest metal concentrations were recorded in winter for Al, Fe, Co, and Cd, in fall for Pb, Cr, Mn, Cu, Zn, and Cd, and in spring for Ni and Pb. When the heavy metal values in water are compared with the standards recommended by USEPA and WHO, it has been determined that they are below the level specified for Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb. Also, when the results are compared with the classification specified by the Turkish standards, Ni is in the 3rd Class water quality class while other metals are in the 1st class. Nickel concentration in water may increase in certain areas as a result of human activities such as mining, fertilizers, pesticides, burning coal and petroleum products (Hussain et al., 2017). Bilgin & Konanç (2016) reported some heavy metals in the Çoruh River water and reported that mining is the most important source of pollution. However, Concentrations of Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb were measured in Yağlıdere Stream (Uncumusaoglu et al., 2016) Also, Cr and Cd values were higher than our study, other metals were lower.

Table 1. *Metal concentrations of water, sediment and TSS samples collected from Çoruh River. It seems that the highest accumulation is in iron*

Sample	Season	**Al**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**Cd**	**Pb**
Sediment	Winter	7587.21	7.36	241.75	12845.22	4.98	4.60	18.19	35.43	0.41	15.26
	Spring	9420.45	7.03	338.79	14096.66	5.14	5.31	24.18	36.69	0.61	23.01
	Summer	5511.21	3.87	277.81	9987.71	4.29	2.24	17.36	45.37	0.46	28.39
	Fall	6300.62	9.87	389.13	13452.69	6.36	3.94	207.53	163.52	1.45	130.16
Water	Winter	308.70	1.52	49.00	596.99	2.40	65.00	2.11	21.33	0.50	2.48
	Spring	70.18	0.76	20.17	556.67	1.95	78.99	2.18	12.56	0.18	5.12
	Summer	56.68	0.16	36.97	316.04	1.39	62.44	2.32	18.21	0.06	4.74
	Fall	155.63	1.89	58.69	496.68	2.35	33.34	15.68	22.98	0.08	1.35
TSS	Winter	29196.25	19.30	822.60	19181.47	7845.53	5128.63	26.17	10729.97	7870.56	16.96
	Spring	12694.56	15.73	35.08	1137.98	0.00	0.00	4153.56	14637.06	1039.76	2779.06
	Summer	12949.13	18.05	25.99	642.74	0.00	0.00	5023.54	14299.82	5239.38	3641.26
	Fall	5880.10	6893.91	133.84	3180.94	1485.66	0.00	2318.95	5626.96	7203.13	6461.48

Heavy Metal Concentration in Sediments: Since sediment contains harmful and toxic substances such as trace elements, it is an important substance that should be monitored in metal studies in the aquatic ecosystem (Balık & Tunca, 2015; Zamani Hargalani et al., 2014). Concentrations of Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb in the sediment samples were varied 5511.21-9420.45, 3.87-9.87, 241.75-389.13, 9987.71-14096.66, 4.29-6.36, 2.24-5.31, 17.36-207.53, 35.43-163.52, 0.41-1.45, and 15.26-130.16 ppb, respectively. Abundance of average metal levels in the sediments is in the order of Fe>Al>Mn>Zn>Cu>Pb >Cr>Co>Ni>Cd. The highest Al, Fe, and Ni concentrations were recorded in spring, while the highest Cr, Mn, Co, Cu, Zn, Cd, and Pb contents were found in fall. Kucuksezgin et al. (2008) reported higher Cr, Mn, Ni and Zn in the sediments of the Gediz River than in our study. Unlike to this, Dundar & Altundag (2007) reported lower Cu, Zn, Cd, and Pb concentrations for Sakarya River than Çoruh River.

Average metal contents of sediment in this study are classified as non-polluted, moderately polluted, and heavily polluted according to the Sediment Quality Guidelines (SQG) declared by USEPA (Gedik et al., 2018; Perin et al., 1997). Based on this assessment, Cu was classified as heavily polluted, Pb was as moderately polluted and the others as non-polluted. It has also been compared with the Interim Canadian Sediment Quality Guidelines (CEQGs) of the Canadian Council of Environment Ministries (CCME), which show the Interim Sediment Quality Targets (ISQG) and the Probable Effect Level (PEL). According to CEQGs; Cr, Cu, Zn, Cd, and Pb contents of sediment samples in this study were lower than PEL values, while Cu, Cd and Pb were higher than ISQG values (Table 2). It is estimated that these high values are caused by the mining activities in the region, since the industrial activities around the sampling station are not much developed.

