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Assessment of Metal Concentrations in Sediments from Lake Bafa (Western Anatolia): An Index Analysis Approach

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Abstract Metals, organic carbon contents were determined in surficial and core sediment samples from Lake Bafa, Western Anatolia in 2010. The ranges of Fe, Mn, Pb, Cu, Ni, Cr, Zn and Hg contents of sediments from the Bafa Lake were 9.4–35 gkg^{-1}, 250–780, 2.3–20, 5.8–55, 1.2–480, 63–278, 26.6–79.9 and 0.013–0.273 mg kg^{-1}, respectively. The mean metal concentrations in surficial sediments obtained in this study decreased in the following order; Fe > Mn > Ni > Cr > Zn > Cu > Pb > Hg for Bafa lake. Total organic carbon concentrations of the bottom sediments from the Bafa Lake varied between 0.35 % and 3.58 %. The mean concentrations of metal were lower than the background levels in earth crust except Cr and Ni in the core sediments. The metal levels were evaluated according to the New Geo-accumulation Index, enrichment and contamination factors. The results confirmed that the Bafa Lake is not facing serious environmental pollution risk due to metal contamination except Hg. The levels of Cr, Ni, Cu, Fe, Zn and Mn generally appear to be uniformly distributed with depth except Hg and Pb due to anthropogenic sources in the core sediments.

Keywords Metals · Lake sediment · Enrichment factor · Contamination factor · New Geo-accumulation Index · Bafa Lake (Western Anatolia)

Lake Bafa is a nature reserve situated in southwestern Turkey, the southern part of it within the boundaries of Milas district of Mugla Province and the northern part within Aydın Province's Soke district. It is one of the largest coastal lakes in Turkey. Having a maximum depth of roughly 20 m, its surface covers an area of approx 7,500 ha. The lake developed as a result of the delta progradation of the Buyuk Menderes (Maeander) River. In the past six or so millennia, the river sediments have gradually in filled nearly the whole marine embayment of the so-called Latmian Gulf, thereby separating its southeastern part from the open sea (Müllenhoff et al. 2004).

Metals are among the most common environmental pollutants and their occurrence in water, sediment and biota indicate the presence of natural or anthropogenic sources. The main natural sources of metals in waters are weathering of minerals. Industrial effluents, non-point pollution sources, as well as atmospheric precipitation, can also be sources of increased concentrations of metals. Fertilizers may be expected to be important sources of metals in an agricultural area and high Hg levels were found in the phosphorus fertilizers (Zheng et al. 2008).

Several metals such as Zn, Co and Cu are considered essential elements to life, while others like Hg, Pb and Cd, do not have a defined biological function and they are generally, toxic to a great variety of organisms. Even the essential metals, if present in high concentrations, can be toxic to the biota (Nriagu 1988).

Many studies have demonstrated that lake ecosystems have been contaminated by trace elements from anthropogenic sources. Urban lakes receive a large quantity of urban runoff, which contains a portion of the solid residues from dry and wet atmospheric deposits, street dust and surface soils. These solid residues may contain heavy metals from various sources such as automobile exhaust, urban fugitive dust and urban garbage (Hu et al. 2011).

Sediment cores contain information about the events that occurred in precultural time in the lakes and its

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catchment area. Changes in metal concentration with depth in sediment cores can show long-term trends of metal input and thereby imply pollution. Vertical profiles of pollutant species in sediment cores have been commonly used as "pollution records". Therefore core sediments can be used to study the pollution history of aquatic ecosystems.

There is almost no information available from the published literatures discussing metal levels in Bafa Lake sediments. The aim of this study is to investigate the metal distributions and concentrations; to evaluate each contaminant using enrichment factor, contamination factor and New Geo-accumulation Index (NIgeo) in the core and surface sediments; to assess the metal contamination status of bottom sediments and impact after ca. 200 years of urbanization in the study area.

