Sigma Journal of Engineering and Natural Sciences, Vol. 39, No. 1, pp. 13-23, March, 2021
Yildiz Technical University Press, Istanbul, Turkey

# DISSEMINATION OF HEAVY METAL CONTAMINATION IN SURFACE SEDIMENTS OF BATLAMA STREAM, GIRESUN, TURKEY

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## ABSTRACT

The aim of this study is to detect the heavy metal contamination in the sediment of Batlama Stream and to evaluate the anthropogenic effect. Field studies were seasonally carried out in 3 stations between June 2014 and July 2015. In the sampling studies carried out in Batlama Stream, contamination factor (CF), enrichment factor (EF), potential ecological risk factor ($Er^i$), lowest effect level (LEL), geoaccumulation index ($I_{geo}$) contamination indicators were used in order to evaluate sediment contamination. In Batlama Stream, average heavy metal level of three stations was detected in mg/dry kg in the sediment as Cr 7.08, Mn 63.62, Fe 858.04, Co 5.47, Ni 4.99, Cu 20.61, Zn 49.60, Cd 0.09, and Pb 20.68. Elements which the sediment has most are Fe, Mn, and Zn. According to EF, Pb was detected as an enriching element. $Er^i$ Pb is in the low risk group. In LEL value, the highest Pb average was found as 31. According to $I_{geo}$ values, Pb is a moderate contaminant. This metal has anthropogenic sources and it is caused by domestic, agricultural, and waste waters. In the elements analysed in Batlama Stream sediment (apart from Pb), it is indicated that it is generally a clean stream and considered reference stream.

***Keywords:*** *Heavy metal, Batlama Stream, ecological risk factor, enrichment factor.*

## INTRODUCTION

As the population of the world is increasing, especially with urbanization, anthropogenic activities (industrialization, agricultural activities, and husbandry) have also increased. As a result, it caused metal accumulation and contamination in natural ecosystems. Due to the fact that metals remain in the nature for a long time, their importance in ecological and environmental studies increases [1-3]. Metal pollution in seas, lakes and rivers occurs as a result of natural or domestic wastes, industrial liquid wastes, mineral wastes, agricultural fertilizers and animal wastes [4-6]. Soluble metals which mix with water sink to the bottom and merge with the sediment. For this reason, in aquatic environments, sediments are known as places where metals are stored. Determining the sediment quality in order to characterize the effects of natural resources and anthropogenic activities is beneficial to ecosystems [7, 8]

Streams are ecosystems which can be shaped with the effects of natural events as well as being based on human-related issues such as domestic, industrial, and agricultural effects. As an important source of drinking water in the city of Giresun, Batlama Stream arises from a natural reservoir (approximately 1700 meters high) on the Bektaş Plateau. The stream is exposed to sewage and agricultural waste from many points of Giresun and its surrounding settlements.

With this study, it was aimed to detect seasonal changes of some heavy metals (Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb) in the sediment of Batlama Stream and to determine the relationship between heavy metal levels in the sediment.

## MATERIAL AND METHODS

### Study Area

Batlama stream with the catchment area of approximately 34.63 ha is located in Giresun, Turkey between 40° North and 38° East (Fig. 1). Agricultural especially hazelnut cultivation, commercial, industrial, mining, livestock, pasture, row crops, forestry, and hydroelectric power plants are main activities that people undertake in the creek basin. Some water quality problems have already been known such as pesticides nutrients from fertilizers, hydrocarbons, and heavy metals (Fig 1). The first station; 1 St: 40°44' 04.41" (N) 38°17'50.26" (E); 2 St: 40°48' 56.97" (N) 38°18'37.67.3'' (E); 3St: 40°54' 17.25" (N) 38°21'18.31" (E). Around the third St., Giresun Industrial Area is located right on the both side of the creek and the plants were drained their effluent in it [9].

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*Manuscript Received 26 August 2019, Accepted 20 December 2020*

