The aquatic ecosystems support a wide range of organisms, including microorganisms, invertebrates, insects, plants, and fish (Marshall, 2013). In addition, these ecosystems provide goods and services that are exploited by humans (Meyer, 2010). Although relevant to the environment, aquatic ecosystems are sinks for various pollutants, such as heavy metals, pesticides, and other synthetic or natural pollutants. The slightest effects reveal changes in growth, reproduction, behavior and survival of aquatic species. Fish can act as indicators of possible larger-scale pollution problems. However, the impacts of these pollutants on aquatic environments are usually visualized when the consequences have reached critical points, such as fish kills or algal blooms (Davies & Govedich, 2001).

The contamination by metals in aquatic ecosystems has been of great concern due to their toxicity, persistence and accumulation in these habitats (Varol, 2011). Metals have less mobility in water columns and their continuous accumulation in natural aquatic systems promotes their precipitation to sediments, which constitute potential sources of heavy metals to the water column and accumulate in aquatic flora and fauna (Raza et al., 2016; Dash, Borah, & Kalamdhad, 2021). The transfer of metals from sediments to water columns and their subsequent bioaccumulation in the food chain are detrimental to both the aquatic ecosystem and human health (Williams & Antoine, 2020). At the aquatic ecosystem level it can affect through the accumulation of metals in the body of fish (Chanamé et al., 2014), decreasing species diversity and even causing their complete disappearance (Haris et al., 2017; Williams & Antoine, 2020).
In this sense, metals also affect public health due to the fact that people make use of the water and consume fish caught from contaminated rivers, facing serious consequences that pose a risk to their integrity, as some of the metals are considered carcinogenic (Arisekar et al., 2020; Li et al., 2017).

The central and southern regions of Peru are the main production areas for rainbow trout (*Onchorhynchus mykiss*), due to their environmental characteristics and conditions for the development of a good culture (Ramírez et al., 2018). In the period from 2006 to 2017, trout production in Peru had an increase of 3,457.37 metric tons, and of this increase, the productions of Junín and Puno accounted for 85% of national production. The growing demand for the consumption of this fish has motivated the increase of fish farms dedicated to this crop to satisfy the emerging market (Cacchi, 2019). In this sense, it is important to know the quality of the aquatic ecosystem where these fish production practices are developed in Peru. Therefore, tools are needed to comprehensively assess the state of this ecosystem. The objective of this study was to evaluate the quality of surface sediment in rivers with fish farming potential (Peru) using indicators of contamination, accumulation and ecological risk of heavy metals and arsenic.

**MATERIALS AND METHODS**

**Study area**

The Tishgo and Chia rivers are located in the Mantaro river basin, central Peru, between latitudes 10°34' S – 13°35' S and longitudes 73°55' W – 76°40' W, at an altitude of 3,460 and 4,100 m.a.s.l., respectively. One of the main uses of the waters of the Tishgo and Chia rivers is for fish production in the Yauli and Huancayo provinces, respectively. The characteristics of these rivers, like most of those belonging to the Mantaro basin, include mountainous areas, steep drops where agriculture and fish farming are also carried out (Figure 1).

**Surface sediment collection**

Surface sediment (top 10 cm) was collected at 54 sampling sites on the Tishgo and Chia rivers during 2018 using a modified Ekman dredge. Three sediment samples were collected at each sampling site. Sediment samples were digested according to USEPA method 3051A with some modifications. In brief, 1.00 gram of dry sample was transferred to a 150 ml beaker, 2.5 ml of nitric acid and 10 ml of hydrochloric acid were added. The beaker was covered with a watch glass.

![Figure 1. Location map of the study area in the Tishgo and Chia rivers in central Peru.](image)
and taken to digestion by the microwave-assisted method. The established digestion program was: 17 minutes at 120 °C, 15 minutes at 210 °C and 30 minutes at 210 °C. After cooling, the digestion product was transferred to a 100 ml flask and the volume was filled with ultrapure water. The sample was stored at 4 °C and filtered before analysis. The determination of heavy metals and arsenic was carried out by flame atomic absorption spectrophotometry (air-acetylene) using a VARIAN AA 240 atomic absorption spectrometer. The standards were then read at different wavelengths for each element.

**Sediment quality indexes**

**Contamination factor**

The contamination factor (CF), expressed as the ratio between the concentration of each metal in the sediment and the background value, was applied to quantify the metal contamination status of the sediment as a function of its concentrations in the sample and its background concentration.

