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Trace metal fractions, sources, and risk assessment in sediments from Umurbey Stream (Çanakkale-Turkey)

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Abstract Trace metal contamination has become a worldwide problem for aquatic systems, as sediments act as a sink for trace metals. This study was conducted to assess geochemical fractions, sources and potential risks of trace metals (Cd, Cr, Cu, Ni, Pb, and Zn) in sediments of Umurbey stream (Çanakkale-Turkey). Sediment samples were taken from seven different locations of Umurbey stream. Aqua regia wet digestion procedure was applied to determine total contents of trace metals and BCR sequential extraction procedure was applied to determine geochemical fractions of trace metals. Trace metal total values were ordered as Zn > Pb > Cr > Cu > Ni > Cd. Just because of topography, geology, and agricultural practices, S4, S5, S6, and S7 sampling points had greater total trace metal concentrations than the other locations. Potential mobility of trace metals in sediment samples was ordered as Cd (62.1%) > Zn (60.8%) > Pb (54.8%) > Cu (46.1%) > Cr (43.0%) > Ni (29.7%). Cd, Zn, Pb, and partially Cu were encountered mostly in mobile phases. Multivariate analyses revealed that pollution in sediment samples was originated from not only anthropogenic but also natural factors. Except for Zn, trace metal concentrations were found to be at tolerable levels of biota. When the contamination factor and risk assessment code results were assessed together, it was observed that Cd, Zn, and partially Pb were weakly adsorbed onto sediments, thus might pose risks on environment in the long run.

Keywords Contamination · Geochemical fraction · Sediment · Trace metals

Introduction

In recent years, trace metal pollution in aquatic environments has become a global concern considering environmental toxicity, bioaccumulation, abundance, and persistence of metals (Gong et al., 2020; Nour et al., 2021; Yan et al., 2020). Since trace metals in sediment could directly be transferred into aquatic environments, they can easily be absorbed by organisms and plant roots, thus be included into food chain, then pose serious environmental and health risks (Liang et al., 2018; Sungur et al., 2014; Tang et al., 2020; Unda-Calvo et al., 2019). Various anthropogenic and natural sources may contaminate sediments with trace metals (Kareem et al., 2020; Lopéz et al., 2021). Just because of increasing populations, intensive local agricultural activities, mining and industrial activities, hazardous chemicals, especially trace metals, are increasingly released into rivers and streams worldwide (Ma et al., 2016; Sakan et al., 2020; Unsal et al., 2014). Therefore, aquatic environments are

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faced with the risk of natural pollution or anthropogenic interventions. High trace metal concentrations of the sediments may directly reflect pollution sources including agricultural and industrial activities, urbanization and atmospheric accumulation (Canuto et al., 2013; Rasool & Xiao, 2019; Sungur & İşler, 2021). On the other hand, alteration or decomposition-like mineralization processes may increase ambient trace metal concentrations (Kelepertzis et al., 2015; Sungur et al., 2020; Vural, 2015).

When the trace metals were reached to sediments, they transformed into different geochemical forms through a series of physical and chemical (e.g., adsorption, decomposition, complexation, precipitation) processes and such processes significantly influence trace metal mobility and behavior (Marinho et al., 2019; Shang et al., 2016). In other words, general behavior (mobility, toxicity, and bioavailability) of trace metals in aquatic environments is largely influenced by various geochemical forms of metals in sediments (Alkinani et al., 2019). Since metals are bound into different chemical forms associated with a matrix, sequential extraction procedures have been designed for the selective extraction of metals bonded to sediments/soils in different fractions (Sakan et al., 2019). Therefore, geochemical fractions of trace metals in rivers and streams should be determined through sequential extraction methods for better comprehension of trace metal behaviors and ecological risks. A procedure developed by BCR (The European Community Bureau of Reference) has most often been used as a standard sequential extraction method to reliably compare results obtained using different sequential extraction methods (Rauret et al., 1999). The BCR sequential extraction procedure is good at reproducibility and recovery (Altundag et al., 2013; Davutluoglu et al., 2011). The procedure has advantages over Tessier-like (Tessier et al., 1979) multiphase methods because three-phase sequential extraction procedure is faster and easier (Dundar et al., 2012; Tüzen, 2003). Geochemical fractions of trace metals also offer a significant tool for assessment of potential trace metal sources (Chlopecka et al., 1996; Filgueiras et al., 2002; Kaasalainen & Yli-Halla, 2003; Karczewska, 1996) and potential mobility of trace metals (Lei et al., 2016; Sakan et al., 2020; Sungur et al., 2019).

Umurbey stream passes through Umurbey Plain (Çanakkale, NW Turkey) which is an intensive agricultural area and surrounded by different geological formations and reaches to sea. Although it passes through the Umurbey plain and has a geologically rich environment, there has not been any study on the geochemical fractions of trace metals in the Umurbey stream. Therefore, modified BCR sequential extraction method (Rauret et al., 1999) was used in present study to assess dynamics, mobility, and risks of trace metals in sediments of Umurbey stream. The primary objectives of the study are as follows: (i) to determine trace metal concentrations and potential sources, (ii) to determine geochemical fractions and mobility of trace metals, and (iii) to assess environmental risks of trace metals.