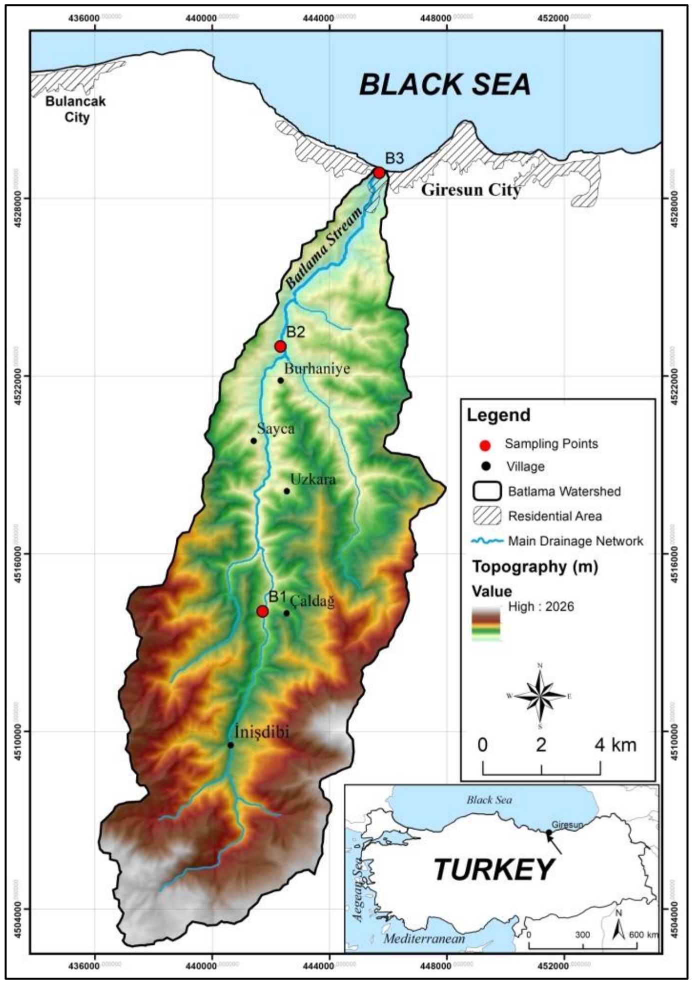


**Figure 1.** Study area and the sampling stations

All sediment samples were collected seasonally from the three stations between June 2014 and May 2015. The sediment samples were taken from 0–10 cm depth with Ekman Dredge grab sampler (20×20×20 cm) at each station. In order to prevent any deterioration in the chemical structure of the sediment, the samples were stored in polyethylene bags at –20 ° C in a freezer in the laboratory. Regarding the sediments, the samples were dried at 103 °C and ground in a mortar and pestle until they reached a constant weight in the drying oven; they were sifted through a 63-micron sieve. Of each sample, 0.5 g was mixed with 10 mL of concentrated nitric acid and underwent digestion procedure at the CEM Mars brand microwave combustion unit. After the organic degradation, the samples were cooled, centrifuged, and filtered through a filter paper. The final volumes of the samples were made to 1 mL by adding concentrated nitric acid. Then the heavy metal contents were analysed in an ICP-MS device with 3 parallel samples [10].

The Enrichment Factor (EF) and the Contamination Factor (CF) were used to determine the anthropogenic contribution to the heavy metal concentration in the sediment samples. The EF is an important toll which means the potential sources of the concentration heavy metal enrichment. The EF factors were obtained by dividing the measured metal/Al (or Fe) rate into the metal/Al (or Fe) rate from the period before contamination. The contamination factor (CF), which is usually used to normalize metal concentrations in order to reduce the influence of particle grain size [11].

### Contamination Factor (CF)

$$CF = {C_{heavy\ metal}}/{C_{background}}$$

### Enrichment Factor (EF)

$$EF= (C_n/C_{ref}) / (B_n/B_{ref})$$

### Potential Ecological Risk Factor ($Er^i$)

$$Er^i = T_r^i \times (C_n/C_{ref})$$

### Geoaccumulation Index($I_{geo}$)

$$I_{geo}=\log_2 \frac{C_n}{1,5.B_n}$$

Descriptive statistical analyses were performed to determine the mean, minimum and maximum standard deviation of the parameters in the dataset. One-way analysis of variance (ANOVA) was used to determine whether there was a significant time-dependent difference in the metal concentrations across the stations ($p <0.05$). The relationships between the metals were determined by principal component analysis (PCA), cluster analysis and Pearson's correlation analysis. In order to evaluate the degree of contamination more extensively, indexes such as Sediment Quality Guidelines (SQG), Geo-accumulation Index ($I_{geo}$), Enrichment Factor (EF), and Ecological Risk Factor ($Er^i$) were used. The PAST statistical program was used for the cluster analysis and SPSS 22 software was used for all other statistical analyses

## RESULTS AND DISCUSSION

Distribution of heavy metal values by stations are given in Table 1. Average values of metals (mg/dry kg) are respectively as follows: Fe> Mn> Zn>Cu> Cr> Co> Ni> Cd.

