RESEARCH ARTICLE

Distribution, water quality, and health risk assessment of trace elements in three streams during the wet season, Guiyang, Southwest China

Jue Zhang¹, Qixin Wu¹,*, Zhuhong Wang², Shilin Gao¹, Huipeng Jia¹, and Yuanyi Shen¹

Trace element pollution derived from human activities in aquatic systems has raised widespread concerns due to its toxicity, persistence, and bioaccumulation. In this article, we presented a systematic investigation of the anthropogenic overprints on trace elements geochemistry in three streams of the human-impacted (agriculture, urban area, and abandoned mining), located at Lake Aha, Guiyang, Southwest China. Concentrations reported in the study demonstrated that the abandoned mining stream showed the highest trace elements (608.16 μg/L), followed by the urban stream (566.11 μg/L) and agricultural stream (457.51 μg/L). Nonmetric multidimensional scaling (NMDS), used to display sampling dates and trace elements, showed discernible temporal variation in trace element concentrations. Trace element concentrations in months (May, September, and October) with less rainfall were higher than in June, July, and August indicated by NMDS. Principal component analysis (PCA) had shown that As, Ba, Mo, and Zn were mainly impacted by the urbanized streams, and Fe and Sr influenced by the mine. Risk assessment of human beings to trace elements demonstrated that As may pose a detrimental health risk. The research found that trace elements were potential tracers for the presence of human activities and environmental changes.

Keywords: Dissolved trace elements, Human activities, Streams, Health risk, Southwest China

1. Introduction

Trace elements consist of metallic elements and metalloids. They are of great importance for considerable technological devices such as electronics, catalysts, and ceramics (Vriens et al., 2017). During the past few decades, the application of trace elements has increased gradually due to economic development. For example, Mo is widely used in alloys, stainless steels, lubricants, and fertilizers (Chen et al., 2014). As could be found in certain insecticides (Wu et al., 2016). Previous studies also showed that Zn and Cd were used in household detergents, metal alloys, and electronics (Chen et al., 2014; Wang et al., 2019). Because of the characteristics of toxicity, persistence, and bioaccumulation, trace elements in the environment have aroused extensive attention over the world (Tchounwou et al., 2012; Liu et al., 2019; Zeng et al., 2020). Widespread trace elements also pose threats to the aquatic environment (Zeng et al., 2015; Zhang et al., 2017; Liang et al., 2018). In general, trace elements in aquatic systems could occur through two pathways including natural processes and anthropogenic activities. Natural processes such as erosion, weathering, and volcanism contribute to a certain amount of trace elements (Li and Zhang, 2010a; Liang et al., 2018). Human activities can also potentially increase the emissions of “anthropogenic” trace elements, which could be released into the rivers by sewage discharge, vehicle transportation, industry, fertilizer leaching, and so on (Zeng et al., 2015; Wu et al., 2016; Wang et al., 2019). Trace elements that are discharged into the environment from human activities have been reported to significantly contribute to river pollution. Due to the mining activities, As and Hg from the Beijiang River accounted for 42% and 28% of the Pearl River system pollution, respectively (Zhen et al., 2016). Furthermore, the sediments could be contaminated by thallium or cadmium because of copper metallurgy/Pb–Zn smelting activities (Wang et al., 2020a). Few trace elements, such as Cu, Cd, and Mn, used for fertilizers or pesticides, may threaten water quality and human health (Li and Zhang, 2010b; Liang et al., 2019). Pb in batteries and vehicles may also discharge the Pb into the environment (Wang et al., 2019). It is worth noting that human activities have become important sources of trace elements in aquatic systems.

Some metals such as Cd, Fe, Mo, and Zn are important for human and animal growth (World Health Organization [WHO], 2017). Bioaccumulation and toxicity of
high-intake trace elements may cause significant threats to human health (Liu et al., 2017). It has been reported that Zn can be accumulated by atmospheric deposition and industrial pollution, which may develop iron deficiency anemia and affect the digestive tract of humans (Yang et al., 2014; Zeng and Han, 2020b). Thallium poisoning is characterized by stomach and intestinal ulcers and alopecia (Wang et al., 2020b). As and Cd, as carcinogens, are the focused subjects of human health risk (Liu et al., 2017). Several pieces of research have indicated that long-term As exposure could cause hepatocellular carcinoma, hypertension, cancers, cirrhosis, and parenchymal cell damage (Chowdhury et al., 2016; Wu et al., 2016). And human exposure to Cd may lead to human bones, lungs, liver, kidney damage, and malfunction (Tchounwou et al., 2012).

With population increase and economic development, several studies had shown significant trace element concentrations in large rivers in China (Zhen et al., 2016; Zhang et al., 2017; Gao et al., 2019; Xiao et al., 2019). The concentrations and distributions of dissolved and suspended sediment trace elements were investigated in the Yangtze River and found that certain trace elements were associated with adverse effects on humans (Yang et al., 2014; Zeng et al., 2015; Zhang et al., 2017). Xiao et al. (2019) and Gao et al. (2019) studied the trace elements in the Yellow River, showing that some trace metals were attributed to anthropogenic factors and the potential deleterious health effects of vanadium and arsenic. Additionally, the dissolved trace elements had been observed in the Pearl River (Zhen et al., 2016; Zeng and Han, 2020a). Serving as the estuary, the accumulation of trace elements caused risks not only to the environment but also to human health (Zhen et al., 2016). The pollution of surface water, groundwater, and seawater by trace elements may contaminate drinking water (Chowdhury et al., 2016). Therefore, research on the impact of trace elements and the assessment of human health risks become important in the aquatic systems, especially in different human activities in rivers.

In this article, eight trace elements are carried out at three streams (agriculture, urban area, and abandoned mining), which are located in Lake Aha Catchment in Guizhou, southwestern China. The purpose of the present study is to (1) understand the dissolved trace element distribution of distinct human activities in streams, (2) determine temporal variation and environmental factors on trace element concentrations, and (3) evaluate the water quality as well as the health risk by hazard quotients (HQ) and hazard index (HI).

2. Materials and methods

2.1. Study area

The study area is shown in Figure 1, including Baiyan Stream (BY), Jinzhong Stream (JZ), and Youyu Stream (YY) at Lake Aha Catchment (26°34′ N, 106°43′ E; Han et al., 2019; Zhang et al., 2019). The continental climate of the study area is subtropical humid, monsoon climate, which is characterized by significant summer rainfall. The rainfall is abundant with annual average precipitation of 1,140–1,200 mm, mostly occurring from May to October (Zeng et al., 2019). In June, the highest precipitation can reach up to 507 mm.

BY, an area of 51.5 km² and a length of 15 km, is mainly forest (40.2%) and agricultural land (36.6%). It is considered a rural environment dominated by agricultural activities. Triassic dolomite and shale are greatly exposed in BY. Flowing through the urban area of Guiyang City, the JZ has a length of 16.5 km and a drain area of 47.5 km². With the rapid development of industry and the acceleration of urbanization, the JZ, situated on the Triassic dolomite, is a typical small urban stream (81.6% residential and commercial land; Lv, 2018). YY (61.9 km² drainage and 18.5 km length) is the abandoned mine-intensive area in Guiyang, with less residential and commercial land (3.3%). The YY rock types are Permian limestone and Triassic shale (Zhang et al., 2019). The geological background is similar in the three streams, but human activities along the streams vary significantly (Figure 1). More details about the three streams are given in Table S1 of the supplementary material.