Material and method

Study area

Çanakkale province (Turkey) has a transitional climate between Aegean and Marmara climate. The study area is located between 40° 15′ 36″–40° 12′ 54″ northern latitudes and 26° 34′ 12″–26° 39′ 18″ eastern longitudes. The elevation varies between 0 and 254 m in the study area. Annual average temperature of the province is 15.1 ± 7.1 °C. July (25.1 °C) and August (25.0 °C) are the hottest and January (6.2 °C) and February (6.7 °C) are the coldest months. Annual average precipitation is 624.0 mm in per year. The study area is an important agricultural production region. Especially peach cultivation is performed. The economy of the region depends on agriculture, and in the area, there is no industrial activity (Everest et al. 2020). Çanakkale (Turkey) is geologically composed of shales, marble, calcareous, clay, sand stones, marl, magmatic rocks, alluviums, and volcanic ash with different origins ranging from Paleozoic to postglacial age. Study area is geologically composed of alluviums, volcanic rocks (basalt, pyroclastic, volcanoclastic rocks), sedimentary rocks (sandstone, calcarenite, marl, clay stone, etc.), and tuffs (ignimbrite and lapilli tuff) (Fig. 1). Çanakkale (Turkey), especially around the study area, is an important metallogenic subprovince with Pb–Zn, Cu, Mo, Au, and Ag-like polymetallic mineralization (Demirela et al. 2014), and Umurbey stream and surroundings are composed of areas including Pb, Cu, and Zn-like metals (Özdemir, 2011).

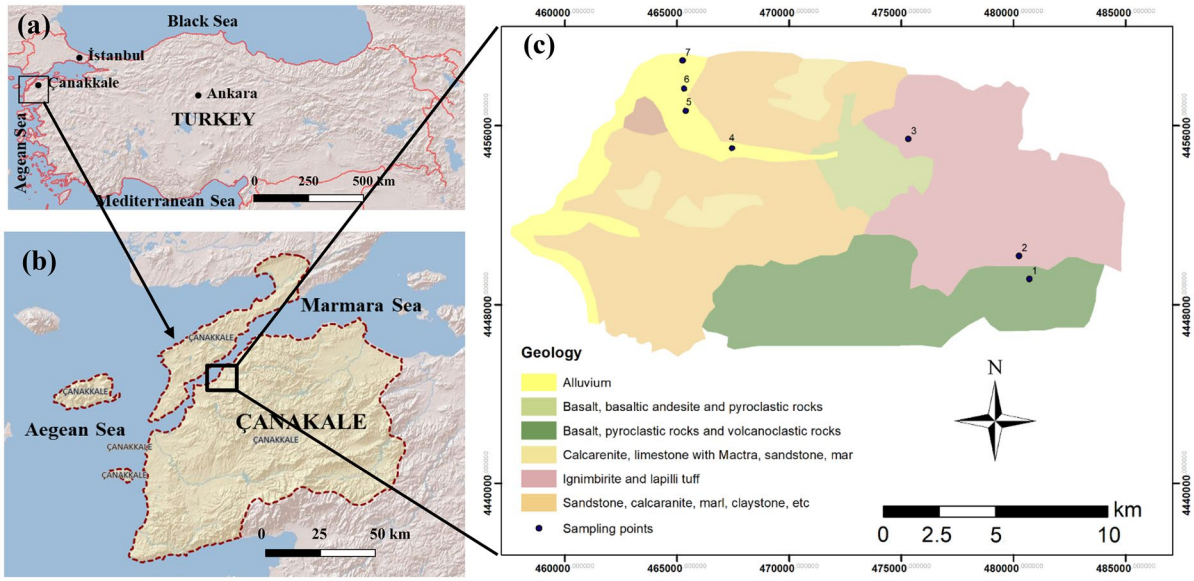


Fig. 1 Map of Turkey (**a**), Çanakkale Province (**b**), and geology of study area (**c**)

Sampling, analysis, and quality control

In sampling, geological formations, basin topography, agricultural practices, and dry seasons were taken into consideration. Digital elevation model (DEM) map presents the topography of the area (Fig. 2). The elevation data were obtained from 30 × 30 m SRTM (Shuttle Radar Topography Mission) data that were produced by NASA. Sediments samples were collected from seven sites along the Umurbey stream (Çanakkale, Turkey). Samples were taken from 30 km section of the stream starting from mountainous section and reaching to the sea (Fig. 2). At each sampling side, a triangle with one m length was set up and samples were collected from each corner (0–5 cm) and then these samples were mixed to obtain a composite sample (approximately 1.5 kg). Nonmetallic tools were used for collection of sediment samples and samples were taken to laboratory adequately in polyethylene containers. Sediment samples were kept in fume hood as to prevent disturbance of odor released during the drying of samples in plastic containers. Dried samples were initially ground in a mortar, then pass through 0.5 mm sieve and made ready for analyses (Prartono et al., 2016).

Sediment reaction (pH) and electrical conductivity (EC) were measured in 1:2.5 (sediment/water, w/v) sediment suspension with a pH and EC meter. Sediment organic matter (OM) was analyzed through oxidation of organic matter in acid medium with dichromate (Nelson & Sommers, 1982). The sediment carbonate ($CaCO_3$) content was determined with a calcimeter (Nelson, 1982). Sediment texture was analyzed in accordance with the principles specified in Gee and Or (2002). To determine pseudo-total trace metal contents of sediment samples, samples were extracted with *Aqua regia* (1:3 HNO_3/HC1) with the use of hotplate digestion technique.

Cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn) quantities at different fractions in sediment samples were determined with the use of modified BCR (Community Bureau of Reference) sequential extraction method. Details of the procedure are provided in the literature (e.g., Rauret et al., 1999; Sahuquillo et al., 1999; Sungur et al., 2021). The Certified Reference Material BCR-701 (lake sediment) was used to certify the experimental results and to assess the method reliability. In this sense, recoveries for trace metals of standard reference material in exchangeable fraction (F_1) varied between 92 and 113%. Recoveries varied between 89 and 111% for reducible fraction (F_2) and between 90 and 112% for oxidizable fraction (F_3) (Table 1). Trace metal concentrations were determined with the use of a flame