The CF values were calculated with equation (1).

\[
CF = \frac{C_{m \text{ sample}}}{C_{m \text{ background}}} \tag{1}
\]

Where, ‘Cm sample’ is the concentration of heavy metals in the sediment sample and ‘Cm background’ is the average concentration of heavy metal present in the upper continental plate raised by Taylor & McLennan (1995). The categories of CF < 1, is described as low contamination factor; 1 < CF < 3, as moderate contamination factor; 3 < CF < 6, as considerable contamination factor; and CF ≥ 6, as very high contamination factor (El-Amier, Elnaggar, & El-Alfy, 2016).

**Pollution load index**

The pollution load index (PLI) was applied to determine the metal contamination in surface sediments using the procedure of Tomlinson et al., 1980, equation (2).

\[
\text{PLI} = \left( \text{CF}_1 \times \text{CF}_2 \times \text{CF}_3 \times \ldots \times \text{CF}_n \right)^{1/n} \tag{2}
\]

Where, \( n \) is the number of metals and CF is the contamination factor. The PLI is a powerful tool for assessing heavy metal contamination. A PLI value of zero indicates perfection, a value of one indicates the presence of only basic levels of contaminants and values above one would indicate progressive deterioration of the site and estuarine quality.

**Geo-accumulation index**

The geo-accumulation index (I_{geo}) was determined to find the metallic contamination of sediment samples. This index was presented by Müller (1979) to determine the difference in concentrations between the samples and the average values that exist naturally in the continental plate. The calculation of this parameter was carried out by means of the equation (3).

\[
I_{\text{geo}} = \log_2 \left( \frac{C_n}{1.5 \times B_n} \right) \tag{3}
\]

Where \( C_n \) represents the concentration of the metal determined in the sediment, \( B_n \) represents the average value of these metals in the upper continental plate as proposed by Taylor & McLennan (1995). The I_{geo} according to Müller (1979) is classified into 7 levels: I_{geo} ≤ 0, level 0 (practically uncontaminated); 0 < I_{geo} < 1, level 1 (uncontaminated to moderately contaminated); 1 < I_{geo} < 2, level 2 (moderately contaminated); 2 < I_{geo} < 3, level 3 (moderately to heavily polluted); 3 < I_{geo} < 4, level 4 (heavily polluted); 4 < I_{geo} < 5 level 5 (heavily to extremely polluted); I_{geo} > 5, level 6 (extremely polluted).

**Ecological risk assessment and potential ecological risk index**

The ecological risk assessment was carried out by calculating the ecological risk factor (Er), using the method developed by Hakanson (1980) to evaluate the potential effect of heavy metals in sediments on the organisms of the aquatic ecosystem. This effect is evaluated for each metal individually. The calculation of this factor was evaluated by means of the equation (4).

\[
\text{Er} = \text{Tr} \times \text{CF} \tag{4}
\]

The contamination factor CF and a coefficient called “Tr”, which refers to a specific toxicity index for each metal, were used; these indexes were established by Hakanson (1980). On the other
hand, the potential ecological risk index (Ri) calculated using equation (5) was determined by the sum of the “Er” evaluated at each site.

\[
Ri = \sum Er
\]

The ecological risk factor (Er) is classified as follows: Er < 40, represents low ecological risk potential; 40 < Er < 80, represents moderate ecological risk; 80 < Er < 160, represents considerable ecological risk; between 160 < Er < 320, represents high ecological risk potential and factors greater than 320 represent very high ecological risk potential. In the case of the potential ecological risk index (Ri), it is classified under the following ranges: Ri < 150 is classified as low ecological risk; 150 ≤ Ri < 300 is classified as moderate ecological risk; 300 ≤ Ri < 600 is classified as considerable ecological risk and Ri ≥ 600 is classified as very high ecological risk.

RESULTS AND DISCUSSION

Distribution of heavy metals and arsenic in sediment of rivers with fish farming potential