2.2. Sampling and analysis

A total of 18 sampling points were performed in the three streams. Of which, 6 sampling points were in BY, 3 sampling points in JZ, and 9 sampling points in YY. The investigated trace elements included As, Ba, Cd, Fe, Li, Mo, Sr, and Zn. In the wet season, the potential impact of trace elements from the point and nonpoint sources on the river waters should be maximum, which can reflect the different characteristics of the three streams. Therefore, water samples were collected monthly from May to October 2017 (wet season), at a depth of below 10 cm. Filtered through a 0.22 μm cellulose–acetate membrane, the water samples were collected in HNO₃-purified high-density polyethylene bottles. All polyethylene bottles were rinsed with river water before using them. After collection, the element determination samples were acidified to pH < 2 with ultrapure HNO₃ and stored at 4 °C in the refrigerator for sample conservation. pH, electrical conductivity (EC), and dissolved oxygen (DO) were measured by the WTW Multi3430 (WTW Company, Weilheim, Upper Bavaria, Germany) in situ after sampling. The trace elements were determined by the ICP-MS (Perkin-Elmer NexION300X) at the Institute of Geochemistry, Chinese Academy of Sciences, with an accuracy analysis of <3% (Zhang et al., 2019).

2.3. Data analysis

Nonmetric multidimensional scaling multivariate statistical techniques (principal component analysis [PCA] and Spearman’s correlation analysis) and non-multidimensional scaling were performed for trace element analysis using the statistical software R. PCA, a useful approach of multidimensional datasets analysis, could reduce the dimensionality of the dataset to obtain meaningful, clear, and precise information (Gredilla et al., 2013; Gao et al., 2020). By extracting significant principal components (PCs) with eigenvalues > 1 via PCA, the association with
trace elements and sampling points of the three streams could be revealed. Spearman’s correlation analysis was used to demonstrate the relationship between selected elements and physical parameters (pH, DO, and EC). Non-metric multidimensional scaling is a kind of method based on ranking order, which means that the original distance data are replaced by the Euclidean distance ranks. The results of NMDS were measured by the numerical values of stress as follows: acceptable: <0.15; preferred: <0.10; and representative: <0.05 (Xu et al., 2018). NMDS was applied to the temporal variation of trace element concentrations by reducing the data to two dimensions. Besides, the difference between sampling dates and trace elements in the study area was determined using the Kruskal–Wallis test. And the post hoc analyses comparison, verified by Bonferroni, showed the pollution level in the investigated streams.

2.4. Water quality index (WQI)

The water quality index (WQI) provides important information on the water matrix by evaluating the comprehensive water quality parameters. Lower scores indicate better water quality, while higher scores indicate worse. It is crucial to determine factor weights in comprehensive water quality assessment. The water quality for drinking is calculated as follows:

$$WQI = \sum W_i \times \left( \frac{C_i}{S_i} \right) \times 100.$$  

Where $i$ stands for different parameters, $W_i$ is the weight assigned to parameters, which depends on its relative importance for drinking purposes (Xiao et al., 2019). $C_i$ and $S_i$ denote the trace element concentrations in the study area and the Chinese standard for drinking water (GB 5749–2006) for each element (China EPA, 2006). The water quality is classified based on the numerical values of WQI as follows: excellent: 0–50, good: 50–100, poor: 100–200, very poor: 200–300, and undrinkable: ≥300.

2.5. Health risk assessment

Health risk assessment is a process used to identify the exposure and tendency of trace elements. And it could be used to assess potential health hazards that affect human health (Gredilla et al., 2013). Generally, direct ingestion, inhalation through mouth and nose, and dermal
absorption through bath are the main pathways for humans’ exposure to trace elements in the water (Liang et al., 2019; Zeng et al., 2015). The noncarcinogenic risk is estimated by HQs, which is quantified using the ratio of average daily exposure doses to the reference dose (RfD) (Li and Zhang, 2010a; Xiao et al., 2019). And the Hazard Index (HI) represents the noncarcinogenic risk of trace elements from different pathways, meaning that it could be calculated by the sum of the HQ from direct ingestion and dermal absorption. If HQ is greater than 1, the adverse effects of mixed trace elements may occur. Where HI > 1, the potential for noncarcinogenic effects is a concern and further study (Phan et al., 2013). Modified by the United States Environmental Protection Agency (EPA), Equations 2 and 3 are used to evaluate the average daily exposure doses on ingestion and dermal absorption (Chowdhury et al., 2016; US EPA, 2004). The relevant exposure variables of calculation are listed in supplementary material Table S2, which comes from the standards set by the EPA (US EPA, 2004). The HQ and HI are calculated as follows:

\[
D_{\text{ingestion}} = \frac{C_w \times IR \times EF \times ED}{BW \times AT}, \quad (2)
\]

\[
D_{\text{dermal}} = \frac{C_w \times SA \times K_P \times ET \times EF \times ED \times 10^{-3}}{BW \times AT}, \quad (3)
\]

\[
HQ = \frac{D}{RfD}, \quad (4)
\]

\[
HI = \sum HQs. \quad (5)
\]

Where RfD is the corresponding reference dose, in µg/kg/day. RfD through ingestion and dermal absorption originates from Wu et al. (2009).

3. Results

3.1. The occurrence of the trace elements

The physical parameters (pH, DO, and EC) of the three streams are shown in Table S3. The pH values of the water samples range from 7.45 to 8.35, with an average of 7.94 and a median of 8.01. Weakly alkaline waters are commonly associated with carbonate rocks (Masresha et al., 2011). The average of DO is 7.07 and varies from 5.27 (YY-7) to 8.18 (YY-3). The EC contents are considerably variable and the highest values could be noticed at YY.

Figure 2 and Table S3 illustrate the trace element concentrations and distributions of the investigated streams in the wet season. The trace elements of BY are in decreasing order of Sr, Ba, Fe, Li, Zn, Mo, As, and Cd. Sr, Fe, and Ba are more than 25 mg/L. Li, Zn, and Mo concentrations vary from 1 to 25 mg/L, while As and Cd have the lowest concentrations (<1 mg/L) among all trace elements. Trace element concentrations for JZ range from 0.01 (Cd) to 456.53 (Sr) µg/L. The higher concentrations of Sr (368.95–600.35 µg/L) appear in JZ compared to the other trace elements. There is no significant difference in the order of trace elements between BY and JZ. The concentrations of trace elements in YY range from 0.01 to 545.25 µg/L (Sr>Fe>Ba>Li>Zn>Mo>As>Cd). And Fe and Sr concentrations are relatively high in all the sites, especially YY-3 and YY-9. The results of the Kruskal–Wallis test on the trace elements indicate that the trace element level differs somewhat among the three streams (P < 0.05), except Cd (Table S4). The average trace element concentrations in the investigated streams decreased in the following order: As: JZ>BY>YY; Ba: JZ>BY>YY; Cd: no difference, Fe: YY>YJZ=BY, Li: JZ>BY=YY, Mo: JZ=BY>YY, Sr: JZ=YY>BY, Zn: JZ=BY>YY (Table S4). The concentrations of As, Li, and Zn in the JZ are 1.81, 6.06, and 3.21 µg/L, which are

Figure 2. The distribution of trace elements. Boxplots display the distribution of trace element concentrations in Baiyan Stream, Jinzhong Stream, and Youyu Stream (µg/L). DOI: https://doi.org/10.1525/elementa.2021.00133.f2
higher than the BY and YY (P < 0.05). Fe concentrations are relatively high in the YY stream compared to the BY (P < 0.05) and JZ (P = 0.003). Ba and Mo show no discernible difference in BY and JZ. And there is no distinct concentration difference in Cd between the three streams.