Table 2. *Comparison of the metal levels in the sediments with CEQGs and SQGs (USEPA) values (mg/kg). Cr, Cu, Zn, Cd, and Pb contents of sediment samples in this study were lower than PEL values, while Cu, Cd and Pb were higher than ISQG values*.

	Al	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb
This Study	7204.87	7.03	311.87	12595.57	5.19	4.02	66.82	70.25	0.73	49.20
SQGs (USEPA)										
Non-polluted	-	<25	-	-	-	<20	<25	<90	-	<40
Moderately polluted	-	25-75	-	-	-	20-50	25-50	90-200	-	40-60
Heavily polluted	-	>75	-	-	-	>50	>50	>200	>6	>60
CEQGs										
ISQG	-	37.3	-	-	-	-	35.7	123	0.6	35
PEL	-	90	-	-	-	-	197	315	3.5	91.3

SQGs, Sediment Quality Guideline (Perin et al. 1997).
CEQGs: Canadian Sediment Quality Guidelines, ISQG: Interim sediment quality guideline PEL: Probable effect level (CCME, 2001).

Heavy Metal Concentration in Total Suspended Solids (TSS): The range of Al, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb in the TSS samples were 5880.10-29196.25, 15.73-6893.91, 25.99-822.60, 642.74-19181.47, 0.00-7845.53, 0.00-5128.63, 26.17-5023.54, 5626.96-14637.06, 1039.76-7870.56, and 16.96-6461.48 ppb, respectively. It was statistically recorded that the concentration of many metals (Al, Fe, Cu, Zn, Cd, and Pb) detected in TSS differed significantly compared to water and sediment (p, 0.05). In addition to these, contamination due to Cd, Pb, AL, Cr, Fe, Ni and Zn draws attention in TSS.

Enrichment Factor (EF) and Pollution Loading Index (PLI): EF is used to make comparisons in different periods of different basins or the same basin and to gain information on geochemical trends (Sinex & Helz, 1981). The five contamination categories according to the enrichment factor are expressed as follows; EF<2 is deficiency to minimal enrichment, EF in 2-5 is moderate enrichment, EF in 5-20 is significant enrichment, EF in 20-40 is very high enrichment, EF>40 is extremely high enrichment (Odat, 2013). The mean EF values of Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb in the sediments were 1, 4, 3, 3, 1, 18, 9, 29, and 30, respectively. The sampled sediments in this study are classified as Deficiency to minimal enrichment for Cr and Ni, as moderate enrichment for Mn, Fe, and Co, as significant enrichment for Cu and Zn, as very high enrichment for Cd and Pb. The EF value is between 0-1.5, it indicates that the origin of the sediments is natural, while EF>1.5 indicates that it is caused by anthropogenic activities (Zhang & Liu, 2002). Thus, it can be concluded that all metals detected in sediment samples in this study, except Cr and Ni, are of anthropogenic origin. Similarly, Varol (2011) found the average EF values of the studied metals except Cr and Mn in the Tigris River sediments above 1.5 and drew attention to the anthropogenic effect in the stream. In contrast, in the Geli Stream sediments, the EF value of Cr is reported above 50 and is classified as extremely severe enrichment (Kalender & Çiçek Uçar, 2013).

When interpreting the PLI value, the following definition can be taken as the basis: PLI<1 reports perfect sediment quality, PLI=1 only baseline levels of pollutant, and PLI> 1 shows that deterioration of site quality (Wojciechowska et al., 2019). The pollution load index results were determined to be high (PLI>1) in the analysed sediment samples. According to this PLI result, it can be said that the sampling site has deteriorated sediment quality and has a high metal load. Similar to this study, PLI values were found as 1.88 in Tigris River (Varol 2011) and 1.47 in Ulukışla Basin (Lermi & Sunkari, 2020). In contrast, it was reported as 0.47 in Çayeli River (Kırıs and Baltas 2021).

