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Original Research

Sediment Quality Assessment in Porsuk Stream Basin (Turkey) from a Multi-Statistical Perspective

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Abstract

Porsuk Stream Basin is a significant aquatic habitat located in the middle of the Aegean and Central Anatolian Regions of Turkey. Similar to may aquatic habitats, it is exposed to intensive agricultural, domestic, and industrial pollution. The aim of this study was to determine the toxic element levels in Porsuk Stream Basin sediment and evaluate the detected data using a multi-statistical technique. For this purpose, sediment samples were collected from 18 stations selected on the basin (three of them located on Porsuk Dam Lake) in summer 2015, and zinc, copper, lead, cadmium, nickel, and chromium accumulations in sediment samples were determined. All the detected data were compared with the consensus-based threshold effect concentrations (TEC), and factor analysis (FA) also was applied to detected data in order to evaluate the contamination grades in the basin. According to detected data, although Cu, Pb, and Cd concentrations were detected below the limit values, Zn, Cr, and Ni concentrations exceeded the limit values in general. According to results of FA, 3 factors – industrial, agricultural, and lead – explained 81.56% of the total variance.

Keywords: Porsuk Stream Basin, sediment quality, factor analysis

Introduction

Heavy metals, which can be strongly accumulated and biomagnified along water, sediment, and aquatic food chain, are the most important inorganic contamination factors and have significant hazardous effects on the ecological balance of the environment. It is clearly revealed and clearly known that sediment may act as a sink of various contaminants and pose a significant risk to water quality [1-5].

Porsuk Stream is one of the most important and the longest branches of the Sakarya River. Porsuk, with a length of 448 km, has a reservoir on the watershed

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(Porsuk Dam Lake) and is exposed to intensive industrial, agricultural, and domestic waste. The stream feeds the Sakarya River, which is one of the longest river systems in Turkey, by passing from the borders of Eskişehir and Kütahya provinces. It is well documented that Porsuk has been heavily polluted by domestic and industrial activities in these cities. Many plants in the area include the nitrogen fertilizer factory, magnesite factory, seyitomer thermic power plant, sugar-beet factory, textile factory, and lots of ceramics factories. Also, Kütahya and Eskişehir sewage wastewater, refined organized industrial districts, and drainage water of agricultural lands are significant pollution factors for the system [6-14].

The aim of this study was to determine the zinc, copper, lead, cadmium, nickel, and chromium accumulations in of Porsuk Stream Basin sediment and evaluate the toxic metal levels data using factor analysis (FA).

Materials and Method

Study Area and Collection of Water Samples

Porsuk Stream Basin and the selected stations are given in Fig. 1 and the location information of the stations is given in Table 1. Sediment samples were collected from 18 stations (three of them on the dam lake) selected on the watershed using an Ekman grab in summer 2015.

Chemical and Statistical Analysis

Sediment samples were dried for 3 h at 105ºC for element analyses. Then all sediment samples were placed (0.25 g of each sample) in Pyrex reactors of a CEM Mars Xpress 5 microwave digestion unit. $HClO_4$:HNO_3 acids of 1/3 proportions were inserted in the reactors respectively. Samples were mineralized at 200ºC for 30 minutes. Afterward, the samples were filtered in such a way as to make their volumes to 100 ml with ultra-pure distilled water. The inductively coupled plasma – optic emission spectrophotometric method was used to determine the toxic element accumulations of sediment samples using a Varian 720 ES ICP–OES Device in an accredited laboratory (Applied Environmental Research Centre Laboratory of Anadolu University). All the investigated toxic element analyses were recorded as averages of triplicate measurements [15-16]. The wavelengths used for toxic element analyses in ICP–OES are given in Table 2.

Factor Analysis (FA) is a quite powerful and widely used statistical technique that helps to assess the effective factors on the quality of aquatic habitats [17-19]. In this study, FA was applied to the results by using the "SPSS 17" package program.