### 3.2. Correlation study

Correlation analysis provides a visual method to reveal the consistent sources of elements through the positive strength of correlation (Gaulier et al., 2019). The correlations among trace elements and physical parameters (pH, DO, and EC) in the study area are shown in Figure 3. Results from correlation analysis show that there are significant correlations between trace elements and physical parameters. pH has strong correlations with Fe (−0.39) and Mo (0.28, P < 0.01). EC is shown to be correlated with trace element concentrations for the strong correlations with the Li, Fe, As, Sr, and Cr (P < 0.01). And there are negative correlations between DO and Zn (r = −0.38, P < 0.01), as well as As (r = −0.37, P < 0.01). Moreover, Sr, Fe, Ba, Li, Zn, Mo, As, and Cd have observed significant correlations. The correlation matrix shows that Sr, Fe, and Li exhibit high correlations. It is suggested that three elements may originate from similar sources with strong positive correlations between Li and Sr (r = 0.33, P < 0.01), Li and Fe (r = 0.49, P < 0.01), and Sr and Fe (r = 0.54, P < 0.01). As is positively correlated with Mo, while Ba and As also show a significant correlation, with a correlation coefficient of 0.76 (P < 0.01). Additionally, Zn has strong positive correlations with As (0.60), Mo (0.63), and Ba (0.57). It also shows positive correlations with Li and Cd. The results may be explained by mixed sources of Zn (Chen et al., 2014).

### 3.3. Principal component analysis

To explore elements of “more information” (e.g., behavior and common origins), the PCA is performed for eight trace elements from the three streams (Figure 4, Figure S1, Table S5, Table S6). The results of PCA show that three PCs (eigenvalues >1) are defined, which explain 88.9% of the data variation. PC1 accounts for 52.7% of the total variance dominated by As, Ba, Mo, and Zn. These element contents have a higher occurrence in the sampling points.
located in the BY and JZ (Figure 4). Li, Fe, and Sr have high loadings in PC2, with 23.3\% of the total variance. And PC3 accounts for 13\% of the total variance that is dominated by Cd. Taking PC1 and PC2 as axes, the various human activities in streams distribute in different quadrants. The BY and the city-affected stream (JZ) are located in the first and fourth quadrants, while the YY sampling points affected by abandoned mines are distributed in the second and third quadrants (Figure 4). The samples from the urban zone (JZ-17, JZ-18) and the samples at the entrance of Lake Aha (BY-13, BY-15, JZ-18) show strong relationships with certain trace elements (As, Ba, Mo, Zn, Cd), while trace element values at some sampling points located in the forest and grassland (YY-5, YY-6) and agricultural land (YY-7, YY-8, BY-10, BY-11) are relatively low (Figure 4). This indicates that As, Ba, Mo, and Zn are affected by urban activities, and Fe and Sr are mainly from mining activities and natural process. Moreover, the highest trace elements could be observed in JZ-17 in the study area (Table S3).

3.4. NMDS analysis
NMDS results are presented in Figure 5, which show the distribution of trace elements among different months. The analyzed stress value of 0.04 is representative. Figure S2 shows a fitting graph (Shepard’s plot) between the distance of the object in the NMDS ranking graph and the distance of the original object, which evaluates the rationality of the NMDS results. The 95\% confidence ellipses overlap a lot. Therefore, 10\% confidence ellipses for each month are superimposed in Figure 4 to understand better the position of different sampling dates in the NMDS space. As shown in Figure 4, the values of June, July, and August on NMDS2 are relatively different, and there is a certain overlap between May, September, and October. And the Kruskal–Wallis test on trace elements and sampling dates also indicates a discernible trend in different months among trace elements, except for Cd ($P < 0.01$).

3.5. WQI
The water quality assessment at the three streams is evaluated using WQI. According to previous studies, the weight of trace elements is given in Table S3 (Xiao et al., 2014; Gao et al., 2019). Li and Sr are not calculated due to the lack of limited values of Environmental Quality Standards for Drinking Water (GB 5749–2006; China EPA, 2006). The natural waters within the three streams are suitable for drinking with the WQI of all samples <50. The WQI values of BY, JZ, and YY are 5.37, 7.22, and 4.08, respectively, showing the difference of each sampling point (Table S3). Sampling points are categorized as excellent water for drinking purposes, and JZ-17 and JZ-18 have relatively high WQI values.
3.6. Human health risk assessment
The health risk assessment of two groups (adults and children) is performed in this study. According to Equations 2 and 3, two pathways of exposure (direct ingestion and dermal absorption) from the three streams are calculated to assess the potential effects on human health. The results of HQs and HI are summarized in Table 1. All trace elements in the three streams pose little hazards for adults and children with HQ\textsubscript{ingestion}, HQ\textsubscript{dermal}, and HI <1. The HQ\textsubscript{ingestion} values vary from 9.47 \times 10^{-5} to 1.67 \times 10^{-1}, 1.41 \times 10^{-4} to 2.50 \times 10^{-1} for adults and children. However, the HQ\textsubscript{dermal} values are lower than the HQ\textsubscript{ingestion} from 2.56 \times 10^{-6} to 3.67 \times 10^{-3} (adults) and from 2.54 \times 10^{-6} to 3.64 \times 10^{-3} (children), respectively, showing that the pathways of direct ingestion more possibly endanger human health. Furthermore, the HQ of children by direct ingestion is sensitive to trace elements, while the HQ through dermal absorption is a little different between adults and children. HI values show higher for children than adults, suggesting that the children are more sensitive to the risk of exposure to trace elements.

4. Discussion
4.1. Trace elements in the study area
4.1.1. Distribution and source of trace elements
The total trace elements for the three streams are in decreasing order of Youyu (608.16 µg/L), Jinzhong (566.11 µg/L), and Baiyan (457.51 µg/L), demonstrating that the impact of mining activities on trace elements is worthy of attention. Results from PCA analysis show sampling points are distributed in different quadrants, which could be attributed to various human activities in the three streams (Figures 1 and 4, Table S1).