Materials and Methods

The surface samples were collected using a Van Veen type grab sampler in September 2010 and the sediment core samples were obtained in November 2010 using a gravity corer. 15 surface and 3 core sediments were sampled and dried, homogenized and reduced fine powder (Fig. 1). For grain size correction, the <63 μm fraction was chosen for analysis. A total of three sediment cores were cut into slices of 5 cm length and metals were analyzed in each slices of the core sediment.

In this study; metal concentration in the bottom sediment of the cores was used for the metal background concentrations. Previous studies showed that the mean accumulation rate was 0.29 cm/year in the Bafa Lake sediments. Presuming the 2nd century BC as the earliest date for the environmental change, a sedimentation rate of 22 cm/100 years can be calculated for the overall period between ca. 400–150 BC (Müllenhoff et al. 2004). Recently, a large number of industrial establishments located along the Buyuk Menderes River have caused metal pollution problems in the sediments (Akcay et al. 2003; Yilgor 2009).

Metal contents in sediments were determined by atomic absorption spectrophotometry after being digestion in a microwave digestion system with a HNO_3–HF–$HClO_4$–HCl acid mixture. The analyses were performed by flame (Fe, Mn, Ni, Cu, Zn, Cr, Pb), cold vapor (Hg) atomic absorption spectroscopy, using the manufacturer's conditions and with background correction. The detection limits for metals are Hg: 0.05 μg kg^{-1}, Pb: 0.10 μg kg^{-1}, Cr:0.06, Cu:0.03, Zn:0.01, Mn:0.02, Ni:0.10, Fe:0.06 mg kg^{-1}. Intercalibration sediment (IAEA-433) sample was used as a control for the analytical methods. The values obtained (in mg kg^{-1} dry weight) for the analysis of six replicates of this sample were as follows: Hg (certified 0.168, s.d.:0.017; found 0.167, s.d.:0.012), Cr (certified 136, s.d.:10; found 136.7, s.d.:2.0), Cu (certified 30.8, s.d.:2.6; found 30.8, s.d.:2.3), Pb (certified 26.0, s.d.: 2.7; found 27.0, s.d.: 3.1), Zn (certified 101, s.d.: 8.0; found 103, s.d.: 1.9), Fe (certified 40,800, s.d.:1,900; found 40,412, s.d.:293), Mn (certified 316, s.d.:16; found 317, s.d.:1.7), Ni (certified 39.4, s.d.:3.1; found 40.9, s.d.:0.98).

Grain size analyses were performed using standard sieving and settling procedures (Hakanson and Jansson 1983) in the study area. Textural classification of the sediment samples was based on the relative percentages of clay (<0.002 mm), silt (0.002–0.063 mm), sand (0.063–2 mm) and gravel (>2 mm). In general particle size is fining towards to the basin in the lake. Bottom sediments were relatively coarse with 85 %–94 % sand (>63 μm) in the east, because east of the lake showed that coastal property. Silt materials covered a large area of the lake,