**Table 1.** Average metal concentrations (mg/dry kg) in the sediment from different stations of Batlama Stream

| Sediment Metals | St.I | St.II | St.III | Mean | St. Dev. | Min. | Max. |
|---|---|---|---|---|---|---|---|
| Cr | 6.59 | 7.14 | 7.49 | 7.08 | 1.09 | 5.67 | 9.45 |
| Mn | 443.07 | 346.48 | 333.33 | 374.30 | 63.62 | 297.06 | 521.27 |
| Fe | 10126 | 9523 | 9524 | 9724 | 858.04 | 7829 | 11062 |
| Co | 6.04 | 5.28 | 5.11 | 5.47 | 0.52 | 4.71 | 6.43 |
| Ni | 5.06 | 4.89 | 5.01 | 4.99 | 1. 01 | 3.85 | 7.25 |
| Cu | 16.87 | 23.49 | 21.48 | 20.61 | 4.68 | 15.59 | 32.35 |
| Zn | 26.32 | 64.28 | 58.21 | 49.60 | 19.17 | 23.85 | 80.59 |
| Cd | 0.00 | 0.17 | 0.12 | 0.09 | 0.09 | 0 | .24 |
| Pb | 9.11 | 34.09 | 18.83 | 20.68 | 17.24 | 8.04 | 71.8 |

**Table 2.** Quality criteria of Batlama Stream Sediment (mg/dry kg) [12, 13]

| GV | Cr | Mn | Fe | Co | Ni | Cu | Zn | Cd | Pb |
|---|---|---|---|---|---|---|---|---|---|
| LEL | 26 | 460 | 20000 | | 16 | 16 | 120 | 0.60 | 31 |
| TEL | 37.30 | | | | 18 | 35.70 | 123 | 0.60 | 35 |
| MET | 55 | | | | 35 | 28 | 150 | 0.90 | 42 |
| TET | 100 | | | | 61 | 86 | 540 | 3 | 170 |
| SAV | 100 | 850 | 47000 | 8 | 80 | 50 | 90 | 0.30 | 20 |
| TS | 7.08 | 374.30 | 9724.30 | 5.47 | 4.99 | **20.61** | 49.6 | 0.09 | 20.70 |

GV: Guidelines Values, LEL (Lowest Effect Level), TEL (Threshold Effect Level), MET (Minimal Effect Threshold), TET (Toxic Effect Threshold), SAV (Shale Average Value), TS= This study

Since there are not any criteria specified in our country to evaluate sediment quality of freshwater, data acquired in the study was evaluated in accordance with the sediment quality criteria published by MacDonald et al. [12], Persaud et al. [13] and with the average heavy metal content of crust reported by Krauskopf [14] . According to effect levels of sediment quality criteria, LEL (Lowest Effect Level) is the limit; below this limit, generally no negative effects are observed on creatures in sediments. TEL (Threshold effect level) is the limit; below this limit, negative effects on creatures in sediments are rarely observed. MET (Minimal effect threshold) is the limit; below this limit, negative effects are not generally observed on most of the creatures in sediments. TET is known as Toxic effect threshold. Above this limit, negative effects are generally observed in most of the creatures in sediments [12] (Table 2).

Iron (Fe) is the most commonly found element in the earth's crust with an average value of 47000 ppm [14]. In this study, the element which was found most in the sediment is Fe with its average value of 9724 (mg/dry kg). The minimum value was found in St. 2 in spring as 9523 (mg/dry kg), and the maximum value was found in St 1 as 10126 (mg/dry kg) (Figure 2).

As one of the sediment quality criteria, LEL value (20000 ppm) was not exceeded in any station (Fig.2). Based on this data, it can be stated that river sediment is at a level that does not pose a threat to aquatic ecosystems (Fig. 2).

In accordance with the stations specified in the sediment, average manganese (Mn) amount is 374.30 (mg/dry kg). The minimum value was found in St.3 as 333.33 (mg/dry kg), and the maximum value was found in St.1 as 443.07 (mg/dry kg). The average Mn amount is well below 850 ppm, which is the average of the earth's crust. Additionally, as one of the sediment quality criteria reported by Persaud et al. (1993), LEL value (460 mg/dry kg) was not exceeded in any station and in any season (Fig. 2).