High trace element concentrations are shown at YY-1 and YY-9. YY-9 is near the village area on the upper reaches of Youyu. And the downstream sampling point (YY-1) is a lake inlet, where a great number of contaminants are accumulated (Figure 1). Moreover, Fe concentrations in the YY are lower than that of the Pearl River (Ouyang et al., 2005), Changjiang (Wang et al., 2011), and the Mississippi River (Reiman et al., 2018) but higher than the other streams BY (24.35 µg/L), JZ (22.90 µg/L), and the Upper Han River (30.64 µg/L; Li and Zhang, 2010b). As previously noted, Youyu sampling sites have many abandoned coal mines, mainly concentrated upstream and less residential and commercial land (Yang et al., 2011; Zhang et al., 2019). The results reveal that Fe concentrations for Youyu are not only affected by geological sources, especially YY-3 and YY-9, but also could be caused by the Fe-containing mines’ wastewater (Yang et al., 2011).

Jinzhong is located in the densely populated area of Guiyang City. The investigated trace elements have a peak value at JZ-17, which could be attributed to industrial and domestic wastewater. The sampling point (JZ-17) is near the Jinyang Sewage Treatment Plant. In this area, relatively large amounts of wastewater containing high loads of...
trace elements may discharge (Zhang et al., 2019). In all of the water samples, trace element concentrations (Zn, As, Mo, Ba) are abundant in BY and JZ (Figure 2, Table S4). It was reported that these trace elements could be applied in many aspects (lubricants, fertilizers, electronics, etc.; Chen et al., 2014; Vriens et al., 2017; Wang et al., 2019). With 36.6% agricultural land and 18.3% urban land, the Baiyan watershed may be polluted by anthropogenic trace elements.

Fe and Sr concentrations are relatively high in all the sites, ranging from tens to hundreds of μg/L. The occurrence of Fe, lithophile elements, is commonly considered as the integration of crustal contribution and pedogenic process (Song et al., 2013; Liang et al., 2018). However, Fe displays different behaviors in the three streams, which indicates the mixture of sources and transport of Fe (rock weathering or anthropogenic sources). Sr is usually stored in the calcite and strontianite in the crust (Song et al., 2013). The high concentration of Sr (278.96–620.73 μg/L) could be explained by a higher proportion of weathered carbonate rocks (Liu et al., 2017). This result is also supported by previous studies on the upper Xijiang River (Liu et al., 2017). The comparison of trace elements in other rivers is given in Table 2. Most trace element concentrations in the study area are significantly higher than the average worldwide values, except Fe and Cd (in BY, JZ, and YY; Gaillardet et al., 2014). However, the concentrations of trace elements are lower than those reported for large river basins, such as the Yellow River (Gao et al., 2019), the Amazon River (Elbaz-Poulichet et al., 1999), the

| Table 1. Hazard quotient (HQ), hazard index (HI), and reference dose (RfD) for trace elements in three streams. DOI: https://doi.org/10.1525/elementa.2021.00133.t1 |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Element         | HQ\textsubscript{ingestion} | HQ\textsubscript{dermal} | HI = ∑HQ\textsubscript{s} RfD\textsubscript{ingestion} | RfD\textsubscript{ingestion} | RfD\textsubscript{dermal} |
|                 | Adult | Child | Adult | Child | Adult | Child | Child | Child | Child | Child | Child |
| Baiyan Stream   |       |       |       |       |       |       |       |       |       |       |       |
| As              | 9.57E-02 | 1.43E-01 | 2.10E-03 | 2.08E-03 | 9.78E-02 | 1.45E-01 | 0.3 | 0.123 |
| Ba              | 5.08E-03 | 7.58E-03 | 6.53E-04 | 6.48E-04 | 5.73E-03 | 8.23E-03 | 200 | 14    |
| Cd              | 1.46E-03 | 2.18E-03 | 2.62E-04 | 2.60E-04 | 1.72E-03 | 2.44E-03 | 0.5 | 0.025 |
| Fe              | 2.31E-03 | 3.45E-03 | 1.39E-04 | 1.38E-04 | 2.45E-03 | 3.59E-03 | 300 | 45    |
| Li              | 4.01E-03 | 5.99E-03 | 7.22E-05 | 7.17E-05 | 4.08E-03 | 6.06E-03 | 20  | 10    |
| Mo              | 1.29E-02 | 1.93E-02 | 3.05E-04 | 3.03E-04 | 1.32E-02 | 1.96E-02 | 5   | 1.9   |
| Sr              | 1.76E-02 | 2.63E-02 | 7.93E-04 | 7.87E-04 | 1.84E-02 | 2.71E-02 | 600 | 120   |
| Zn              | 2.73E-04 | 4.08E-04 | 7.38E-06 | 7.32E-06 | 2.81E-04 | 4.15E-04 | 300 | 60    |
| Jinzhong Stream |       |       |       |       |       |       |       |       |       |       |       |
| As              | 1.67E-01 | 2.50E-01 | 3.67E-03 | 3.64E-03 | 1.71E-01 | 1.67E-01 | 0.3 | 0.123 |
| Ba              | 4.97E-03 | 7.41E-03 | 6.38E-04 | 6.34E-04 | 5.61E-03 | 8.04E-03 | 200 | 14    |
| Cd              | 6.11E-04 | 9.13E-04 | 1.10E-04 | 1.09E-04 | 7.21E-04 | 6.11E-04 | 0.5 | 0.025 |
| Fe              | 2.24E-03 | 3.34E-03 | 1.34E-04 | 1.33E-04 | 2.37E-03 | 2.24E-03 | 300 | 45    |
| Li              | 9.53E-03 | 1.42E-02 | 1.72E-04 | 1.70E-04 | 9.71E-03 | 9.53E-03 | 20  | 10    |
| Mo              | 1.57E-02 | 2.34E-02 | 3.72E-04 | 3.69E-04 | 1.61E-02 | 1.57E-02 | 5   | 1.9   |
| Sr              | 2.23E-02 | 3.33E-02 | 1.00E-03 | 9.97E-04 | 2.33E-02 | 2.23E-02 | 600 | 120   |
| Zn              | 3.23E-04 | 4.82E-04 | 8.72E-06 | 8.65E-06 | 3.32E-04 | 3.23E-04 | 300 | 60    |
| Youyu Stream    |       |       |       |       |       |       |       |       |       |       |       |
| As              | 2.64E-02 | 3.94E-02 | 5.79E-04 | 5.75E-04 | 2.64E-02 | 3.94E-02 | 0.3 | 0.123 |
| Ba              | 2.75E-03 | 4.10E-03 | 3.53E-04 | 3.50E-04 | 2.75E-03 | 4.10E-03 | 200 | 14    |
| Cd              | 4.28E-04 | 6.39E-04 | 7.70E-05 | 7.64E-05 | 4.28E-04 | 6.39E-04 | 0.5 | 0.025 |
| Fe              | 3.81E-03 | 5.68E-03 | 2.28E-04 | 2.27E-04 | 3.81E-03 | 5.68E-03 | 300 | 45    |
| Li              | 7.20E-03 | 1.08E-02 | 1.30E-04 | 1.29E-04 | 7.20E-03 | 1.08E-02 | 20  | 10    |
| Mo              | 5.76E-03 | 8.60E-03 | 1.36E-04 | 1.35E-04 | 5.76E-03 | 8.60E-03 | 5   | 1.9   |
| Sr              | 2.46E-02 | 3.67E-02 | 1.11E-03 | 1.10E-03 | 2.46E-02 | 3.67E-02 | 600 | 120   |
| Zn              | 9.47E-05 | 1.41E-04 | 2.56E-06 | 2.54E-06 | 9.47E-05 | 1.41E-04 | 300 | 60    |

\[ a \text{ Wu et al. (2009).} \]