Water Quality Index: WQI values of metals in water samples were calculated and found as 146. According to the evaluation of the WQI values of the Çoruh River over five different classifications, it was observed that it was in the poor water quality class. In a study conducted in Aksu River, it was observed that the water quality of the river was in excellent class according to WQI values and was deteriorated by anthropogenic pollutants (Şener et al., 2017). Also, the WQI value of Emet Stream has been determined over 300 and classified as heavily polluted water quality (Omwene et al., 2019).

Target Hazard Quotient: Target Hazard Quotient (THQ) values calculated for drinking water consumption in Çoruh stream are shown in Table 3. According to the evaluations, it was concluded that the THQ and TTHQ values in Cr, Mn, Ni, Zn, Cu, Pb, Co, and Cd were below 1. This means that it does not pose a health risk concern. Also, the highest TTHQ value was found in <1 age group.

Table 3. *Non-carcinogenic risk of heavy metals of different age groups. The THQ and TTHQ values in Cr, Mn, Ni, Zn, Cu, Pb, Co, and Cd were below 1*

Age Group	WI[1] (mL/kg-day)	THQ								TTHQ
		Cr	Mn	Ni	Zn	Cd	Cu	Pb	Co	
<1	29	0.010	0.009	0.087	0.002	0.012	0.032	0.050	0.196	0.397
1 to < 2	13	0.005	0.004	0.039	0.001	0.005	0.014	0.022	0.088	0.178
2 to <3	15	0.005	0.004	0.045	0.001	0.006	0.017	0.026	0.101	0.205
3 to <6	11	0.004	0.003	0.033	0.001	0.004	0.012	0.019	0.074	0.151
6 to <11	10	0.004	0.003	0.030	0.001	0.004	0.011	0.017	0.067	0.137
11 to <16	6	0.002	0.002	0.018	0.000	0.002	0.007	0.010	0.040	0.082
16 to <21	6	0.002	0.002	0.018	0.000	0.002	0.007	0.010	0.040	0.082
21 to <50	11	0.004	0.003	0.033	0.001	0.004	0.012	0.019	0.074	0.151
50+	11	0.004	0.003	0.033	0.001	0.004	0.012	0.019	0.074	0.151
All ages	11	0.004	0.003	0.033	0.001	0.004	0.012	0.019	0.074	0.151

[1]EPA Recommended Ratings for Drinking Water Intake Rates by Age (EPA, 2019)

Statistical Analysis: Regardless of water, sediment and TSS, seasonal variation of all detected metals has not been detected ($p>0.05$), which reveals the presence of metal presence in the study area throughout the year.

Four principal components (PC) were obtained with an eigenvalue of more than 1, explaining greater than 99.24 % of total variance (Table 4). PC 1 grouped metals such as Al, Mn, Fe, Co, and Ni reveal 53.55 % of the total variance. Al, Mn, and Fe had originated from natural sources (Wang et al., 2017). Co and Ni are derived from country of origin. Also, the metals in the PC1 mainly come from industrial and traffic activities. Cu and Zn in PC2 are strongly correlated and clearly separate from the other heavy metals regarding their correlation coefficient analysis and PC 2 explains 24.81 % of the total variance. This separation between them and other heavy metals may suggest that the enrichment of Cu in the suburban soils may be related with the application of agricultural runoff, manure, and Cu-contained agrochemicals. PC3 with a variance loading of 20.88 % was dominated by the loading Cr and Pb (Table 5).