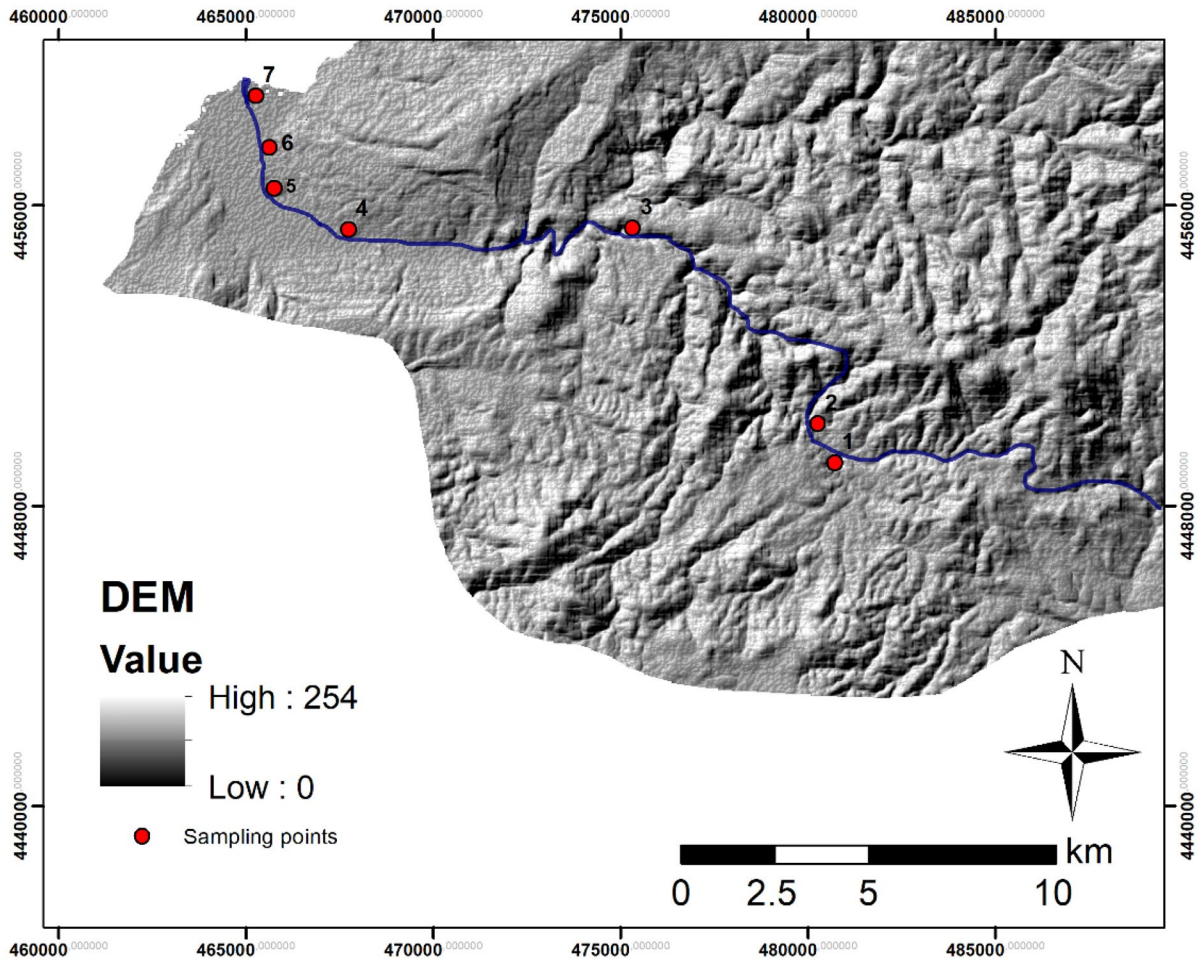


Fig. 2 Location of the sampling areas on the DEM map

atomic absorption spectrometer (Analytic Jena brand, novAA-350 model) device.

Risk assessment

Low effect level (LEL) and severe effect level (SEL) index values were used to assess potential effects of total concentrations of the trace metals on biota of aquatic environments. While the LEL value indicates the concentration of metal in sediment that can be tolerable by biota, SEL value indicates the level that would affect the biota (Kijowska-Strugała et al., 2020). Also, contamination factor and risk assessment code were used for estimation the environmental risks of trace metals. Contamination factor (C_f) was used to assess relative retention time (Sakan et al., 2019). Mobile phase (nonresidual) is defined as the ratio of trace metal concentration to residual phase (Jamali et al., 2007; Sungur et al., 2016). The C_f can be calculated using Eq. (1):

$$C_f = \frac{C_i}{C_n} \tag{1}$$

where C_i and C_n are the mobile and stable fractions of the trace metals, respectively. High C_f values indicate low retention times and greater environmental risk levels (Nemati et al., 2011; Sungur et al., 2016). C_f classification is presented in Table 2.

Risk assessment code (RAC) is defined as acid soluble fraction (F_1) and used to assess environmental risks of trace metals (Li et al. 2013; Sungur et al.,

Table 1 Quality control of the BCR sequential extractions using BCR-701 Certified Reference Materials (mean ± standard deviation in μg/g)

Fractions	Metals	Certified	Determined	Recovery (%)
Exchangeable/acid soluble (F_1)	Cd	7.34 ± 0.35	7.74 ± 0.62	105.4
	Cr	2.26 ± 0.16	2.17 ± 0.32	96.0
	Cu	49.3 ± 1.7	45.4 ± 3.2	92.1
	Ni	15.4 ± 0.9	17.3 ± 1.24	112.5
	Pb	3.18 ± 0.21	3.42 ± 0.48	107.5
	Zn	205 ± 6	214 ± 10	104.6
Reducible (F_2)	Cd	3.77 ± 0.28	3.36 ± 0.48	89.1
	Cr	45.7 ± 2.0	41.5 ± 4.6	90.9
	Cu	124 ± 3	134 ± 7	108.1
	Ni	26.6 ± 1.3	24.6 ± 3.1	92.6
	Pb	126 ± 3	114 ± 5	90.5
	Zn	114 ± 5	127 ± 7	111.4
Oxidizable (F_3)	Cd	0.27 ± 0.06	0.30 ± 0.10	111.1
	Cr	143 ± 7	152 ± 9	106.3
	Cu	55.2 ± 4.0	49.5 ± 4.8	89.7
	Ni	15.3 ± 0.9	17.1 ± 1.6	111.9
	Pb	9.3 ± 2.0	10.1 ± 3.1	108.8
	Zn	45.7 ± 4.0	42.4 ± 5.2	92.7

2019). Equation (2) was used for determination of RAC:

$$\mathrm{RAC}(\%) = \left(\frac{F_1}{F_1 + F_2 + F_3 + F_4}\right) \times 100 \quad (2)$$

F_1 is qualified as exchangeable and adsorptive fractions and anthropogenic factors are the general sources of F_1. This fraction includes weakly bound and more bioavailable portion of the metals (Botsou et al., 2016; Sungur et al., 2019). RAC classification was presented in Table 2.