Of the water samples, trace element concentrations (Zn, As, Mo, Ba) are abundant in BY and JZ (Figure 2, Table S4). It was reported that these trace elements could be applied in many aspects (lubricants, fertilizers, electronics, etc.; Chen et al., 2014; Vriens et al., 2017; Wang et al., 2019). With 36.6% agricultural land and 18.3% urban land, the Baiyan watershed may be polluted by anthropogenic trace elements.
Changjiang River (Wang et al., 2011), and the Mississippi River (Reiman et al., 2018). In general, the dilution of the trace element contents is observed in the wet season (Liang et al., 2018). Due to the dilution effect, the contribution of increased rainfall may cause trace element levels to decrease (Liang et al., 2019; Ferreira et al., 2020). The environmental factors, such as water flow, the interaction between water and particles, and stream hydrology, may impact on the seasonal occurrence of trace elements in the aquatic systems (Marques et al., 2016; Liang et al., 2019). Although samples are collected during the wet season, the factors contribute to the seasonal occurrence and distribution of trace elements. However, Zn concentrations of the 3 streams are larger than those of the Yellow River (Gao et al., 2019). Sr concentrations are about half that of the Mississippi River but similar to that in the Xijiang River (Liu et al., 2017). And Ba concentrations (except in YY) are higher than those in the Pearl River (Ouyang et al., 2005) and the Xijiang River (Liu et al., 2017). The trace element concentrations (As and Cd) in JZ are in line with the results obtained in the stream from southwest Guizhou, which is also a main populated area (Zhao et al., 2017). Compared to recent research in the Karstic river surrounded by mining, Sr concentrations in the YY are as high as research, while Zn and As show lower levels (Ling et al., 2018).

Table 2. Comparison of trace element concentrations in Lake Aha catchment with other rivers (unit: μg/L). DOI: https://doi.org/10.1525/elementa.2021.00133.t2

| Rivers                        | As  | Ba  | Cd  | Fe   | Li  | Mo  | Sr  | Zn  | References                  |
|-------------------------------|-----|-----|-----|------|-----|-----|-----|-----|-------------------------------|
| Baiyan Stream                 | 1.05| 35.26| 0.02| 24.35| 2.79| 2.33| 370.30| 2.53|                               |
| Jinzhong Stream               | 1.81| 36.25| 0.01| 22.90| 6.06| 2.69| 456.53| 3.21|                               |
| Youyu Stream                  | 0.28| 20.04| 0.01| 42.20| 5.35| 1.06| 545.25| 1.02|                               |
| World average                 | 0.62| 23  | 0.08| 66   | 1.84| 0.42| 60   | 0.6  | Gaillardet et al. (2014)      |
| Yellow River, China           | 2.4 |     |     |      | 8.71|     | 0.77 |     | Gao et al. (2019)             |
| Upper Amazon, Portugal        | 138.40| 0.18|     |     | 4.09| 856.87| 19.08|     | Elbaz-Poulichet et al. (1999) |
| Changjiang River, China       | 7.04|     | 0.28| 1,660| 9   |     | 167  | 18.75| Wang et al. (2011)           |
| Mississippi, USA              | 11  | 97  |     | 3,497| 9   |     | 15   | 15   | Reiman et al. (2018)         |
| Xijiang River, China          | 26.43| 0.01|     |     | 0.90| 259.00| 1.83 |     | Liu et al. (2017)            |
| Pearl River Delta, China      | 0.15| 31.91| 0.13| 161.91| 5.12| 2.41| 96.15| 61.85| Ouyang et al. (2005)         |
| Three Gorges Reservoir (Chongqing), China | 1.54 | 0.03 |     |     |     |     | 128.54|     | Zhao et al. (2017)           |
| Diaojiang, China              | 15  |     |     | 518  | 5   | 450 |     |     | Ling et al. (2018)           |
| China a                       | 10  | 700 | 5   | 300  | 70 | 1,000|     | 1,000| China EPA (2006)             |
| WHO b                         | 10  | 1,300| 3   | 300  | 70 |     |     | 70   | WHO (2017)                   |
| U.S. PEA c                    | 10  | 2,000| 5   | 300  | 70 |     |     | 50   | U.S. EPA (2012)              |
| Grade 1 d                     | 10  |     |     |     |     |     |     |     | China EPA (2002)             |

4.1.2. Trace elements on sampling dates

Combined with NMDS, the Kruskal–Wallis test is used for the distribution of trace elements on the sampling dates, showing significant difference in the investigated trace elements by the sampling dates ($P < 0.01$). The concentrations of Ba, Fe, Li, and Sr were the lowest in July, and the concentrations of Mo and Zn were the highest in June. Cd and Mo display no difference in the sampling dates (Figure 5, Figure S3). Compared with the traditional concentration comparison method, NMDS clearly shows the temporal distribution of trace elements under the scope of mixed element occurrence. Trace elements in June, July, and August are lower than that in May, September, and October (As, Ba, Fe, Li, and Zn). The rainfall might reduce trace elements because of water dilution. However, uncertainty is unavoidable in temporal variability because of insufficient information about local industrial and agricultural activities on the sampling dates. Moreover, the analysis does not take into account the valence state of trace elements and the rule of migration and transformation for trace elements. Further knowing what happened on the sampling dates becomes difficult. With limited observed data, we only reach a general conclusion on the temporal variation in the pollution levels of trace elements in the three streams.
4.1.3. Relationship between trace elements and physical parameters

Physical parameters, such as pH, DO, and EC, alter trace element distribution in the environment. Generally, pH could affect the dissolution and mobility of trace elements by releasing free metals through competition between the binding sites of metals and hydrogen ions (Gao et al., 2020). However, there is no significant relationship between pH and dissolved trace elements, except for Fe. Acid mine drainage has been shown to change the migration and transformation of Fe (Yang et al., 2011; Bu et al., 2015). And this is also supported by a negative correlation between pH and Fe concentrations (Figure 3). Strong correlations could be observed between EC and most trace elements ($P < 0.01$), indicating that EC is the dominant parameter for the study area. The EC is used to measure the contents of soluble salt ions. The high EC values of surface water samples (YY-3 and YY-9), taken from surface water adjacent to the abandoned mines, reflect the impact of human activities (Table S3). During summer, the conductivity value increases with high water temperature, and the trace element ions may also change through time (Barzegar et al., 2019). Moreover, Zn and As concentrations in the surface water samples have a strong relationship with the levels of DO, and their concentrations may be affected by oxidation–reduction processes due to oxidizing (Bu et al., 2015).