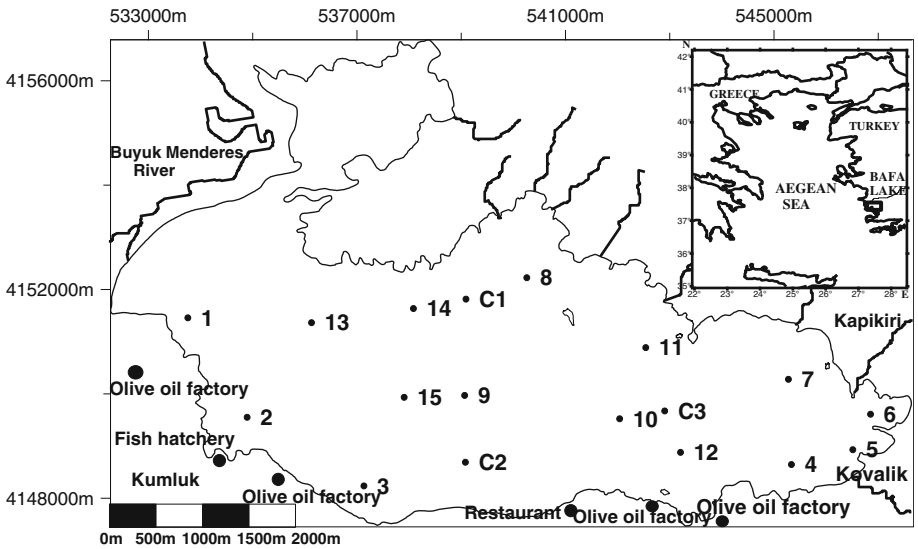

Fig. 1 Location of surface and core sediment sampling sites in Bafa Lake

while clayey silts (relatively fine with 13 %–18 % clay) were present in the basin and northwest shore of the lake. According to grain size classification C1 was covered by clayey silt along the core, while C2 and C3 were covered by silt in the depth of first 5 cm and clayey silt in the other depths of these cores. The amount of organic carbon (%) was determined by spectrophotometrically in dried sediment samples following the sulfochromic oxidation method. The accuracy of this method is ±0.017 % organic matter (HACH Publication 3061, 1988).

Results and Discussion

The metal contents in surficial sediment samples are reported in Table 1 together with the background limits from C1 core sediment and average crustal values given by Turekian and Wedepohl (1961). Analysis showed that Hg, Cu, Zn, Ni, Fe concentrations in sediments from the stations 8, 9, 10 were consistently higher than those from the other locations. These stations were located in the central part of the basin, indicating that these metals originated from parent rock weathering. In contrast, Pb (23.5 mg kg^{-1}) and Mn (780 mg kg^{-1}) concentrations were the highest at station 6 and Cr (277 mg kg^{-1}) concentration was maximum at stations 1 and 3. All of the determinants were examined and Mn showed the least variability between the sites. Sta.6 was located in the eastern part of the lake, while stations 1 and 3 were in the western part and this area is under the influence of waters runoff coming from the Buyuk Menderes River. Increasing metal concentrations (especially Hg, Cu, Zn, Ni, Fe, Cr and Mn) tend to be associated with fine-grained sediments, and this can be seen in the high metal levels found in stations 1, 2, 3, 8, 9, 10 with high silt and clayey silt contents.

Iron is the most abundant metal in all sediments because it is one of the most common elements in the Earth's Crust. The total concentration of Fe in Bafa Lake surficial sediment samples ranged between 9,377 and 33,091 mg kg^{-1} and concentrations were below the background value of C1 core sample and the average crustal value. The concentrations of Hg, Mn and Zn were smaller than the average crustal levels for all sites in Bafa Lake. Ni and Cr were above the average crustal value except sta. 4, 5 and 7, while Cu was lower than average crustal value except sta. 8, 9 and 10. Pb was generally below the mean crustal concentration. The highest Cr and Ni content in the lake were derived from the mafic and ultramafic rocks cropping out in the drainage area of rivers. These results suggesting that Pb and Cu contamination in most of the study area were not significant. The mean metal concentration in surficial sediments recorded in this study decreased in the following order; Fe > Mn > Ni > Cr > Zn > Cu > Pb > Hg for Bafa lake. This order showed changes according to the stations. The orders were different in stations 4, 5, 6, 7 with high sand contents from the eastern part of the lake. The order was (Fe > Mn > Cr > Zn > Ni > Cu > Pb > Hg) in stations 4 and 7 while, the sequence was observed as Fe > Mn > Cr > Ni > Zn > Cu > Pb > Hg at station 6. The order was different at station 5 and sorted in decreasing order (Fe > Mn > Cr > Zn > Cu > Pb > Ni > Hg).