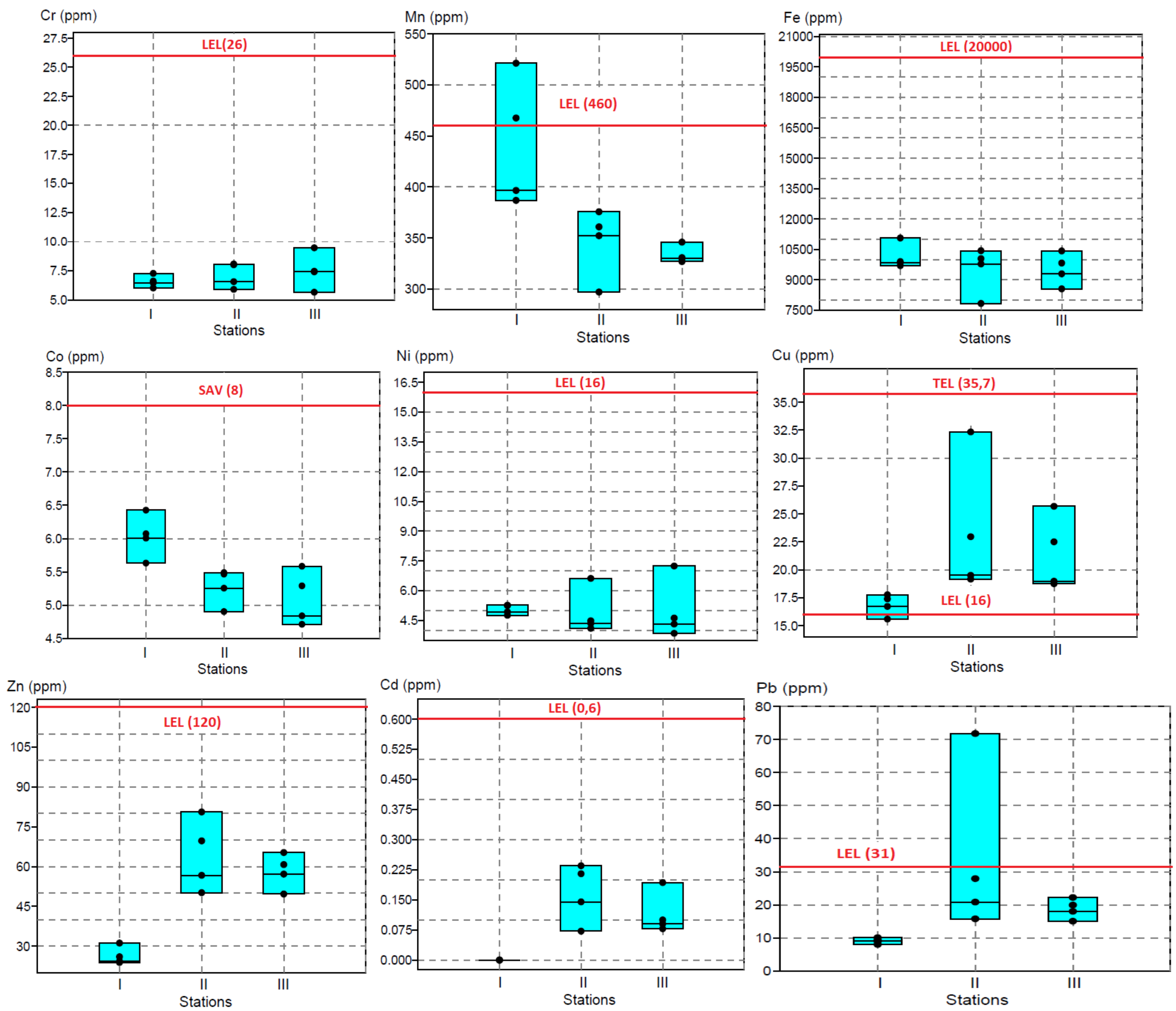


**Figure 2.** Boxplot graphics and levels of heavy metals in the sediment

The annual average zinc (Zn) amount found in the sediment is 49.60 (mg/dry kg). The minimum value was recorded in St. 1 as 26.32 (mg/dry kg), and the maximum value was recorded in St. 2 as 64.28 (mg/dry kg) (Figure 2). These values are considerably lower than the naturally existing zinc value in the sediment (100 mg / dry kg) [15]. In addition, the LEL limit value of 120 (mg / dry kg), which is one of the sediment quality criteria, was not exceeded in any station and in any season. Based on these findings, it can be concluded that basin sediments were not exposed to zinc contamination.

Annual average chrome (Cr) amount found in the sediments which were collected seasonally from three stations in Batlama Stream is 7.08 (mg/dry kg). The minimum value was recorded in St. 1 as 6.59 (mg/dry kg), and the maximum value was recorded in St. 3 as 7.49 (mg/dry kg). These values are considerably lower than the average chrome value which naturally exists in the earth's crust (100 mg / dry kg) (Table 2). Additionally, LEL (26 mg / dry kg) and TEL (37.3 mg / dry kg) limit values, which are among sediment quality criteria, were not exceeded in any stations and in any seasons (Fig. 2). Based on these findings, it can be concluded that the stream was not exposed to chrome contamination.