4.2. Water quality assessment

The comparison of trace elements with drinking water guidelines (i.e., China, the WHO, and the U.S. EPA) shows that the concentrations of Fe, Ba, Zn, Mo, As, and Cd for the three streams are within permissible limits (China EPA, 2002; U.S. EPA, 2012; WHO, 2017). Furthermore, compared with Environmental Quality Standards for Surface Water (GB3838-2002), the average concentrations of trace elements (Zn, As, Cd) are also below the standard limits for Grade I (Table 2; China EPA, 2002). The metal-based WQI is a useful approach for the trace element level in aquatic systems. The present study found that the water quality of all samples was excellent (WQI: 0–50). However, the WQI values show the relative difference of each sampling point, though the water qualities of the investigated streams are considered good (Table S3). Due to the discharge of industrial and domestic wastewater from Guiyang City, the highest WQI could be observed in JZ-17 (5.31) and JZ-18 (4.72), indicating the differences for specific sites in trace element pollution. Similar to the results of PCA, water samples located in the urban area and the estuary of the lake are with higher WQI values.

4.3. Human health risk

Risk assessment of human beings to trace elements shows that the water samples from the three streams present no obvious health risk. However, children are more vulnerable than adults under the exposure of trace elements with higher HQingestion and HI values for children. For the HQingestion, As for child is over an order of magnitude than the adult, demonstrating the adverse health effects of As require more attention (Table 1). Exposure to single excessive trace elements has been shown to have negative implications for human health (Ferreira et al., 2020; Zeng and Han, 2020b). Among the investigated elements, HQingestion, HQdermal, and HI of As for adult and child are much higher than other elements. Moreover, a high HI index on As is observed with a maximum value of 0.17 in JZ. The results suggest that As may cause potential adverse effects on human health. The body can be affected by arsenic exposure through diet, inhalation through mouth and nose, and dermal absorption, potentially impacting on human health, such as skin lesions, cancer, diabetes, and lung disease (Carlin et al., 2016). Therefore, the adverse health effects of single exposure to trace elements require more attention, particularly As in children’s health and human activity areas.

5. Conclusions

This research analyzed the occurrence, distribution, water quality, and health risk of eight trace elements at three streams with different human activities. The study reported that trace element concentrations were significant not only in individual elements but also in total concentrations (agriculture < urban area < abandoned mining). NMDS and the Kruskal–Wallis test demonstrated that there were significant differences in the investigated elements by the sampling dates, and the overall pollution level in May, September, and October was significantly higher. Among the eight investigated elements, the WQI of all sampling sites from the three streams was lower than 50 (excellent water), which indicated it was suitable for drinking natural water. Various sources (natural processes and anthropogenic activities) for trace elements were revealed by correlation analysis and PCA. The results showed that YY sampling points were dominated by Fe and Sr, and samples at the urban zone and the entrance of the lake were polluted by As, Ba, Mo, and Zn. The noncarcinogenic risk assessment indicated that As was a potential threat to human health, particularly for sensitive children. More concerns were given to the site-specific differences in trace element pollution, and temporal changes were analyzed using NMDS in the present study to understand trace element pollution levels in different streams, which deepened our understanding of trace element behaviors. And it provides a reference for the trace elements to indicate different human activities.

Data accessibility statement

Data summaries are reported in the research paper and supplemental material, which are available as online supporting information.

Supplemental files

The supplemental files for this article can be found as follows:

Figures S1–3. Tables S1–6.

Acknowledgment

The authors appreciate the editor and reviewers for their helpful comments.
Funding
This research was funded by the National Natural Science Foundation of China (41863004, 41863003, 41763019), the Joint Fund of the National Natural Science Foundation of China and Guizhou Province, China (U1612442), the first-class discipline construction project in Guizhou Province—Public Health and Preventive Medicine (No. 2017[85], GNYL [2017]007), and the Guizhou Science and Technology Support Program ([2019]2832, [2016]1028).

Competing interests
The authors have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Author contributions
Contributed to conception and design: JZ, QW.
Contributed to acquisition of data: JZ, SG, HJ, YS.
Contributed to analysis and interpretation of data: JZ, QW, ZW, SG, HJ, YS.
Drafted and/or revised the article: JZ, QW, ZW, SG, HJ, YS.
Approved the submitted version for publication: JZ, QW, ZW, SG, HJ, YS.

References
Barzegar, R, Asghari Moghaddam, A, Soltani, S, Baomid, N, Tziritis, E, Adamowski, J, Inam, A. 2019. Natural and anthropogenic origins of selected trace elements in the surface waters of Tabriz area, Iran. Environmental Earth Sciences 78(8). DOI: http://dx.doi.org/10.1007/s12665-019-8250-z.
Bu, H, Wang, W, Song, X, Zhang, Q. 2015. Characteristics and source identification of dissolved trace elements in the Jinshui River of the South Qinling Mts., China. Environmental Science and Pollution Research International 22: 14248–14257. DOI: 10.1007/s11356-015-4650-0.
Carlin, DJ, Naujokas, MF, Bradham, KD, Cowden J, Heacock M, Henry, HF, Lee, JS, Thomas, DJ, Thompson, C, Tokar, EJ, Waalkes, MP. 2016. Arsenic and environmental health: State of the science and future research opportunities. Environmental Health Perspectives 124(7): 890–899. DOI: http://dx.doi.org/10.1289/ehp.1510209.
Chen, J, Gaillardet, J, Bouchez, J, Louvat, P, Wang, YN. 2014. Anthropophile elements in river sediments: Overview from the Seine River, France. Geochemistry, Geophysics, Geosystems 15(11): 4526–4546. DOI: http://dx.doi.org/10.1002/2014GC005516.
China EPA. 2002. Environmental Quality Standards for Surface Water (GB 3838–2002). Beijing, China: Ministry of Ecology and Environment of the PRC.
China EPA. 2006. Environmental Quality Standards for Drinking Water (GB 5749–2006). Beijing, China: National Health Commission of the PRC.
Chowdhury, S, Mazumder, MAJ, Al-Attas, O, Husain T. 2016. Heavy metals in drinking water: Occurrences, implications, and future needs in developing countries. Science of the Total Environment 569: 476–488. DOI: http://dx.doi.org/10.1016/j.scitotenv.2016.06.166.
Elbaz-Poulichet, F, Seyler, P, Maurice-Bourgoin, L, Guyot, J-L, Dupuy, C. 1999. Trace element geochemistry in the upper Amazon drainage basin (Bolivia). Chemical Geology 157(3): 319–334. DOI: http://dx.doi.org/10.1016/S0009-2541(99)00015-7.
Ferreira, MdS, Fontes, MPF, Pacheco, AA, Lima, HN, Santos, JZL. 2020. Risk assessment of trace elements pollution of Manaus urban rivers. Science of the Total Environment 709: 134471. DOI: http://dx.doi.org/10.1016/j.scitotenv.2019.134471.
Gaillardet, J, Viars, J, Dupré, B. 2014. Trace elements in river waters, in Holland, HD, Turekian, KK eds., Treatise on geochemistry. Second Edition. Oxford, UK: Elsevier: 195–235.
Gao, B, Gao, L, Gao, J, Xu, D, Wang, Q, Sun, K. 2019. Simultaneous evaluations of occurrence and probabilistic human health risk associated with trace elements in typical drinking water sources from major river basins in China. Science of the Total Environment 666: 139–146. DOI: http://dx.doi.org/10.1016/j.scitotenv.2019.02.148.
Gao, S, Wang, Z, Wu, Q, Zeng, J. 2020. Multivariate statistical evaluation of dissolved heavy metals and a water quality assessment in the Lake Ala watershed, Southwest China. PeerJ 8: e9660. DOI: http://dx.doi.org/10.7717/peerj.9660.
Gaulier, C, Zhou, C, Guo, W, Bratkic, A, Supervile, PJ, Billon, G, Baeyens, W, Gao, Y. 2019. Trace metal speciation in North Sea coastal waters. Science of the Total Environment 692: 701–712. DOI: http://dx.doi.org/10.1016/j.scitotenv.2019.07.314.
Gredilla, A, de Vallegueto, SFO, Amigo, JM, de Diego, A, Madariaga, JM. 2013. Unsupervised pattern-recognition techniques to investigate metal pollution in estuaries. Trac-Trends in Analytical Chemistry 46: 59–69. DOI: http://dx.doi.org/10.1016/j.trac.2013.01.014.
Han, G, Yang, T, Wu, Q, Wang, Z. 2019. Ca and Sr isotope compositions of rainwater from Guiyang city, Southwest China: Implication for the sources of atmospheric aerosols and their seasonal variations. Atmospheric Environment 214: 116854. DOI: http://dx.doi.org/10.1016/j.atmosenv.2019.116854.
Li, L, Liu, H, Li, H. 2018. Distribution and migration of antimony and other trace elements in a Karstic river system, Southwest China. Environmental Science and Pollution Research 25: 28061–2807. DOI: http://dx.doi.org/10.1007/s11356-018-2837-x.
Li, S, Zhang, Q. 2010a. Risk assessment and seasonal variations of dissolved trace elements and heavy metals in the Upper Han River, China. Journal of Hazardous Materials 181(1–3): 1051–1058. DOI: http://dx.doi.org/10.1016/j.jhazmat.2010.05.120.
Li, S, Zhang, Q. 2010b. Spatial characterization of dissolved trace elements and heavy metals in the upper Han River (China) using multivariate statistical techniques. Journal of Hazardous Materials 176(1–3):
Liang, B, Han, G, Liu, M, Li, X, Song, C, Zhang, W, Yang, K. 2019. Spatial and temporal variation of dissolved heavy metals in the Mun River, Northeast Thailand. Water 11(2). DOI: http://dx.doi.org/10.3390/w11020380.