Statistical analysis

The multivariate statistics analyses were used for determination sources of trace metals in sediments. Principal component analysis (PCA) and hierarchical cluster analysis (HCA) were mostly used methods for determination potential sources of trace metals (e.g., Chai et al., 2019; Hadzi et al., 2019; Sungur & Özcan, 2015; Zhuang & Lu, 2020). MINITAB-18 statistical software was used in all statistical analyses.

Results and discussion

Geochemical characteristics and trace metal content of the sediments

Descriptive statistics for geochemical characteristics of the sediment samples are provided in Table 3. Sediment pH values varied between 7.18 and 8.04 with an average value of 7.59 indicating slightly alkaline nature of the sediments. Average electrical conductivity (EC) was measured as 1173 μS/cm and the greatest value (6300 μS/cm) was observed in S7 location close to the sea (Table 3). Organic matter contents of sediment samples varied between 0.29 and 1.13% with an average value of 0.60% which was considered as low. Calcium carbonate ($CaCO_3$) contents exhibited large variations among the sampling points, and the average values was calculated as 6.15% indicating moderately calcareous nature of the samples. Percent sand, silt, and clay fractions were respectively identified as 69.28, 17.86, and 12.86%.

Trace metal concentrations of the sediment samples also exhibited quite a large variation among the sampling points. Trace metal concentrations were ordered as Zn > Pb > Cr > Cu > Ni > Cd. The sampling

Table 2 Indices for contamination factor (C_f) and risk assessment code (RAC)

C_f value	Contamination level (Devi & Saroha, 2014)	RAC value (%)	Risk level (Jain, 2004)
$C_f < 1$	Clean	RAC < 1	Nonrisky
$1 < C_f < 3$	Low contamination	1 < RAC < 10	Low risk
$3 < C_f < 6$	Moderate contamination	10 < RAC < 30	Medium risk
$6 < C_f < 9$	Considerable contamination	30 < RAC < 50	High risk
$C_f > 9$	High contamination	RAC > 50	Extreme risk

Table 3 Geochemical properties and and pseudo-total trace metal contents in sediment samples

Sample station	Geographical position		pH	EC (µS/cm)	CaCO3 (%)	O.M. (%)	Grain size (%)			Trace metals (µg/g)					
	x	*y*					Clay	Silt	Sand	Cd	Cr	Cu	Ni	Pb	Zn
S1	472,833	4,569,849	8.04	270	< 0.2	0.29	6.0	2.7	91.3	1.73	76.35	50.95	18.07	48.80	339.55
S2	484,015	4,574,907	8.02	190	< 0.2	0.39	8.0	6.7	85.3	1.22	70.34	52.55	20.60	34.45	196.95
S3	495,913	4,576,686	7.46	354	0.55	1.13	18.0	24.7	57.3	1.56	50.68	32.84	21.26	29.48	284.90
S4	518,866	4,578,976	7.64	236	6.09	0.34	8.0	4.7	87.3	3.96	87.40	88.20	29.20	151.03	1421.50
S5	532,931	4,577,590	7.39	411	14.79	0.58	32.0	20.7	47.3	3.64	138.15	65.05	84.19	64.70	753.50
S6	537,910	4,567,743	7.41	450	6.64	0.54	10.0	48.7	41.3	4.35	106.13	111.05	55.08	62.00	958.00
S7	544,166	4,562,990	7.18	6300	2.68	0.94	8.0	16.7	75.3	5.00	77.19	105.60	19.49	233.05	2268.80
	Minimum		7.18	190	0.55	0.29	6.00	2.72	41.28	1.22	50.68	32.84	18.07	29.48	196.95
	Maximum		8.04	6300	14.79	1.13	32.00	48.72	91.28	5.00	138.15	111.05	84.19	233.05	2268.80
	Average		7.59	1173	6.15	0.60	12.86	17.86	69.28	3.07	86.60	72.32	35.41	89.07	889.03
	Standard deviation		0.33	2263	5.44	0.32	9.30	15.99	20.46	1.53	28.25	29.77	25.10	75.33	747.92
						Low effect level (LEL)[a]				0.6	26	16	16	31	120
						Severe effect level (SEL)[a]				10	110	110	75	250	820

[a]Kijowska-Strugała et al. (2020)

points of S4, S5, S6, and S7 had greater total trace metal concentrations than the other locations (Fig. 1 and Table 3). We can justify this situation in two ways. Firstly, by present basin are some ore fields rich in Zn, Pb, and Cu. Surrounding main stream and their tributaries transport these metals, and these transporter streams confluence just ahead of 4th sampling point (Fig. 2). Despite the low solubility, trace metals can be transported for hundreds of kilometers when they got into river and stream-like aquatic environments, then they are adsorbed onto river or stream sediments (Zhang et al., 2018). Secondly by agricultural activities may also increase concentration of trace metals. Agricultural activities are intensified after the S4 sampling point. On the other hand, lithological-originated trace elements, except for Cr and Ni, accumulated mostly at S7 sampling point (Table 3). Accumulation trend of Cd, Cu, Pb, and Zn in S7 location is mostly attributed to topographic and geological structure and agricultural activities. So, the locations with a smooth terrain and close to the sea clearly reflect the transportation and accumulation.