Descriptive statistics of heavy metal and arsenic concentrations in surface sediment of the Chia and Tishgo rivers are presented in Table 1 along with threshold values of probable effect concentration (PEC) (MacDonald, Ingersoll, & Berger, 2000), upper continental crust (UCC) reference values (Taylor & McLennan, 1995) and interim sediment quality guidelines (ISQG) values (Canadian Council of Ministers of the Environment, 2004). The decreasing order of mean heavy metal and metalloid concentrations in the Tishgo River was Zn > Pb > As > Cu and in the Chia River it was Zn > Cu > As > Pb. In the Tishgo River, the highest mean concentrations of Zn, Cu, As and Pb were recorded in the lower course of the river. Meanwhile, in the Chia River, the highest mean concentrations were recorded in the upper course of the river. The mean concentrations of heavy metals and metalloids recorded in the rivers studied were lower than the threshold values of the PEC. In the Chia River, the mean concentrations of 50% of the elements studied (Cu, 19.26 mg kg⁻¹; As, 11.32 mg kg⁻¹) exceeded the ISQG values (18.70 mg kg⁻¹; 124 mg kg⁻¹; 7.24 mg kg⁻¹, respectively). While, in the Tishgo River, the mean concentrations of 75% of the elements evaluated (Cu, 21.17 mg kg⁻¹; Z, 125.08 mg kg⁻¹; As, 19.34 mg kg⁻¹) exceeded the ISQG values. All chemical elements evaluated in the Tishgo River exceeded the UCC reference values.

The maximum Cu concentration (20.87 mg kg⁻¹) was recorded in the upper course of the Chia River and the lowest concentration (17.25 mg kg⁻¹) in the lower course. While the distribution of this metal in the Tishgo river presented a different pattern from that of the Chia River, with the maximum Cu concentration being recorded in the lower course of the river (23.41 mg/kg). However, the maximum Cu concentrations in both rivers were lower than the UCC reference values (25 mg kg⁻¹). The maximum Pb concentrations at the sampling sites in each sector in both rivers showed irregular distribution patterns ranging from 7.85 to 11.05 mg kg⁻¹ and from 24.08 to 29.31 mg kg⁻¹ in the Chia and Tishgo rivers, respectively. In the Tishgo River, the maximum concentrations of Pb and Zn in the different sectors exceeded the UCC reference value (25 mg kg⁻¹, 71 mg kg⁻¹, respectively). In the Chia River, the maximum Zn concentration recorded in the upper river (77.99 mg/kg) was higher than the UCC reference value (71 mg kg⁻¹). In both rivers, all maximum As concentrations were higher than the UCC reference value (1.5 mg kg⁻¹) (Figure 2). These results could be related to domestic wastewater discharges, metallic input from tributary rivers coming from areas with operational mining units, runoff from agricultural areas in the study area. The use of fertilizers and pesticides could be responsible for the release of Cu, Cd, Pb and Zn (Barra-Rocha, Fernandes-Costa, & Pimenta-Azevedo, 2019) and significant contribution in the sediments collected in the studied rivers.

The spatial distribution of heavy metals and arsenic in water bodies depends on natural and anthropogenic sources. Trace metal contents from natural sources derive mainly from soils and mineral weathering (Custodio et al., 2018). Cu is one of the essential nutrients required by biological systems for the activation of some enzymes. However, in aquatic environments Cu is toxic to a variety of organisms, even at very low concentrations. Likewise, the high concentrations of Cu in the upper course of the Chia River and lower course of the Tishgo River would be due to anthropogenic contributions. Pb is a heavy metal found in nature in the tetravalent (Pb⁴⁺) and divalent (Pb²⁺) forms. The divalent form is predominantly and slightly soluble in water (Deng et al., 2008).
Pb is extremely toxic to most life forms, especially aquatic organisms. Zn is another essential nutrient for life; it activates enzymes. It is found in food and drinking water in the form of salts or organic complexes (Diop et al., 2015). The main sources of Zn contamination of the aquatic environment are zinc-containing fertilizers, effluents from treatment plants and mining. Urban runoff, mine drainage and municipal wastewater are the most concentrated sources of zinc in water. Arsenic is found in the earth’s crust, in minerals in the form of amorphous and crystalline dust. In some areas the concentration of arsenic can be higher than normal and creates serious health hazards for humans and animals. It enters the environment through natural weathering of rocks, mining and smelting processes, pesticide use and coal combustion. The results showed arsenic contents that exceeded PEC, UCC reference and ISQG values.