Organic matter and grain size are the relevant features of the lake sediments. The organic content of the muddy sediments are higher than sandy ones, with regard to clay particles tend to bind high quantity organic matter (Carvalho et al. 2005). Organic carbon concentrations in surface sediments from Bafa Lake ranged from 0.35 % to 3.58 % (Table 1). The relatively high concentrations of OC at stations 3 and 6 reflect "high" organic matter flux to sediments due to the effect of anthropogenic and natural

Table 1 Metal (mg kg^{-1} dry weight) and organic carbon (%) contents in the surficial sediments

	Stations										Average crustal[a]	BG[b]
	1	2	3	4	5	6	7	8	9	10		
Fe[c]	28.0	27.9	33.1	9.96	9.38	25.7	11.7	29.1	28.6	29.0	47.0	36.4
Cr	277	254	277	68.9	63.1	125	93.8	231	235	229	90	263
Mn	603	735	666	270	250	780	300	656	661	721	850	668
Pb	5.60	14.2	11.1	4.78	3.64	23.5	2.31	11.9	14.4	16.2	20	15.5
Ni	223	280	295	14.2	1.21	101	15.0	303	318	320	68	423
Zn	51.5	76.0	79.9	33.2	30.3	76.7	26.62	76.6	76.6	78.4	95	81.5
Cu	17.9	22.6	35.7	8.31	7.28	35.9	5.79	51.5	55.1	54.7	45	34.7
Hg	0.087	0.105	0.181	0.013	0.022	0.110	0.093	0.152	0.175	0.260	0.40	0.07
Org. C	1.69	2.36	3.14	0.35	0.35	3.58	0.70	2.92	2.55	2.86	–	–

[a] Average crustal values (mg kg^{-1}) (Turekian and Wedepohl 1961)

[b] *BG* Background values from the bottom layer of C1 core

[c] Fe: g kg^{-1}

inputs. Bafa Lake received several raw sewage, streams and industrial outfalls (olive oil factory). Surface sediments in the southern part of the lake (sta. 4 and 5) contained 0.35 % OC due to direct inputs from the Kovalık region. The relationship between metal concentrations and those of organic carbon have therefore also been examined for the present data set; effort has been focused on those areas where Mn and Pb concentrations were the highest and TOC values greatest, i.e., station 6. Decomposition of the organic matter was found to release metals back to sediments and accumulated; and this process might be responsible for the strong association of Zn and Cu with organic carbon (Bardarudeen et al. 1996). Besides, the release of organically bound metals through influx from land runoff might have also contributed to the elevated level of Zn and Cu, despite they are meagre in amount. Zn and Cu are generally good indicators of anthropogenic inputs.

Spearman rank-order correlation coefficients were computed between variables including all metals, organic carbon and grain size, measured in the surface sediments of Bafa Lake. As results of the analysis, many metals turned out to be significantly positive correlated ($p < 0.05$). The highest coefficients were those for Fe–Ni ($r = 0.88$), Fe–Zn ($r = 0.80$), Fe–Hg ($r = 0.84$), Pb–Mn ($r = 0.88$), Pb–Cu ($r = 0.87$), Ni–Cu ($r = 0.88$), Ni–Hg ($r = 0.89$), Zn–Cu ($r = 0.81$), Zn–Hg ($r = 0.86$). The lowest correlation ($r = 0.48$) were observed between Fe and Pb. This implies that the concentration of Pb was not directly controlled by continental weathering. Metal concentrations in sediment showed significant positive correlations between metals and organic carbon levels. Metal accumulations showed negative correlations with sand but significant correlations were found for silt and clay. The organic carbon content played a role in favoring the accumulation of metals in the sediments of the lake as shown by the good correlation with most elements (Zn, Ni, Pb, Mn, Cu, Fe, Hg), underscoring its role in binding the metals in ligands (Naidu et al. 1997). Those correlations probably indicated that such elements have the same source, possibly lithologic, characteristic of sediment was non-impacted and therefore, of natural origin (Salomons and Fostner 1984).

Metal concentrations in the sediments of Bafa Lake were compared to the other studies performed in other lakes of Turkey and Europe (Karadede and Unlu 2000; Ozmen et al. 2004; Altindag and Yigit 2005, Nguyena et al. 2005). The comparison of the data set revealed that levels of Cr were generally higher than lakes except Van Lake due to geological structure of the western part of Turkey. Mn, Zn, Cu and Pb values were generally similar to findings from other studies in Bafa Lake, however the highest Cu level was found in Van Lake (Yener and Yildiz 2010).