Liang, B, Han, G, Liu, M, Yang, K, Li, X, Liu, J. 2018. Distribution, sources, and water quality assessment of dissolved heavy metals in the Jialingjiang River Water, Southeast China. International Journal of Environmental Research and Public Health 15(12). DOI: http://dx.doi.org/10.3390/ijerph15122752.

Lv, J. 2018. The hydrochemical characteristics and source-sink effects of atmospheric CO2 of small karst river under the influence of anthropogenic activities. Guiyang, China: Guizhou University. Available at https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CDFD&dbname=CDFDLAST2019&filename=1019819052.nh&v=Cf9cfjg7DxO1%25mmd2Fwqzq85sKHBd3sQROH%25mmd2FCOOc7xPxtU%25mmd2BjEFNkIr3RGseEO2hAL.

Marques, E, Silva-Filho, E, Souza, G, Gomes, O. 2016. Seasonal variations of water quality in a highly populated drainage basin, SE Brazil: Water chemistry assessment and geochemical modeling approaches. Environmental Earth Sciences 75. DOI: http://dx.doi.org/10.1007/s12665-016-6297-7.

Masresha, AE, Skipperud, L, Rosseland, BO, Zinabu, GM, Meland, S, Teiena, H-C, Salbua, B. 2011. Specification of selected trace elements in three Ethiopian Rift Valley Lakes (Koka, Ziway, and Awassa) and their major inflows. Science of the Total Environment 409(19): 3955–3970. DOI: http://dx.doi.org/10.1016/j.scitotenv.2011.06.051.

Ouyang, TP, Zhu, ZY, Kuang, YQ, Huang, NS, Tan, JJ, Guo, GZ, Gu, LS, Sun, B. 2005. Dissolved trace elements in river water: Spatial distribution and the influencing factor, a study for the Pearl River Delta Economic Zone, China. Environmental Geology 49(5): 733–742. DOI: http://dx.doi.org/10.1007/s00254-005-0118-8.

Phan, K, Phan, S, Huoy, L, Suy, B, Wong, MH, Hashim, JH, Yasin, MS, Aljunid, SM, Sthiannopkao, S, Kim, KW. 2013. Assessing mixed trace elements in groundwater and their health risk of residents living in the Mekong River basin of Cambodia. Environmental Pollution 182: 111–119. DOI: http://dx.doi.org/10.1016/j.envpol.2013.07.002.

Reiman, JH, Xu, YJ, He, S, Delduco, EMJC. 2018. Metals geochemistry and mass export from the Mississippi-Atchafalaya River system to the Northern Gulf of Mexico. Chemosphere 205: 559–569. DOI: http://dx.doi.org/10.1016/j.chemosphere.2018.04.094.

Song, S, Li, FD, Li, J, Liu, Q. 2013. Distribution and contamination risk assessment of dissolved trace metals in surface waters in the Yellow River Delta. Human and Ecological Risk Assessment 19(6): 1514–1529. DOI: http://dx.doi.org/10.1080/10700739.2012.708254.

Tchounwou, PB, Yedjou, CG, Patlolla, AK, Sutton, DJ. 2012. Heavy metal toxicity and the environment, in Luch A ed., Molecular, clinical and environmental toxicology. Basel, Switzerland: Springer: 133–164.

U.S. EPA. 2004. Risk assessment: “Supplemental guidance for dermal risk assessment.” Part E of risk assessment guidance for superfund, human health evaluation manual (Volume I). Washington, DC: Environmental Protection Agency. Available at https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100NXH8.txt.

U.S. EPA. 2012. Edition of the drinking water standards and health advisories. Washington, DC: Environmental Protection Agency. Available at https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100N01H.txt.

Vriens, B, Voegelin, A, Hue, SJ, Kaegi, R, Winkel, LHE, Buser, AM, Berg, M. 2017. Quantification of element fluxes in wastewaters: A nationwide survey in Switzerland. Environmental Science & Technology 51(19): 10943–10953. DOI: http://dx.doi.org/10.1021/acs.est.7b01731.

Wang, J, Jiang, Y, Sun, J, She, J, Yin, M, Fang, F, Xiao, T, Song, G, Liu, J. 2020a. Geochemical transfer of cadmium in river sediments near a lead-zinc smelter. Ecotoxicology and Environmental Safety 196: 110529. DOI: http://dx.doi.org/10.1016/j.ecoenv.2020.110529.

Wang, J, Zhou, Y, Dong, X, Yin, M, Tsang, DCW, Sun, J, Liu, J, Song, G, Liu, Y. 2020b. Temporal sedimentary record of thallium pollution in an urban lake: An emerging thallium pollution source from copper metallurgy. Chemosphere 242: 125172. DOI: http://dx.doi.org/10.1016/j.chemosphere.2019.125172.