A comparison of the current trace metal (Cd, Cr, Cu, Ni, Pb, and Zn) concentrations found in several studies of stream and river sediments around Turkey are provided in Table 4. The Cd values of this study were lower than the values of the Gümüşler creek (Yalcın et al., 2008) and Mustafakemalpasa stream (Omwene et al., 2018), although the current values were relatively higher than the values of the Ankara stream (Eker et al., 2017), Ergene river (Sungur et al., 2014), Pazarsuyu stream (Ustaoğlu & Tepe, 2019), Sakarya river (Dundar et al., 2012), and Ulukisla stream (Lermi & Sunkari, 2020). The Cr values of current study were higher than the values of the Pazarsuyu stream (Ustaoğlu & Tepe, 2019) and Sakarya river (Dundar et al., 2012), although the current values were lower than the values of the Ergene river (Sungur et al., 2014), Gümüşler creek (Yalcın et al., 2008), Mustafakemalpasa stream (Omwene et al., 2018), and Ulukisla stream (Lermi & Sunkari, 2020). The Cu and Zn values of the present study were higher than with the results of the other studies. The Ni values of this study were lower than the results of the other studies, except for those of the Gümüşler creek (Yalcın et al., 2008). The Pb values of the current study were similar to the values of the Ulukisla stream (Lermi & Sunkari, 2020) and higher than the values of other rivers and streams (Table 4).

Table 5 Results of factor loadings of the total metals (PCA loadings > 0.8 are shown in bold)

	Factor 1	Factor 2	Communality
% of Variance	58.0%	36.20%	(94.2%)
Cd	**0.902**	0.405	0.978
Cr	0.166	**0.970**	0.969
Cu	**0.872**	0.276	0.837
Ni	0.006	**0.982**	0.964
Pb	**0.949**	−0.157	0.924
Zn	**0.989**	−0.002	0.978

Identification of trace metal sources

Multivariate analyses (PCA and HCA) were used to define pollutant sources. Two factors explained 94.2% of total variation (Table 5 and Fig. 3a). Factor 1 was dominated by Cd, Cu, Pb, and Zn and explained 58.0% of total variation. Factor 2 was dominated by Cr and Ni and explained 36.2% of total variation (Table 5). PCA analyses revealed two sources for trace metals: First, Cd, Cu, Pb, and Zn were mainly

Table 4 Comparison of trace metals in study area with various streams and river sediments around Turkey (μg/g)

Locations	Cd	Cr	Cu	Ni	Pb	Zn	References
Ankara stream	0.3	–	32.0	68.0	18.0	111.0	Eker et al. (2017)
Ergene river	2.4	272.4	85.6	82.9	33.6	281.6	Sungur et al. (2014)
Gümüşler creek	4.4	496.4	26.2	28.3	49.1	64.8	Yalcın et al. (2008)
Mustafakemalpasa stream	8.8	516.0	26.2	274.0	65.6	110.0	Omwene et al. (2018)
Pazarsuyu stream	0.2	10.6	17.8	–	19.7	32.7	Ustaoğlu and Tepe (2019)
Sakarya river	2.6	37.0	37.5	83.0	41.3	76.7	Dundar et al. (2012)
Ulukisla stream	1.9	138.8	62.9	220.1	91.9	323.0	Lermi and Sunkari (2020)
Yeşilırmak river	–	–	37.9	–	29.6	126.2	Tüzen (2013)
Umurbey stream	3.1	86.6	72.3	35.4	89.1	889.0	This study

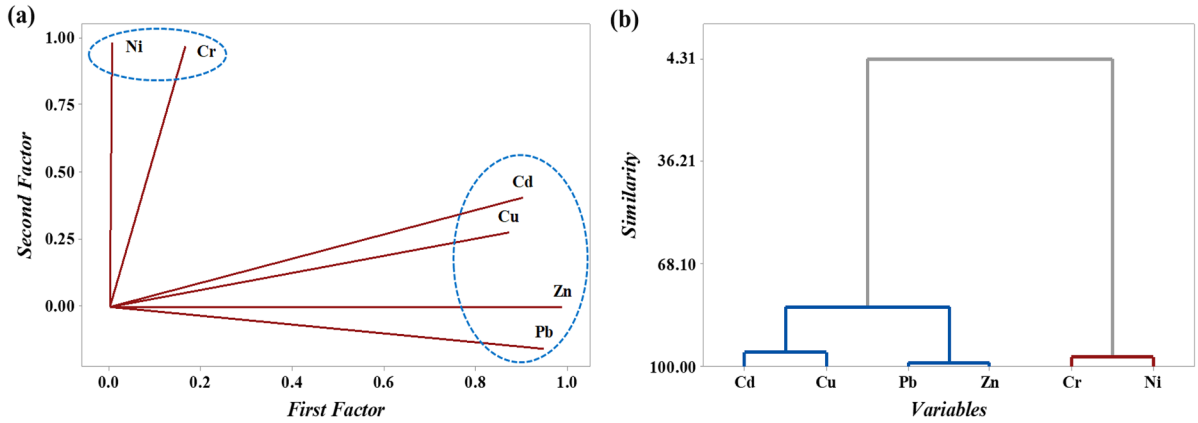


Fig. 3 PCA loading plot (**a**) and dendrogram of HCA for trace metals (**b**) in sediment samples

resulted from environmental lithology and partially from anthropogenic factors. Second, Cr and Ni were mainly resulted from lithogenic factors.