The vertical distribution patterns for Fe, Cr, Mn, Pb, Ni, Zn, Cu and Hg in the C1, C2, C3 cores from Bafa Lake are shown in Fig. 2. The vertical solid line in some of the plots shows the average composition of sedimentary rock (Turekian and Wedepohl 1961). The mean metal concentration in three core sediments recorded decreased in the following order; Fe > Mn > Ni > Cr > Zn > Cu > Pb > Hg for Lake Bafa. The mean concentrations for each element were lower than the background levels in earth crust (Fe:47,000, Cr:90, Mn:850, Pb:20.0, Ni:68, Zn:95.0, Cu:45.0, Hg:0.40 mg kg^{-1}) except Cr and Ni in the core sediments. The high concentrations of Cr and Ni originated from the geochemical structure of the Menderes massif (Ergin et al. 1993; Akcay et al. 2003). The levels of Cr, Ni, Cu, Fe, Zn and Mn generally appeared to be uniformly distributed with depth (Fig. 2). The levels did not indicate any significant anthropogenic input, thus are derived predominantly from lithologic material. Hg and Pb were anthropogenically enriched in top layers of C1 and C3 sediment cores from the Bafa Lake, respectively, but the decrease of these elements with depth in these cores was generally uniform. Hg concentrations in the top layer of C1 core sediment (0–5 cm) were higher than the background value of 0.07 mg kg^{-1} from the bottom layer of C1 core sample. The source of this metal can be attributed to the pesticides and fertilizers which are used in the agricultural land around the lake. The other source of this metal was anthropogenic inputs via the Buyuk Menderes River. Yilgor (2009) found high Hg concentrations with the range of 0.12–1.25 mg kg^{-1} in the sediments from Buyuk Menderes Rivers. In this study, the elevated Pb values were observed especially at 0, 2, 4 cm in the C3 core sediment. Yilgor (2011) determined the sediment chronology using 210Pb dating method in Bafa Lake and found that these results corresponded to 2010, 2004, 2000, respectively. The concentrations of Hg reached peak value at 2 cm in the C1 core sediment profile corresponding to 2004 with the maximum concentration of 0.84 mg kg^{-1}. OC levels varied from 0.58 % to 3.02 % with a mean value of 1.8 % in the core sediments. The average OC contents in C1, C2 and C3 were 1.37 %, 1.52 % and 2.31 %, respectively. The levels of OC generally appear to be uniformly distributed with depth in C2 and C3 core sediments. OC values decreased along the C1 core sediment samples (Fig. 2).

Enrichment factor (EF) was used as an index to evaluate anthropogenic influences of metals in sediments. $EF = (Cx/Cne)sample/(Cx/Cne)background$, where $(Cx/Cne)_{sample}$ is the ratio of concentration of the element (Cx) to normalizing element (Cne) in the sediment sample and $(Cx/Cne)_{background}$ is the same ratio in unpolluted reference baseline. In this study metal concentration in bottom sediment of the core was used as the background