Contamination and accumulation of heavy metals and arsenic in sediments

Table 1 shows the values of contamination factors (CF) and pollution load indices (PLI) for heavy metals and arsenic in sediment from the Tishgo and Chia rivers. In the Tishgo River, all the CF for Cu and 26% of the CF for Pb resulted less than one (CF < 1) qualifying for both heavy metals as low CF. Seventy-four percent of the CF for Pb and 100% of the CF for Zn were between 1 and 3, qualifying as moderate CF. In the case of As, 100% of the CF were greater than six (CF > 6), qualifying as high CF. In the Chia River, 100% of the CF for Cu, 100% of the CF for Pb and 93% of the CF for Zn were less than one (CF < 1) qualifying as low CF. Seven percent of the CF for Zn were between 1 and 3 (moderate CF), 63% of the CF for As were between 3 and 6 (considerable CF) and 37% of the CF were greater than 6 (CF > 6), qualifying as high CF. Based on these results, a high As contamination condition is observed for both rivers. The results of the pollution load indexes (PLI) for heavy metals and As of the Tishgo and Chia rivers ranged from 1.657 to 2.337 and from 0.732 to 1.418, respectively. The PLI results for the Tishgo River were greater than one (PLI > 1) denoting the environmental deterioration that this river has been experiencing. The highest PLI values were recorded at sampling sites S3 to S9, corresponding to the lower part of the river course. In the Chia River, 60% of the sampling sites indicated that there is no appreciable contamination by these elements (PLI < 1). However, 40% of the sampling sites indicated PLI environmental deterioration (PLI > 1), middle and upper part of the Chia River course.

Figure 3 shows the geo-accumulation index ($I_{geo}$) values for heavy metals and arsenic recorded
The potential ecological risk index (Ri) is a complex pollution index resulting from the sum of the risk factors (Er) (Williams & Antoine, 2020). Regarding the potential ecological risk index (Ri), it was found that 51% of the sampling sites presented a moderate Ri (150 ≤ Ri < 300). While 49% of the sampling sites showed a low Ri (Ri < 150). In the Chía River, the ecological risk values found for Cu, Pb and Zn are < 40, qualifying as low ecological risk. In 59% of the sampling sites the ecological risk values for As were found in the range of 40 to 80, qualifying as moderate ecological risk. In 11% the ecological risk values for As qualified as considerable ecological risk and 30% as low ecological risk. The Ri along the course of the Chia River qualified as low (< 150).

Figure 4 shows the behavior of the potential ecological risk index for both rivers. In the Tishgo River it can be observed that in several sampling sites the Ri values were > 150, indicating a moderate potential ecological risk index. The sampling sites that exceeded the value of 150 corresponded to the middle and upper reaches of the Tishgo River. In the Chía River, none of the sampling sites exceeded the marked limit, indicating a low potential ecological risk index along the course of the Chia River. However, the results of this index indicate an ascending behavior in this river.
Table 2. Contamination factor and pollution load index (PLI) of heavy metals and arsenic in sediments of Tishgo and Chia rivers.