Cobalt (Co) is found at an average rate of 8 ppm in the earth's crust [13]. In this study, it was calculated to be 5.47 (mg/dry kg). The minimum value was found in St. 3 as 5.11 (mg/dry kg), and the maximum value was found in St. 1 as 6.04 (mg/dry kg). As can be understood from these values, river sediment does not contain any danger for aquatic ecosystem in terms of cobalt element.

Ni concentration is 4.99 (mg/dry kg) on average. The minimum value was found in St. 2 as 4.89 (mg/dry kg), and the maximum value was found in St. 1 as 5.06 (mg/dry kg). Compared to the Çömlekçi Stream, Batlama Stream has a lower concentration Cadmium (Cd) is an element which is not obligatory for living things, and causes genetic and ecological toxicity on animals as well as negatively affecting plant growth and development. Its release to nature is mainly through power plants, metal industry, geological decomposition, atmospheric deposition, phosphate fertilizers used, incinerated solid wastes, toxic wastes from industrial plants and sewages [16, 17]. The average Cd content annually detected in the sediment of the river is 0.09 ppm. The maximum value was recorded in St.3 as 0.17 (mg/dry kg). The obtained values are in the range of 0.1 - 0.5 mg / kg which is the average Cd value in the earth's crust [17]. Additionally, these results are well below the LEL (0.6 ppm) value of the sediment quality criteria in all stations and in all seasons. Consequently, sediment values of the streams are appropriate for freshwater ecosystems in terms of Cd.

**Table 3.** Comparison of heavy metal concentrations in sediments of Batlama Stream with other world rivers.

| Location | Zn | Cr | Cu | Ni | Mn | Co | Fe | References |
|---|---|---|---|---|---|---|---|---|
| Mangonbangon River , Philippines | 213 | 89 | 116 | 61.14 | 261 | 15.31 | 22006 | [46] |
| Ganga River , India | 67 | 69 | 29 | 26.7 | 372 | - | 31988 | [47] |
| Gomti River, India | 76 | 16 | 23 | 23.92 | - | - | - | [48] |
| Korotoa River , Bangladesh | - | 109 | 76 | 95 | - | - | - | [35] |
| Langat River, Malaysia | - | 21 | - | 7,84 | - | - | 28300 | [49] |
| Huaihe River, China | 183 | - | 31 | 32.79 | 876 | - | 33388 | [50] |
| Jialu River, China | 107 | 60 | 39 | 42.44 | - | - | - | [51] |
| Shur River, Iran | 522 | - | 9 | - | - | - | 26000 | [52] |
| Tigris River, Turkey | 509 | 135 | 1257 | 284 | - | - | - | [53] |
| Batlama River, Turkey | 49 | 7 | 20 | 4.99 | 343 | 5.47 | 7829 | This study |

Studies on sediment quality in our country and in the world have increased in recent years. Average concentrations of heavy metal were compared with the studies carried out on Ganga and Gomti rivers in India, Korotoa River Bangladesh, Langat River in Malaysia, Huaihe and Jialu rivers in China, Şur River in Iran, Dicle River in Turkey, and Mangonbangon River in Philippines. It was found out that most of the pollution was related to industrial development in the rivers we compare. Especially Zn and Cu are high in Dicle and Şur rivers. Similarly, Cr and Ni concentrations did not exceed the values in Dicle and Korota rivers; it is rather low compared to other rivers listed. Ganga and Huaihe rivers are the ones with the highest Mn levels among the rivers compared. Similarly, average Fe concentrations reported in Ganga, Langat, Huaihe and Shur rivers are high. Ustaoğlu and Tepe [18] found in the research of heavy metal levels in the sediment of Pazarsuyu Brook that Fe, Mn, Zn, Cu, Pb, Cr, Co, Cd elements were the most abundant in the sediment. They were found respectively as 8312 ppm, 155.83 ppm, 32.74 ppm, 19.69 ppm, 17.79 ppm, 10.64 ppm, 4.26ppm, and 0.16ppm. The heavy metal levels detected in the sediment of Pazarsuyu Brook, which is subjected to the pressure of domestic, agricultural wastes, agricultural fertilizers and pesticides and HEPP constructions, and stone and gravel pits, are not at a level that is dangerous for aquatic life. Fe and Mn are the metals which are found abundantly in the earth's crust [19, 20]. Akbulut and Tunçer [21] found in the study they carried out that Fe and Mn accumulation was high in the sediment. In our study, it was detected that these metals are higher than others. Anoymous [22] indicated that pesticides which are commonly used in agricultural areas and have Cu and Mn as active agent, and artificial fertilizers which are high in Cr, Ni, Mn [23,24] can mix in the brook as a result of rain and human activities; and it could be considered the reason of high accumulation levels. Pb exists in lead mineral along with Cu and Zn [22], and in our study, it was found to be high in 2 St. It is thought that the increase in the number of gas stations in the region is effective in the increase of lead.