With HCA analyses, the differences and similarities between sediment trace metals were presented in a dendrogram (Fig. 3b). Present findings revealed that Cd, Cu, Pb, and Zn exhibited similar behaviors and Cr and Ni showed similar behaviors and generated two clusters. Hence, it indicated that each cluster with similar behaviors had different origins. HCA and PCA analysis results were consistent and supporting each other. Lower quantities of Cr and Ni in lithologic structure were because lithological structure was poor in these elements. Cd, Cu, Pb, and Zn were also influenced by lithogenic sources. Lithology of the present research site is rich in these four elements (Cicek & Oyman, 2016 and references therein). However, different from Cr and Ni, agrochemicals may be also contributed to Cd, Cu, Pb, and Zn quantities.

Trace metal geochemical fractions in sediments

Table 6 and Fig. 4 present geochemical partitioning and percent distribution of trace metals. Different fractions of trace metals were ordered as follows: $F_4 > F_3 > F_2 > F_1$ for Cd, Cr, and Zn; $F_4 > F_3 > F_1 > F_2$ for Cu; $F_4 > F_1 > F_3 > F_2$ for Ni; $F_4 > F_2 > F_1 > F_3$ for Pb. Sequential extraction results revealed that metals were dominantly placed into residual fraction (F_4). The F_4 fraction in general reflects the metal fraction in sediment mineral structure. This fraction is the least immobile fraction since the metal is a part of sediment crystalline structure and tightly bound to crystal structure. Therefore, such findings indicated that sediment samples reflected the geological characteristics of the surrounding environment.

Metal solubility and mobility is ordered as $F_1 > F_2 > F_3 > F_4$. Based on extractable trace metal quantities, it can be assumed that the first three fractions ($F_1 + F_2 + F_3$) were mobilizable fractions (Rauret, 1998). Based on the first three fractions, not including the residual fraction (F_4), the average percentage rates of trace metal potential mobility in the sediment samples were ordered as follows:

Cd (62.1%) > Zn (60.8%) > Pb (54.8%) > Cu (46.1%) > Cr (43.0%) > Ni (29.7%).

Cd, Zn, Pb, and relatively Cu were considered to be potentially mobile elements, and Cr and Ni were considered as slightly mobile elements (Fig. 4 and Table 6). Since trace metals of uncontaminated sediments are bound to silicates and primary minerals, they are primarily immobile. On the other hand, trace metals of contaminated environments are highly mobile and bound to other fractions (Rauret, 1998; Sungur et al., 2019). Greater mobile fractions of Cd, Zn, and Pb than the immobile fractions could be explained by richness of anthropogenic and geological structure. Recent studies revealed that if the geological structure was rich in metals, then contamination could be lithological-originated (Sungur et al., 2020; Vural, 2018, 2020). Lithological-originated trace metals are more bound to soil/sediment matrix. These metals existing and bound to structure of silicates are released

Table 6 Trace metal concentrations (μg/g dry wt) in the BCR sequential extraction fractions for sediment samples

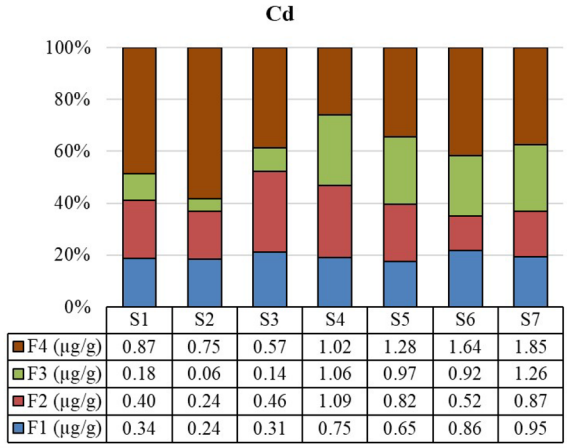
		Fractions				Sum
		Acid soluble (F_1)	Reducible (F_2)	Oxidizable (F_3)	Residual (F_4)	($F_1+F_2+F_3+F_4$)
Cd	Minimum	0.24	0.24	0.06	0.57	1.29
	Maximum	0.95	1.09	1.26	1.85	4.93
	Mean	0.59	0.63	0.66	1.14	3.01
	SD	0.29	0.30	0.51	0.47	1.45
	%Ratio	19.5	20.8	21.8	37.9	100
Cr	Minimum	1.94	4.73	14.95	26.77	57.35
	Maximum	11.91	11.89	31.27	85.70	136.30
	Mean	6.14	7.98	23.51	49.98	87.62
	SD	4.18	2.86	6.21	19.56	29.28
	%Ratio	7.01	9.11	26.83	57.04	100
Cu	Minimum	1.90	1.89	3.69	16.88	28.45
	Maximum	17.98	11.73	41.48	62.96	103.06
	Mean	6.44	6.16	18.42	36.34	67.36
	SD	5.33	3.78	13.99	14.39	29.70
	%Ratio	9.6	9.2	27.3	53.9	100
Ni	Minimum	1.96	1.07	1.86	16.96	25.50
	Maximum	8.96	4.06	8.04	58.50	75.62
	Mean	4.65	2.85	4.00	27.21	38.71
	SD	2.31	0.94	2.32	14.61	18.30
	%Ratio	12.0	7.4	10.3	70.3	100
Pb	Minimum	0.78	4.44	2.42	13.31	28.92
	Maximum	49.50	76.70	19.30	85.60	220.54
	Mean	10.23	27.46	8.92	38.47	85.09
	SD	17.52	29.40	6.76	25.65	72.27
	%Ratio	12.0	32.3	10.5	45.2	100
Zn	Minimum	24.97	24.03	23.71	101.40	200.05
	Maximum	296.61	260.58	774.60	643.00	1974.79
	Mean	104.26	123.89	253.80	310.31	792.26
	SD	98.64	91.73	271.29	189.31	638.41
	%Ratio	13.2	15.6	32.0	39.2	100