| Sampling site | Tishgo River | Chia River |
|---------------|--------------|------------|
|               | Contamination Factor (CF) | PLI | Contamination Factor (CF) | PLI |
|               | Cu  | Pb  | Zn  | As | Cu  | Pb  | Zn  | As |
| 1             | 0.808 | 1.134 | 1.630 | 12.773 | 0.598 | 0.231 | 0.846 | 4.261 | 0.840 |
| 2             | 0.727 | 1.006 | 1.627 | 14.913 | 0.573 | 0.218 | 0.778 | 3.895 | 0.784 |
| 3             | 0.737 | 1.466 | 1.699 | 14.187 | 0.573 | 0.178 | 0.744 | 3.798 | 0.732 |
| 4             | 0.936 | 1.294 | 1.764 | 13.473 | 0.690 | 0.278 | 0.739 | 3.308 | 0.828 |
| 5             | 0.906 | 1.367 | 1.790 | 13.473 | 0.616 | 0.232 | 0.779 | 3.365 | 0.782 |
| 6             | 0.823 | 1.084 | 1.820 | 12.273 | 0.560 | 0.184 | 0.780 | 3.898 | 0.748 |
| 7             | 0.905 | 1.402 | 1.787 | 12.053 | 0.674 | 0.393 | 0.718 | 3.776 | 0.920 |
| 8             | 0.892 | 1.412 | 1.846 | 12.813 | 0.608 | 0.318 | 0.652 | 4.016 | 0.844 |
| 9             | 0.887 | 1.430 | 1.893 | 10.080 | 0.682 | 0.228 | 0.749 | 4.525 | 0.852 |
| 10            | 0.629 | 0.771 | 1.415 | 11.493 | 0.678 | 0.365 | 0.695 | 3.561 | 0.885 |
| 11            | 0.528 | 0.773 | 1.406 | 13.640 | 0.636 | 0.287 | 0.775 | 4.527 | 0.895 |
| 12            | 0.648 | 0.841 | 1.510 | 12.233 | 0.738 | 0.276 | 0.695 | 5.989 | 0.960 |
| 13            | 0.677 | 1.104 | 1.316 | 10.320 | 0.631 | 0.370 | 0.756 | 3.662 | 0.896 |
| 14            | 0.677 | 1.177 | 1.384 | 8.787 | 0.633 | 0.333 | 0.748 | 4.042 | 0.893 |
| 15            | 0.651 | 0.806 | 1.426 | 11.587 | 0.656 | 0.322 | 0.771 | 4.763 | 0.939 |
| 16            | 0.600 | 1.204 | 1.386 | 15.547 | 0.624 | 0.535 | 0.839 | 4.959 | 1.086 |
| 17            | 0.613 | 1.127 | 1.305 | 15.560 | 0.632 | 0.398 | 0.821 | 6.329 | 1.069 |
| 18            | 0.585 | 1.167 | 1.377 | 15.407 | 0.640 | 0.384 | 0.800 | 7.608 | 1.106 |
| 19            | 0.510 | 0.904 | 1.373 | 17.580 | 0.808 | 0.262 | 0.812 | 6.116 | 1.013 |
| 20            | 0.550 | 0.708 | 1.306 | 14.827 | 0.746 | 0.418 | 0.862 | 5.172 | 1.086 |
| 21            | 0.734 | 0.759 | 1.396 | 18.627 | 0.775 | 0.374 | 0.926 | 7.425 | 1.188 |
| 22            | 0.693 | 1.354 | 1.315 | 20.027 | 0.666 | 0.389 | 0.843 | 9.279 | 1.193 |
| 23            | 0.737 | 1.079 | 1.542 | 17.180 | 0.752 | 0.398 | 0.956 | 7.984 | 1.229 |
| 24            | 0.798 | 1.017 | 1.546 | 16.800 | 0.760 | 0.406 | 1.047 | 7.239 | 1.237 |
| 25            | 0.756 | 1.174 | 1.495 | 16.727 | 0.830 | 0.553 | 0.964 | 9.149 | 1.418 |
| 26            | 0.809 | 1.198 | 1.501 | 14.787 | 0.760 | 0.383 | 1.098 | 6.841 | 1.216 |
| 27            | 0.883 | 1.381 | 1.424 | 14.133 | 0.835 | 0.432 | 0.961 | 8.683 | 1.317 |

Figure 3. Geo-accumulation indices obtained from sediment samples of the Tishgo and Chia rivers.
Table 3. Ecological risk factor (Er) and potential ecological risk index (Ri) of heavy metals and arsenic in sediment of the Tishgo and Chia rivers.