Wang, L, Wang, YP, Xu, CX, An, ZY, Wang, SM. 2011. Analysis and evaluation of the source of heavy metals in water of the River Changjiang. Environmental Monitoring and Assessment 173(1–4): 301–313. DOI: http://dx.doi.org/10.1007/s10661-010-1388-5.

Wang, X, Liu, L, Zhao, L, Xu, H, Zhang, X. 2019. Assessment of dissolved heavy metals in the Laoshan Bay, China. Marine Pollution Bulletin 149. DOI: http://dx.doi.org/10.1016/j.marpolbul.2019.110608.

World Health Organization. 2017. Guidelines for drinking-water quality. Fourth edition. Geneva, Switzerland: World Health Organization.
Wu, B, Zhao, DY, Jia, HY, Zhang, Y, Zhang, XX, Cheng, SP. 2009. Preliminary risk assessment of trace metal pollution in surface water from Yangtze River in Nanjing Section, China. Bulletin of Environmental Contamination and Toxicology 82(4): 405–409. DOI: http://dx.doi.org/10.1007/s00128-008-9497-3.

Wu, X, Cobbina, SJ, Mao, G, Xu, H, Zhang, Z, Yang, L Xiao, J, Jin, Z, Wang, J. 2016. A review of toxicity and mechanisms of individual and mixtures of heavy metals in the environment. Environmental Science and Pollution Research 23(9): 8244–8259. DOI: http://dx.doi.org/10.1007/s11356-016-6333-x.

Xiao, J, Jin, Z, Wang, J. 2014. Geochemistry of trace elements and water quality assessment of natural water within the Tarim River Basin in the extreme arid region, NW China. Journal of Geochemical Exploration 136: 118–126. DOI: http://dx.doi.org/10.1016/j.jgeoexp.2013.10.013.

Xiao, J, Wang, L, Deng, L, Jin, Z. 2019. Characteristics, sources, water quality and health risk assessment of trace elements in river water and well water in the Chinese Loess Plateau. Science of the Total Environment 650: 2004–2012. DOI: http://dx.doi.org/10.1016/j.scitotenv.2018.09.322.

Xu, Z, Li, T, Bi, J, Wang, C. 2018. Spatiotemporal heterogeneity of antibiotic pollution and ecological risk assessment in Taihu Lake Basin, China. Science of the Total Environment 643: 12–20. DOI: http://dx.doi.org/10.1016/j.scitotenv.2018.06.175.

Yang, S, Wu, P, Zhang, R, Zhang, C, Han, Z. 2011. Contribution rate of iron and manganese ingredients in typical tributaries of the Aha Reservoir. Guizhou. Journal of Safety and Environment 11(05): 98–102. DOI: http://dx.doi.org/10.3969/j.issn.1009-6094.2011.05.022.

Yang, Z, Xia, X, Wang, Y, Ji, J, Wang, D, Hou, Q, Yu, T. 2014. Dissolved and particulate partitioning of trace elements and their spatial-temporal distribution in the Changjiang River. Journal of Geochemical Exploration 145: 114–123. DOI: http://dx.doi.org/10.1016/j.jgeoexp.2014.05.013.

Zeng, J, Han, G. 2020a. Preliminary copper isotope study on particulate matter in Zhujiang River, southwest China: Application for source identification. Ecotoxicology and Environmental Safety 198: 110663. DOI: http://dx.doi.org/10.1016/j.ecoenv.2020.110663.

Zeng, J, Han, G. 2020b. Tracing zinc sources with Zn isotope of fluvial suspended particulate matter in Zhujiang River, Southwest China. Ecological Indicators. DOI: http://dx.doi.org/10.1016/j.ecolind.2020.106723.

Zeng, J, Han, G, Yang, KH. 2020. Assessment and sources of heavy metals in suspended particulate matter in a tropical catchment, northeast Thailand. Journal of Cleaner Production 265: 121898. DOI: http://dx.doi.org/10.1016/j.jclepro.2020.121898.

Zeng, J, Yue, F, Wang, Z, Wu, Q, Qin, C, Li, SL. 2019. Quantifying depression trapping effect on rainfall chemical composition during the rainy season in karst agricultural area, southwestern China. Atmospheric Environment 218: 116998. DOI: http://dx.doi.org/10.1016/j.atmosenv.2019.116998.

Zeng, X, Liu, Y, You, S, Zeng, G, Tan, X, Hu, X, Hu, X, Huang, L, Li, F. 2015. Spatial distribution, health risk assessment and statistical source identification of the trace elements in surface water from the Xiangjiang River, China. Environmental Science and Pollution Research 22(12): 9400–9412. DOI: http://dx.doi.org/10.1007/s11356-014-4064-4.

Zhang, H, Jiang, Y, Wang, M, Wang, P, Shi, G, Ding, M. 2017. Spatial characterization, risk assessment, and statistical source identification of the dissolved trace elements in the Ganjiang River-feeding tributary of the Poyang Lake, China. Environmental Science and Pollution Research 24(3): 2890–2903. DOI: http://dx.doi.org/10.1007/s11356-016-7988-z.

Zhang, J, Wang, Z, Wu, Q, An, Y, Jia, H, Shen, Y. 2019. Anthropogenic rare earth elements: Gadolinium in a small catchment in Guizhou Province, Southwest China. International Journal of Environmental Research and Public Health 16(20). DOI: http://dx.doi.org/10.3390/ijerph16204052.

Zhao, X, Li, TY, Zhang, TT, Luo, W-J, Li, JY. 2017. Distribution and health risk assessment of dissolved heavy metals in the Three Gorges Reservoir, China (section in the main urban area of Chongqing). Environmental Science and Pollution Research 24(3): 2697–2710. DOI: http://dx.doi.org/10.1007/s11356-016-8046-6.

Zhen, G, Li, Y, Tong, Y, Yang, L, Zhu, Y, Zhang, W. 2016. Temporal variation and regional transfer of heavy metals in the Pearl (Zhujiang) River, China. Environmental Science and Pollution Research 23(9): 8410–8420. DOI: http://dx.doi.org/10.1007/s11356-016-6077-7.
How to cite this article: Zhang, J, Wu, Q, Wang, Z, Gao, S, Jia, H, Shen, Y. 2021. Distribution, water quality, and health risk assessment of trace elements in three streams during the wet season, Guiyang, Southwest China. *Elementa: Science of the Anthropocene* 9(1). DOI: https://doi.org/10.1525/elementa.2021.00133

**Domain Editor-in-Chief:** Steven Allison, University of California, Irvine, CA, USA

**Guest Editor:** Juan Liu, Guangzhou University, Guangzhou, China

**Knowledge Domain:** Ecology and Earth Systems

**Part of an Elementa Special Feature:** Pan-Pacific Anthropocene

**Published:** April 5, 2021  **Accepted:** February 3, 2021  **Submitted:** September 4, 2020

**Copyright:** © 2021 The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. See http://creativecommons.org/licenses/by/4.0/.

*Elem Sci Anth* is a peer-reviewed open access journal published by University of California Press.