SD standard deviation

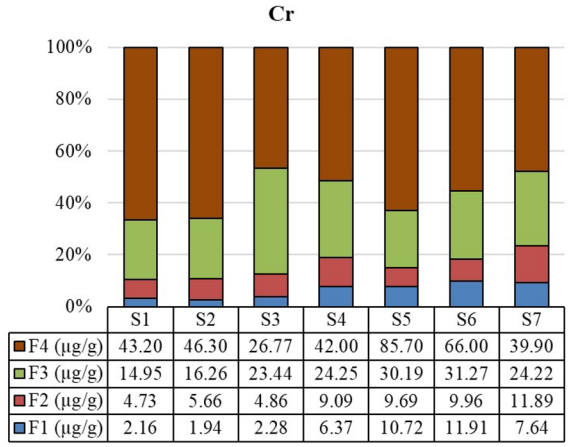
only through advanced decomposition and get into more mobile forms. High mobility of Cd, Zn, Pb, and partially of Cu indicates the environmental pollution originated from these elements. Present findings revealed that pollution in natural environments was resulted not only from the anthropogenic sources, but also from natural sources since surrounding environment of the present study area is rich in relevant metals (Cicek & Oyman, 2016 and references therein).

Risk assessment

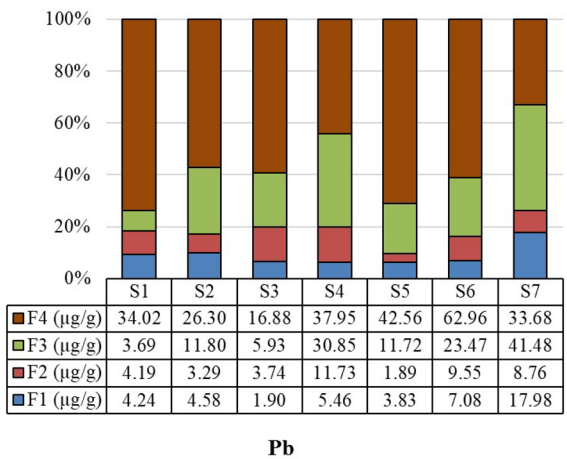
When the trace metal concentrations were compared to LEL and SEL values (Table 2), it was observed that Cd and Pb concentrations were greater than LEL value almost in all samples and but lower than SEL value. Similarly, Cr and Ni concentrations of all locations, except for S5, and Cu concentrations of all points, except for S6, were lower than SEL value. These findings revealed in



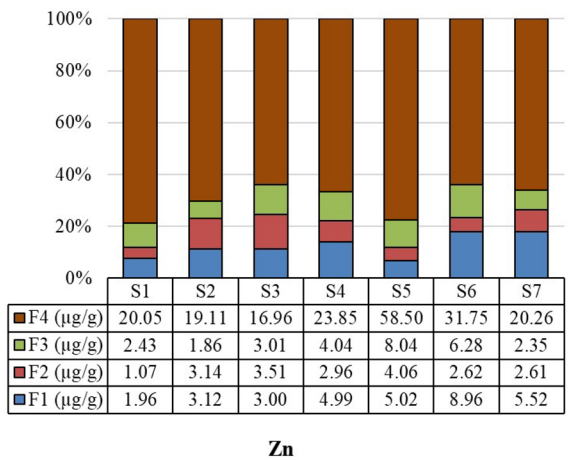
	S1	S2	S3	S4	S5	S6	S7
F4 (µg/g)	0.87	0.75	0.57	1.02	1.28	1.64	1.85
F3 (µg/g)	0.18	0.06	0.14	1.06	0.97	0.92	1.26
F2 (µg/g)	0.40	0.24	0.46	1.09	0.82	0.52	0.87
F1 (µg/g)	0.34	0.24	0.31	0.75	0.65	0.86	0.95



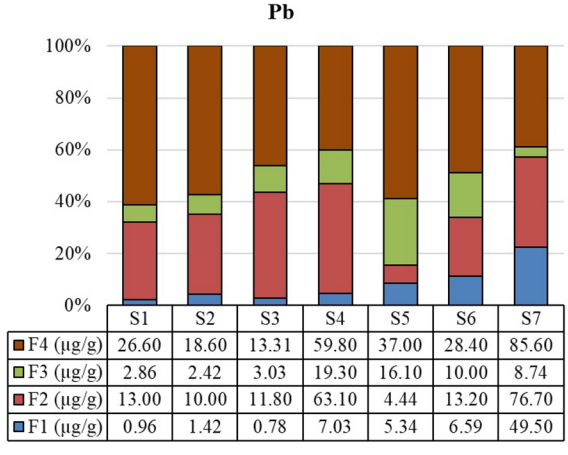
	S1	S2	S3	S4	S5	S6	S7
F4 (µg/g)	43.20	46.30	26.77	42.00	85.70	66.00	39.90
F3 (µg/g)	14.95	16.26	23.44	24.25	30.19	31.27	24.22
F2 (µg/g)	4.73	5.66	4.86	9.09	9.69	9.96	11.89
F1 (µg/g)	2.16	1.94	2.28	6.37	10.72	11.91	7.64



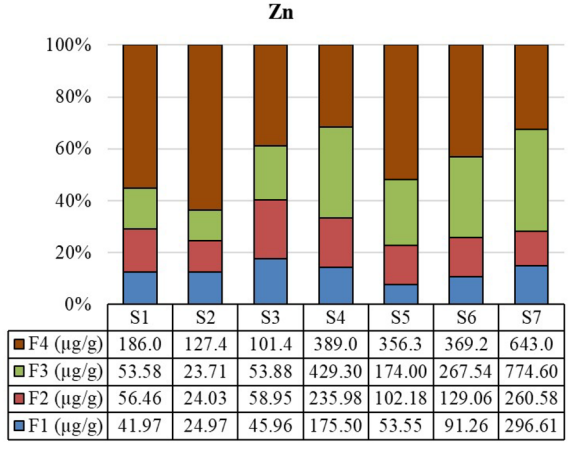
	S1	S2	S3	S4	S5	S6	S7
F4 (µg/g)	34.02	26.30	16.88	37.95	42.56	62.96	33.68
F3 (µg/g)	3.69	11.80	5.93	30.85	11.72	23.47	41.48
F2 (µg/g)	4.19	3.29	3.74	11.73	1.89	9.55	8.76
F1 (µg/g)	4.24	4.58	1.90	5.46	3.83	7.08	17.98