## Statistical Analyses

Pearson's correlation analysis: According to the results of Pearson's correlation test which is carried out to determine the relationships of variables with each other, although many metals are related to each other, Mn, Ni, Cu showed no correlation with other metals. Co and Mn shows medium level of correlation ($r=0.665$, $P<0.05$), and Co and Fe shows high level of correlation ($r=0.761$, $P<0.01$). Zn and Ni shows high level of correlation ($r=0.738$, $P<0.01$). Pb and Zn shows high level of correlation in a positive way ($r=0.765$, $P<0.01$). Zn, on the other hand, shows Fe and Co and Pb shows Fe negative correlation (Table 3).

The results of correlation analysis applied to heavy metal data acquired from the stream sediment are similar to the information in the literature. Cr, Mn, Cu, Ni, Zn, and Cd elements are grouped together and it is understood that these heavy metals result from anthropogenic sources [25]. The negative correlation between Pb and other metals in the sediment shows that contamination sources of Pb are different from other metals.

**Table 4.** Pearson correlation matrix for metals in sediments of the Batlama Stream

| N=12 | Cr | Mn | Fe | Co | Ni | Cu | Zn | Cd | Pb |
|---|---|---|---|---|---|---|---|---|---|
| **Cr** | 1 | | | | | | | | |
| **Mn** | -.289 | 1 | | | | | | | |
| **Fe** | .538 | .235 | 1 | | | | | | |
| **Co** | .143 | **.665*** | **.761**** | 1 | | | | | |
| **Ni** | .287 | .201 | .071 | -.039 | 1 | | | | |
| **Cu** | -.153 | -.401 | -.088 | -.370 | -.427 | 1 | | | |
| **Zn** | -.041 | **-.644*** | -.563 | **-.809**** | -.172 | **.738**** | 1 | | |
| **Cd** | .169 | -.507 | -.255 | -.666* | .327 | .601* | .791** | 1 | |
| **Pb** | -.268 | -.214 | **-.687*** | -.527 | -.230 | .453 | **.765**** | .452 | 1 |

In the factor analysis applied to heavy metals detected in the sediment, 3 factors which have eigenvalues higher than 1 and explain 83.07% of the total variance were detected. While all elements (Zn, Cd, Cu) found in the 1st factor which explains 40.506% of the total variance have a powerful positive charge, Mn and Co and powerful negative charge supports such situation. In the 2nd factor which forms 25.682% of the total variance, Fe and Cr have powerful positive charge, and Pb has negative charge. Ni itself forms the 3rd factor which has 16.88% share in the total variant (Table 4).

According to Suresh et al. [26], if the coefficient relationship between metals is high, it shows that these metals have similar transportation behaviours and come from the same source. The weak relationship between other metals indicates that these metals are not controlled by one element. Instead, geochemical support and mergence exist by being controlled one combination [27]. Inverse relationship between Mn and Zn is an indicator of Zn's external input of heavy metal which can be related to anthropogenic sources [28].

Table 4 Rotation component matrix for metals in surface sediments from Batlama stream.

## Cluster analysis:

Clustering analysis was applied to the data so as to observe variables' relationships with each other and clustering of variables. According to clustering dendrogram, two big clustering draw attention (Figure 2). First group includes Co, Ni, and Cr. It means that transportation mechanisms and/or sources of these elements are similar. The second group represents possible common sources/processes of Cu, Pb, Zn. Cd, Fe and Mn are located away from these two groups (Figure 3).