| Sampling site | Tishgo Ecological risk | Chia Ecological risk | Ri |
|---------------|------------------------|----------------------|----|
|               | Cu | Pb | Zn | As |               | Cu | Pb | Zn | As |
| 1             | 4.04 | 5.67 | 1.63 | 127.73 | 139.07 | 2.99 | 1.15 | 0.85 | 42.61 | 47.60 |
| 2             | 3.63 | 5.03 | 1.63 | 149.13 | 159.42 | 2.86 | 1.09 | 0.78 | 38.95 | 43.68 |
| 3             | 3.69 | 7.33 | 1.70 | 141.87 | 154.58 | 2.86 | 0.89 | 0.74 | 37.98 | 42.48 |
| 4             | 4.68 | 6.47 | 1.76 | 134.73 | 147.65 | 3.45 | 1.39 | 0.74 | 33.08 | 38.66 |
| 5             | 4.53 | 6.83 | 1.79 | 134.73 | 147.88 | 3.08 | 1.16 | 0.78 | 33.65 | 38.67 |
| 6             | 4.11 | 5.42 | 1.82 | 122.73 | 134.09 | 2.80 | 0.92 | 0.78 | 38.98 | 43.48 |
| 7             | 4.53 | 7.01 | 1.79 | 120.53 | 133.85 | 3.37 | 1.96 | 0.72 | 37.76 | 43.81 |
| 8             | 4.46 | 7.06 | 1.85 | 128.13 | 141.49 | 3.04 | 1.59 | 0.65 | 40.16 | 45.44 |
| 9             | 4.44 | 7.15 | 1.89 | 100.80 | 114.28 | 3.41 | 1.14 | 0.75 | 45.25 | 50.55 |
| 10            | 3.15 | 3.86 | 1.41 | 114.93 | 123.35 | 3.39 | 1.83 | 0.70 | 35.61 | 41.52 |
| 11            | 2.64 | 3.87 | 1.41 | 136.40 | 144.31 | 3.18 | 1.44 | 0.78 | 45.27 | 50.66 |
| 12            | 3.24 | 4.20 | 1.51 | 122.33 | 131.28 | 3.69 | 1.38 | 0.70 | 59.89 | 65.66 |
| 13            | 3.38 | 5.52 | 1.32 | 103.20 | 113.42 | 3.15 | 1.85 | 0.76 | 36.62 | 42.38 |
| 14            | 3.39 | 5.88 | 1.38 | 87.87 | 98.52 | 3.16 | 1.67 | 0.75 | 40.42 | 46.00 |
| 15            | 3.25 | 4.03 | 1.43 | 115.87 | 124.58 | 3.28 | 1.61 | 0.77 | 47.63 | 53.30 |
| 16            | 3.00 | 6.02 | 1.39 | 155.47 | 165.87 | 3.12 | 2.68 | 0.84 | 49.59 | 56.23 |
| 17            | 3.06 | 5.64 | 1.31 | 155.60 | 165.60 | 3.16 | 1.99 | 0.82 | 63.29 | 69.27 |
| 18            | 2.92 | 5.83 | 1.38 | 154.07 | 164.20 | 3.20 | 1.92 | 0.80 | 76.08 | 82.00 |
| 19            | 2.55 | 4.52 | 1.37 | 175.80 | 184.25 | 4.04 | 1.31 | 0.81 | 61.16 | 67.32 |
| 20            | 2.75 | 3.54 | 1.31 | 148.27 | 155.86 | 3.73 | 2.09 | 0.86 | 51.72 | 58.40 |
| 21            | 3.67 | 3.80 | 1.40 | 186.27 | 195.13 | 3.87 | 1.87 | 0.93 | 74.25 | 80.92 |
| 22            | 3.46 | 6.77 | 1.31 | 200.27 | 211.81 | 3.33 | 1.94 | 0.84 | 92.79 | 98.91 |
| 23            | 3.68 | 5.40 | 1.54 | 171.80 | 182.42 | 3.76 | 1.99 | 0.96 | 79.84 | 86.54 |
| 24            | 3.99 | 5.09 | 1.55 | 168.00 | 178.62 | 3.80 | 2.03 | 1.05 | 72.39 | 79.27 |
| 25            | 3.78 | 5.87 | 1.50 | 167.27 | 178.41 | 4.15 | 2.76 | 0.96 | 91.49 | 99.36 |
| 26            | 4.05 | 5.99 | 1.50 | 147.87 | 159.40 | 3.80 | 1.91 | 1.10 | 68.41 | 75.23 |
| 27            | 4.42 | 6.90 | 1.42 | 141.33 | 154.08 | 4.17 | 2.16 | 0.96 | 86.83 | 94.13 |

CONCLUSIONS

The accumulation of metals in the sediments of rivers with fish farming potential can have a negative impact on aquatic ecosystems with repercussions on human health. Therefore, in this study, the sediment of the Tishgo and Chia rivers was analyzed to evaluate the contamination, accumulation and potential ecological risk of heavy metals and arsenic. The decreasing order of the mean concentrations of heavy metals and metalloid in the Chia River was Zn > Cu > As > Pb and in the Tishgo River was Zn > Pb > As > Cu. In the Chia River, the highest mean concentrations of Zn, Cu, As and Pb were recorded in the upper course of the river. While in the Tishgo River, the highest mean concentrations were recorded in the lower course of the river. The mean concentrations of heavy metals and metalloids recorded in the rivers studied were lower than the threshold values of the probable effect concentration.

Based on the results, a high As contamination condition is observed for both rivers. The results of the pollution load indexes (PLI) of heavy metals and As for the Tishgo and Chia rivers ranged from 1.657 to 2.337 and from 0.732 to 1.418, respectively. The PLI results for the Tishgo river were greater than one (PLI > 1), indicating the environmental deterioration that this river has been experiencing. In the Chia River, 60% of the sampling sites indicated no appreciable contamination by these elements (PLI < 1). The Igeo values of As in both rivers showed a state of contamination, from moderately to severely contaminated. In the Tishgo River the potential ecological risk ranged from low to moderate and in the Chia River from low to considerable.

The results of this research can be very useful for special measures to be adopted to control the entry of heavy metals with toxicological effects in the aquatic environments of the Tishgo and Chia rivers for the protection of these aquatic
ecosystems and human health. The analysis of the data also reflects applicability and necessity of the evaluation indexes of contamination, accumulation and potential ecological risk of toxic metals.

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