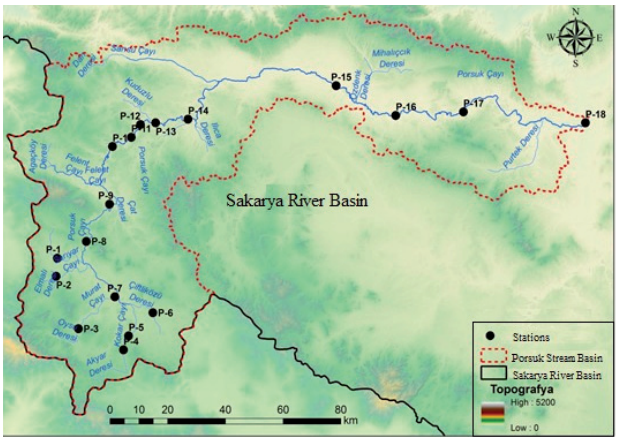

Fig. 1. Porsuk Stream Basin and stations.

Table 1. Location information for stations.

Stations	Name of Station	Coordinates	
		X	Y
P1	Aslanapa	39.20881	29.86675
P2	Tokul Village	39.15352	29.86566
P3	Source	38.99798	29.96448
P4	Zafertepe Village	38.96072	30.10365
P5	Beşkarış Village	38.98336	30.16605
P6	Hacıbeyli Village	39.05681	30.25909
P7	Çayırbaşı Village	39.0999	30.10393
P8	Ada Village	39.26397	29.98031
P9	Ağaçköy Village	39.38014	30.06653
P10	Kütahya Exit	39.55533	30.06802
P11	Reservoir 1	39.586	30.14198
P12	Reservoir 2	39.62566	30.17688
P13	Reservoir 3	39.63312	30.23757
P14	Eskişehir Entrance	39.64833	30.36753
P15	Alpu Village	39.76836	30.96016
P16	Beylikova Village	39.68423	31.20469
P17	Yunusemre Village	39.70131	31.47751
P18	Sakarya River Entrance	39.67838	31.97093

Results

Toxic Element Levels in Sediment

Toxic element accumulations detected in the sediment of Porsuk Stream Basin and the limit values according to consensus-based threshold effect concentrations (TEC) are given in Fig. 2 [20].

The highest Zn levels were recorded as 830.13 mg kg^{-1}, 886.73 mg kg^{-1}, and 900.53 mg kg^{-1} at the P8, P12, and P15 Stations, respectively, and the lowest Zn levels were recorded as 182.93 mg kg^{-1} and 158.26 mg kg^{-1} at

Table 2. Wavelengths of investigated elements.

Elements	Wavelength (nm)
Nickel	231.604
Zinc	213.856
Cadmium	226.502
Copper	324.754
Lead	220.353
Chromium	205.552

the P7 and P18 Stations, respectively. According to consensus-based threshold effect concentrations (TEC) [20], Zn accumulations exceeded the limit value in the entire basin.

The highest Cu levels were recorded as 38.87 mg kg^{-1} and 33.68 mg kg^{-1} at the P8 and P11 Stations, respectively, and the lowest Cu levels were recorded as 5.89 mg kg^{-1} and 7.28 mg kg^{-1} at the P5 and P9 Stations, respectively. According to TEC [20], Cu accumulations did not exceed the limit value except for the P8 and P11 Stations (which were higher than the limit value).