	S1	S2	S3	S4	S5	S6	S7
F4 (µg/g)	20.05	19.11	16.96	23.85	58.50	31.75	20.26
F3 (µg/g)	2.43	1.86	3.01	4.04	8.04	6.28	2.35
F2 (µg/g)	1.07	3.14	3.51	2.96	4.06	2.62	2.61
F1 (µg/g)	1.96	3.12	3.00	4.99	5.02	8.96	5.52



	S1	S2	S3	S4	S5	S6	S7
F4 (µg/g)	26.60	18.60	13.31	59.80	37.00	28.40	85.60
F3 (µg/g)	2.86	2.42	3.03	19.30	16.10	10.00	8.74
F2 (µg/g)	13.00	10.00	11.80	63.10	4.44	13.20	76.70
F1 (µg/g)	0.96	1.42	0.78	7.03	5.34	6.59	49.50



	S1	S2	S3	S4	S5	S6	S7
F4 (µg/g)	186.0	127.4	101.4	389.0	356.3	369.2	643.0
F3 (µg/g)	53.58	23.71	53.88	429.30	174.00	267.54	774.60
F2 (µg/g)	56.46	24.03	58.95	235.98	102.18	129.06	260.58
F1 (µg/g)	41.97	24.97	45.96	175.50	53.55	91.26	296.61

Fig. 4 Results of BCR sequential extraction partitioning and relative abundance in each fraction of trace metals in the sediment samples

general that sediment Cd, Cu, Pb, Ni, and Cr accumulations were at tolerable levels of the biota. On the other hand, Zn concentration was greater than SEL value in S4, S6, and S7 locations. Such a finding indicated that sediment Zn concentrations were at influential level of biota.

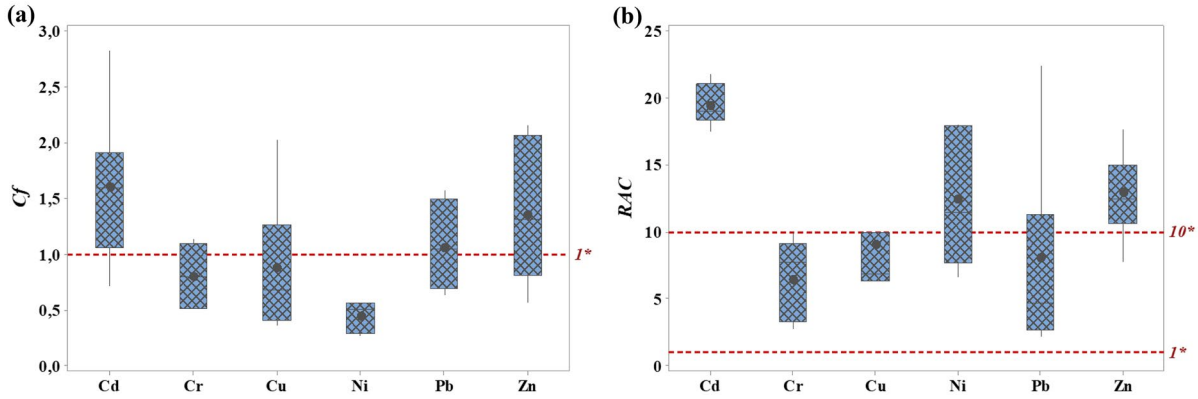


Fig. 5 Boxplot of contamination factor (**a**) and risk assessment code (**b**) for trace metals in the samples (asterisk = C_f, and RAC limits, o = mean, horizontal line = median, vertical line = minimum and maximum)

Calculated average C_f values are presented as a dendrogram in Fig. 5a. Trace metal C_f values were ordered as Zn > Cd > Pb > Cu > Cr > Ni. While Cr (0.80), Ni (0.45), and Cu (0.88) did not exhibit a contamination, Cd (1.60), Zn (1.35), and Pb (1.05) exhibited low contamination. Contamination factor is an important indicator of the risk level of trace metals on environment. High C_f values indicate that lower retention time and high risk levels on environment.

Trace metal RAC values were ordered as Cd > Zn > Ni > Cu > Pb > Cr. While Cr (6.41%), Cu (9.10%), and Pb (8.04%) constituted a low risk (Fig. 5b), Cd (19.45%), Ni (12.43%), and Zn (12.90%) constituted a medium risk. Although Ni was placed into risky group, it was considered not pose a serious risk based on total concentration (Table 3). Present findings revealed that Cd, Zn, and partially Pb were mobile, less adsorbed onto sediments, and might pose potential risks on environment. High mobility rates of Cd, Zn, and Pb indicate that contamination of these trace metals were mainly from agricultural practices and richness of lithological structure. Also, Zn was considered to be accumulated especially in smooth sections as to influence biota and may pose a risk on environment.

Conclusion

The present study focused on the means for determining the trace metals content in sediment samples from Umurbey stream. Current findings revealed that ratio of potentially mobile fractions of Cd, Zn, and Pb were greater than the ratio of immobile fraction. PCA analyses revealed two main sources for trace metals: (i) Cd, Cu, Pb, and Zn were primarily originated from lithogenic and anthropogenic sources; (ii) Cr and Ni were originated from lithogenic sources. Entire findings revealed that metal pollution in natural environments was originated from not only anthropogenic but also natural factors. Risk assessments pointed out Cd, Zn, and Pb contamination in the study area. They can be incorporated into water which can easily be absorbed by organisms and plant roots. Present findings revealed that relevant metals were weakly adsorbed onto sediments and pose potential risks on environment. Therefore, it is suggested that future studies focus on to determine trace metals uptake by organisms and plants.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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