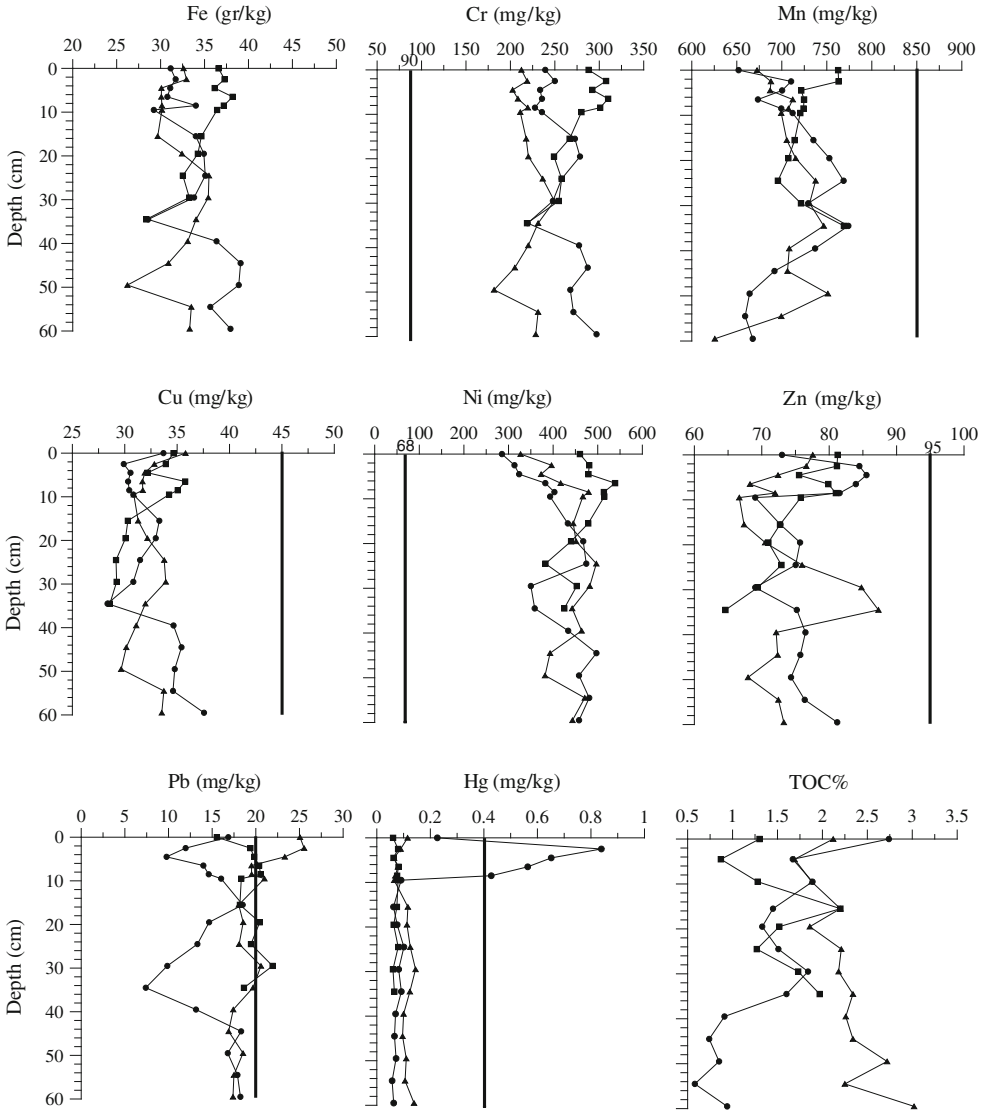

Fig. 2 Depth profiles of the concentration of metals (C1: *dotted circle*, C2: *dotted square*, C3: *dotted triangle*) and TOC (%) in Bafa Lake's sediment cores. The line is the distribution of the elements of the Earth's Crust in Shale's Sedimentary Rocks (Turekian and Wedepohl 1961)

(unpolluted) reference value. Commonly, geochemical normalization of the metals data to a conservative element such as Al and Fe is employed in order to identify anomalous metal concentration. Al and Fe are the most abundant elements on the earth. In this study, Fe was used as normalizing element to calculate the enrichment factor. Iron in the sediment is mainly from natural weathering processes and has been broadly used to normalize the metal concentrations in order to reduce particle grain size influence because variations in Fe concentration could be explained by particle grain size differences, with fine-grained sediments having high Fe concentrations. Several authors have successfully used Fe to normalize metals contaminants (Zhang et al. 2007; Esen et al. 2008).