Table 4. *Varimax rotated component matrix for trace elements in water and TSS samples. Four principal components (PC) were obtained with an eigenvalue of more than 1, explaining greater than 99.24 % of total variance*

Eigenvalues	**5.36**	**2.48**	**2.09**
Variance (%)	53.55	24.81	20.88
Cumulative (%)	53.55	78.36	99.24
Variable	**Factor 1**	**Factor 2**	**Factor 3**
Al	**0.851**	0.522	-0.037
Cr	-0.009	-0.051	**0.993**
Mn	**0.998**	-0.035	-0.014
Fe	**0.999**	0.007	0.002
Co	**0.998**	-0.022	0.055
Ni	**0.989**	-0.025	-0.142
Cu	-0.233	**0.947**	0.221
Zn	0.327	**0.940**	0.043
Cd	**0.691**	0.370	0.581
Pb	-0.148	0.536	**0.831**

"Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Table 5. *Correlation matrix of trace elements in Çoruh River. PC3 with a variance loading of 13.94% was dominated by the loading Cr and Pb.*

		Water										
Sediment		**Al**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Cd**	**Pb**
	Al	1	.688	.591	.648	.777	-.165	.035	.613	.[a]	.873	-.668
	Cr	.231	1	.730	.664	.954*	-.622	.687	.658	.[a]	.359	-.916
	Mn	.062	.632	1	.046	.549	-.877	.700	.991**	.[a]	.129	-.943
	Fe	.761	.805	.502	1	.852	.168	.015	-.009	.[a]	.714	-.343
	Co	.064	.961*	.795	.690	1	-.360	.454	.486	.[a]	.575	-.783
	Ni	.917	.577	.188	.932	.392	1	-.927	-.829	.[a]	.336	.827
	Cu	-.326	.779	.807	.340	.912	-.017	1	.610	.[a]	-.418	-.759
	Zn	-.407	.722	.786	.253	.871	-.108	.996**	1	.[a]	.172	-.901
	As	.895	.184	-.303	.640	-.066	.873	-.468	-.545	.[a]	.[a]	.[a]
	Cd	-.229	.782	.884	.407	.923	.048	.989*	.979*	.[a]	1	-.233
	Pb	-.392	.711	.814	.257	.868	-.107	.995**	.999**	.[a]	.985*	1
		All Samples										
TSS		**Al**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Cd**	**Pb**
	Al	1	-.059	.760**	.624*	.812**	.815**	.273	.692*	.895	.687*	.124
	Cr	-.626	1	-.090	-.143	.100	-.094	.234	.099	.184	.557	.807**
	Mn	.894	-.210	1	.922**	.809**	.820**	-.357	.085	-.303	.411	-.277
	Fe	.896	-.215	1.000**	1	.550	.568	-.400	-.082	.640	.179	-.338

	Co	.865	-.151	.998**	.998**	1	.981**	-.123	.383	-.066	.727**	-.009
	Ni	.944	-.333	.992**	.992**	.982*	1	-.175	.357	.873	.616*	-.170
	Cu	-.650	-.170	-.917	-.916	-.936	-.860	1	.848**	-.468	.431	.762**
	Zn	.239	-.907	-.220	-.215	-.279	-.094	.557	1	-.545	.662*	.577*
	As	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	1	-.430	-.553
	Cd	.318	.405	.618	.608	.656	.549	-.684	-.690	.^{a}	1	.637*
	Pb	-.950	.813	-.727	-.732	-.683	-.806	.435	-.503	.^{a}	-.009	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
^{a}. Cannot be computed because at least one of the variables is constant.

4. Conclusions and Recommendations

Average concentrations of all metals investigated in Çoruh River water were lower than WHO and USEPA standard recommended limits. On the other hand, in terms of Turkish standards, Cr, Mn, Fe, Co, Cu, Zn, Cd, and Pb metals have 1st class water quality, while Ni has 3rd class water quality. On the contrary, when WQI values were evaluated, it was observed that the river was in the poor water quality class.

Since THQ values in water samples are under the limit value of 1, It can be said that the use of the water of the Çoruh River as drinking water will not cause health problems for consumers after the necessary procedures. According to enrichment factor, the Çoruh River sediments in this study are classified as Deficiency to minimal enrichment for Cr and Ni, as moderate enrichment for Mn, Fe, and Co, as significant enrichment for Cu and Zn, as very high enrichment for Cd and Pb. PLI results also showed that the sediment quality deteriorated and it had a high metal load. Moreover, Cu, Cd and Pb content were higher than ISQG values reported by CEQGs. It suggests that the reason for these pollution factors in the sediment is due to the mining activities in the region. Because the sampling area is not well developed in terms of industry and agricultural activities are very low.

Authors' Contributions

All authors contributed equally to the study.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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