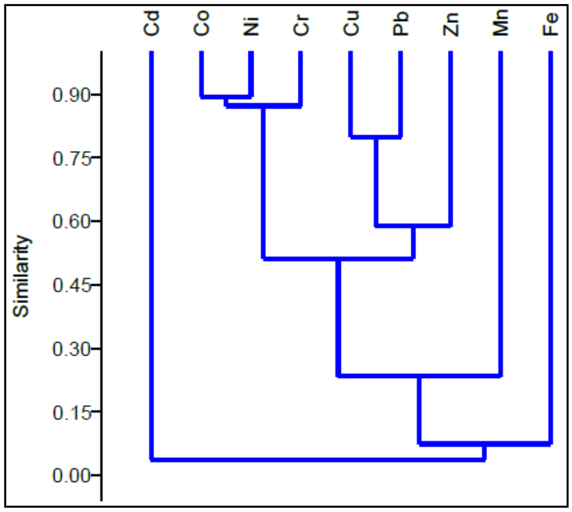


**Figure 3.** Cluster analysis (CA) dendrogram of the Batlama Stream sediments

## Enrichment Factor (EF):

Enrichment factor is a frequently used index to determine the possible sources of metals, anthropogenic effect and grade. Average enrichment factors of the metals studied in Batlama stream are as follows in a decreasing way: Pb> Zn> Cu> Mn> Cd>Co>Fe>Cr>Ni. In general, the highest enrichment values were detected in St.2. While Pb showed significant degree enrichment in St.2, moderate degree enrichment was detected in St.1 and 3. While Zn showed moderate enrichment in St. 2 and 3, it showed minimum enrichment in St.1. While Cu had moderate enrichment in St. 2 and 3, it had minimum enrichment in St.1. While Mn showed moderate enrichment in St. 1, it showed minimum enrichment in St. 2 and 3. Cd showed moderate enrichment in St. 2 and minimum enrichment in St.3, and its enrichment level was found to be 0 in St. 1. Co, on the other hand, showed minimal increase in all stations. Fe showed minimal increase in all stations. It was observed that Cr and Ni elements did not show an increase in general (Table 5). These increases of Pb observed in St.2 indicated anthropogenic based input and it must be paid attention for the health of ecosystem. Additionally, this area is well known with natural Pb deposits [29,30].

**Table 5.** Enrichment (EF) in the Batlama Stream by sample stations enrichment factors (EF) grade standards for EF Sutherland (2000)

| | B 1 | B2 | B 3 | Mean | Value | |
|---|---|---|---|---|---|---|
| **Cr** | 0.36 | 0.38 | 0.38 | 0.38 | EF<2 Minimal enrichment | |
| **Mn** | 2.53 | 1.98 | 1.9 | 2.14 | 2≤EF<5 | Moderate enrichment |
| **Fe** | 1.04 | 0.98 | 0.98 | 1.00 | 5≤EF<20 | Significant enrichment |
| **Co** | 1.54 | 1.35 | 1.3 | 1.40 | 20≤EF<40 | Very high enrichment |
| **Ni** | 0.36 | 0.35 | 0.36 | 0.36 | EF≥40 | Extremely high enrichment. |
| **Cu** | 1.82 | 2.53 | 2.32 | 2.22 | | |
| **Zn** | 1.34 | 3.28 | 2.97 | 2.53 | | |
| **Cd** | 0 | 2.70 | 1.86 | 1.52 | | |
| **Pb** | 2.21 | 8.27 | 4.57 | 5.01 | | |

Enrichment factor (EF) is used in evaluating origins of elements [31,32]. Enrichment factor is a convenient tool to differentiate between anthropogenic and natural sources of elements [33]. If EF values are between 0.05 and 1.5, elements are natural; if they are 1.5 >, it means it has anthropogenic sources [34-38]. In our study, the value of Mn, Cu, Zn, and Pb concentration is >1.5.

## Contamination Factor (CF):

As an index used to make an evaluation about the sources of metals, CF values are sorted in a decreasing way as follows: Pb> Zn> Cu> Mn> Cd> Co> Fe> Cr> Ni. According to CF values, all elements apart from Pb showed low contamination. On the other hand, Pb showed moderate contamination in St. 2. As can be observed from average values, all elements apart from Pb have values less than 1 (Table 6). These index values were < 1 in all stations; the concentration of these elements is less than the background values in stations and for this reason, it is categorized as uncontaminated. Distribution of metals depends not only on their sources but also on hydromechanical flow of the water [39-41].

**Table 6.** Contamination factor (CF) in the Batlama Stream sediment sample stations

| Contamination Factor (CF) | | | | | Grade standards for EF Hakanson [11]. (1980) |
|---|---|---|---|---|---|
| | **B 1** | **B2** | **B 3** | **Mean** | **Value** |
| **Cr** | 0.07 | 0.08 | 0.08 | 0.08 | CF<1 low contamination |
| **Mn** | 0.52 | 0.41 | 0.39 | 0.44 | 1≤CF<3 moderately contaminated |
| **Fe** | 0.21 | 0.20 | 0.20 | 0.21 | 3≤CF<6 considerably contaminated |
| **Co** | 0.32 | 0.28 | 0.27 | 0.29 | CF>6 very high contamination |
| **Ni** | 0.07 | 0.07 | 0.07 | 0.07 | |
| **Cu** | 0.37 | 0.52 | 0.48 | 0.46 | |
| **Zn** | 0.28 | 0.68 | 0.61 | 0.52 | |
| **Cd** | 0 | 0.56 | 0.38 | 0.31 | |
| **Pb** | 0.46 | 1.70 | 0.94 | 1.03 | |