An EF value of 1.5 indicates that the given element has principally originated from lithogenic source. However, in order to distinguish anthropogenic inputs from natural sources for a given element, EF estimates should be at least 10 or greater (Zhang et al. 2007). The enrichment factor of metals ranged between (Cr) 0.67–1.36, (Mn) 0.87–1.66, (Pb) 0.49–2.28, (Ni) 0.01–0.96, (Zn) 0.83–1.51, (Cu) 0.54–2.14 and (Hg) 0.68–4.70 in the study area. Enrichment factors of Cr, Mn, Ni and Zn were relatively less than 1.5 at each station, indicating very limited input from man-made sources. In other words, these elements have not been enriched in the lake sediments with respect to their crustal averages. The enrichment factors of Cu and Pb were less than 1.5 in most of the samples, while the enrichment factors of Pb and Cu were greater than 1.5 at the stations 6 and 8, 9, 10, respectively. EF analysis further indicated that Pb came from human impacts, while Cu increased due to fine-grained sediments at the stations 8, 9, 10. The enrichment factors of Hg were greater than 1.5 at the sampling stations except station 4 (which is located in the eastern part of the lake) and the maximum enrichment of Hg was calculated as 4.7 at station 10. EFs values below

Table 2 Contamination factors (Cf) and degree of contamination (Cd) of Bafa Lake sediments

Station	*Cf*								*Cd*
	Fe	Cr	Mn	Pb	Ni	Zn	Cu	Hg	
1	0.78	1.05	0.90	0.37	0.53	0.64	0.53	1.26	6.06
2	0.77	0.97	1.10	0.95	0.66	0.94	0.66	1.51	7.57
3	0.92	1.05	1.00	0.74	0.70	0.99	1.05	2.61	9.05
4	0.28	0.26	0.40	0.32	0.03	0.41	0.24	0.19	2.13
5	0.26	0.24	0.37	0.24	0.00	0.37	0.21	0.31	2.02
6	0.71	0.47	1.17	1.57	0.24	0.95	1.05	1.58	7.74
7	0.33	0.36	0.45	0.15	0.04	0.33	0.17	1.33	3.15
8	0.81	0.88	0.98	0.80	0.72	0.95	1.51	2.18	8.83
9	0.79	0.89	0.99	0.96	0.75	0.95	1.62	2.51	9.47
10	0.81	0.87	1.08	1.08	0.76	0.97	1.61	3.75	10.91
C1	0.86	0.90	0.97	1.08	0.67	0.89	0.96	3.25	9.58
C2	1.18	1.16	1.02	0.74	1.04	1.23	1.13	1.19	8.69
C3	0.92	0.93	1.08	1.29	0.69	1.03	1.02	1.09	8.05

than 10.0 are not considered significant, because such small enrichments may arise from differences in the composition of local soil material and references soil used in EFs calculation.

Contamination factor (*Cf*) to describe the contamination of a given toxic substance in a basin was suggested by Hakanson (1980). $Cf = Ce/Cn$, where Ce = concentration of the element in samples and Cn = background concentration of the element. *Cf*, calculated as the ratio between the sediment metal content at a given station and the background concentrations, reflects the metal enrichment in the sediment. *Cf* was classified into four groups by Hakanson (1980): $Cf < 1$, low contamination factor; $1 \leq Cf < 3$, moderate contamination factor; $3 \leq Cf < 6$, considerable contamination factor; and $Cf > 6$, very high contamination factor. The "degree of contamination", *Cd*, is defined as the sum of all contamination factors of various metals for a given basis.

$$Cd = \sum_{n=1}^{n=8} Cf$$

The *Cf* for 8 metals in these sediments was calculated using the raw elemental data. For the description of contamination degree, the following terminologies have been used: $Cd < 8$, low degree of contamination; $8 < Cd < 16$, moderate degree of contamination; $16 < Cd < 32$, considerable degree of contamination; $Cd > 32$, very high degree of contamination. The Cf values for the sediment samples were given in Table 2. They were between low and moderate for Fe, Cr, Mn, Pb, Ni, Zn, Cu and between low and considerable for Hg according to the Hakanson (1980) classification. Contamination factor values of Hg ranged between 0.19 and 3.75 and the CF of Hg at station 10 was viewed to be a considerable contamination in the Bafa Lake. The degree of contamination (Cd) values are provided in Table 2; Cd values indicated a moderate degree of contamination suggesting anthropogenic pollution at stations 3, 8, 9, 10 and C1, C2, C3 cores. Other sampling stations showed low degree of contamination.

The first version of New Geo-accumulation Index was developed for rivers by Ruiz (2001) and many studies have used this index (Zhang et al. 2007; Hu et al. 2011) but this new version was more applicable in estuaries (Caeiro et al. 2005). This index was used to assess metal pollution in sediments in addition to enrichment factor. NIgeo = $\log_2$ (Cn\1.5*Bn), where Bn; is the concentration of the metal

Table 3 New Geoaccumulation Index (NIgeo) values of metals in Bafa Lake sediments

Station	Fe	Cr	Mn	Pb	Ni	Zn	Cu	Hg
1	−0.93	−0.30	−0.62	−2.37	−1.66	−1.24	−1.54	−0.25
2	−0.94	−0.43	−0.33	−1.02	−1.33	−0.68	−1.20	0.01
3	−0.69	−0.30	−0.48	−1.38	−1.25	−0.61	−0.54	0.80
4	−2.42	−2.31	−1.78	−2.61	−5.63	−1.88	−2.65	−3.01
5	−2.51	−2.44	−1.89	−2.99	−9.18	−2.01	−2.84	−2.26
6	−1.06	−1.45	−0.25	−0.30	−2.80	−0.67	−0.54	0.08
7	−2.18	−1.86	−1.63	−3.64	−5.55	−2.20	−3.17	−0.17
8	−0.88	−0.56	−0.50	−1.27	−1.22	−0.67	−0.01	0.54
9	−0.90	−0.54	−0.49	−1.01	−1.14	−0.67	0.08	0.74
10	−0.88	−0.58	−0.36	−0.84	−1.14	−0.64	0.07	1.32
C1	−0.81	−0.73	−0.64	−0.47	−1.18	−0.76	−0.64	1.11
C2	−0.34	−0.37	−0.55	−1.03	−0.53	−0.28	−0.41	0.25
C3	−0.71	−0.69	−0.47	−0.21	−1.12	−0.53	−0.55	−0.45

"n" in unpolluted sediments and Cn; the concentration of metal. The factor 1.5 is introduced to include possible variations of the background values due to lithogenic effects. Unpolluted NIgeo < 1; very lightly polluted $1 <$ NIgeo < 2; lightly polluted $2 <$ NIgeo < 3; moderately polluted $3 <$ NIgeo < 4; highly polluted $4 <$ NIgeo < 5; very highly polluted NIgeo > 5. Table 3 showed New Geo-accumulation Index values of metals in Bafa Lake. For the elements Fe, Cr, Mn, Pb, Ni, Zn and Cu, almost all the surface and core sediments may be classified as unpolluted (NIgeo < 1). The relatively highest NIgeo value was observed for Hg, classifying station 10 as very "lightly polluted". This result clarified a very lightly enrichment for the element Hg in the Bafa Lake and its origin should be identified, in order to assess a possible human influence in the area.

Bafa Lake is a nature reserve situated on the western part of Turkey. Down-core variations of elements indicated an increase of mercury probably during the past few decades. The metal concentrations in various stations of Bafa Lake follow the order Fe > Mn > Ni > Cr > Zn > Cu > Pb > Hg. Enrichment factors of Cr, Mn, Ni and Zn were less than 1.5 in the sampling area, suggesting that these metals have originated from lithogenic sources in Bafa Lake. EFs of Pb and Cu calculated for stations 6 and 8, 9, 10 were higher than 1.5, respectively. It means that Pb was provided by anthropogenic sources, while Cu was observed to be enriched from fine-grained sediments at these stations. The elevated enrichment levels of Hg showed anthropogenic sources. Obtained data showed that sediments were low to moderately contaminated by metals originating from agricultural drainage water as well as industrial and domestic wastewater, transported by the Buyuk Menderes River. Similar results were found using the New Geo-accumulation Index in the study area. The above results confirmed that the Bafa Lake was not currently facing any serious environmental pollution risk by metal contamination with the exception of Hg. Hg concentrations and sources should be investigated in further studies.

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