In order to interpret the degree of contamination detected in Batlama Stream, Geo-accumulation index values ($I_{geo}$) were calculated (Chart 5.6). In Batlama Stream, no contamination was observed in all elements but Pb. Insignificant contamination was found in Pb. While Pb was -1.73 only in St. 1, it was 0.18 in St. 2 and 0.66 in St. 3. The average value was calculated as insignificant contamination with 0.53. $I_{geo}$ showed that all metals are between 0 and 1 (Table 7). In Batlama stream, Cr, Mn, Fe, Co, Ni, Cu, Zn, and Cd elements did not change because of anthropogenic effects. However, it was found out that for Pb, this value was on the limit in stations apart from St.1. This metal might come from cars and industrial wastes. Also, this Pb might be caused by agricultural activities across the stream. The high Pb levels in St.2 might be related to the location of these stations. Additionally, this area is well known with natural Pb deposits [42-44].

**Table 7**. Geoaccumulation index values ($I_{geo}$) in the Batlama stream by sample sations.

| Geoaccumulation index | | | | | Grade standards for Igeo Müller [48] | |
|---|---|---|---|---|---|---|
| | **B 1** | **B2** | **B 3** | **Mean** | **Value** | $I_{geo}$ status |
| **Cr** | -4.32 | -4.32 | -4.32 | -4.32 | Igeo≤0 | Practically uncontaminated |
| **Mn** | -1.5 | -1.88 | -1.94 | -1.78 | 0<*Igeo*<1 | Uncontaminated to moderately contaminated |
| **Fe** | -2.83 | -2.94 | -2.94 | -2.83 | 1<*Igeo*<2 | Moderately contaminated |
| **Co** | -2.25 | -2.39 | -2.47 | -2.39 | 2<*Igeo*<3 | Moderately to heavily contaminated |
| **Ni** | -4.32 | -4.32 | -4.32 | -4.32 | 3<*Igeo*<4 | Heavily contaminated |
| **Cu** | -2 | -1.51 | -1.64 | -1.68 | 4<*Igeo*<5 | Heavily to extremely contaminated |
| **Zn** | -2.47 | -1.15 | -1.28 | -1.51 | *Igeo*≥5 | Extremely contaminated |
| **Cd** | 0 | -1.43 | -1.94 | -2.25 | | |
| **Pb** | -1.73 | 0.18 | 0.66 | 0.53 | | |

### Ecological risk factor ($Er^i$):

$Er^i$ indicator was used to evaluate potential ecological risks (Table 8). Based on the results of $Er^i$ index, all elements are in the limit of low ecological risk. Based on $Er^i$ indexes in general, it can be stated that there is not any potential environmental danger in terms of the elements analysed in the region. Results are close to the results acquired in Zarrin Gol River [34] and Tajan River [45].

**Table 8.** Ecological risk factor ($Er^i$) Batlama stream sediment by samples stations [46].

| Metal | B I | B II | B III | Mean | Value | Ecological risk factor for an individual metal |
|---|---|---|---|---|---|---|
| **Cr** | 0.15 | 0.16 | 0.16 | 0.16 | Er < 40 | Low risk |
| **Ni** | 2.61 | 2.04 | 1.96 | 2.2 | 40 ≤ Er < 80 | Moderate risk |
| **Cu** | 1.07 | 1.01 | 1.01 | 1.03 | 80 ≤ Er < 160 | Considerable risk |
| **Zn** | 0.28 | 0.68 | 0.61 | 0.52 | 160 ≤ Er < 320 | High risk |
| **Cd** | 0 | 16.68 | 11.53 | 9.4 | Er ≥ 320 | Very high risk |
| **Pb** | 2.28 | 8.52 | 4.71 | 5.17 | | |

## CONCLUSION

With the sediment samples taken from 3 specified stations in Batlama Stream, heavy metal contents and potential ecological risks which might be caused by them were studied. According to enrichment and contamination factors of metals, minimal-medium level of accumulation was detected. After all these evaluations, it was concluded that the metals studied in Batlama Stream do not exist in concentrations which can pose a threat for the ecosystem for now. It is important for the protection of ecosystem and the future of lake that Pb concentration which is on the limit value now does not increase.

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