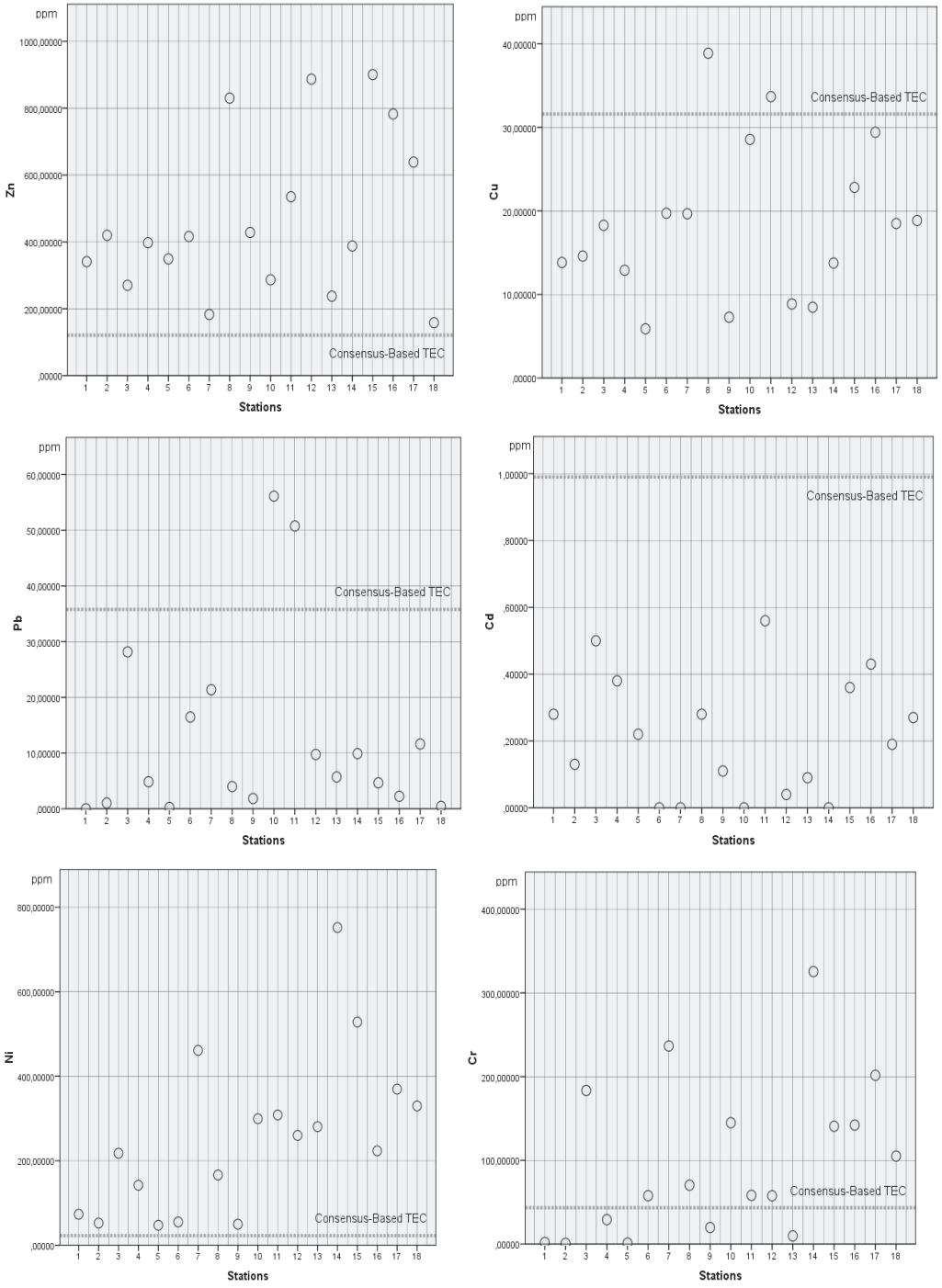

Fig. 2. Zn, Cu, Pb, Cd, Ni, and Cr levels in Porsuk Stream Basin sediment.

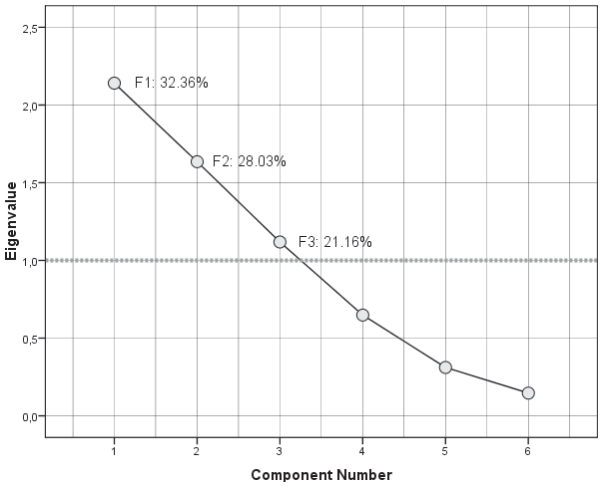

Fig. 3. Scree plot of FA.

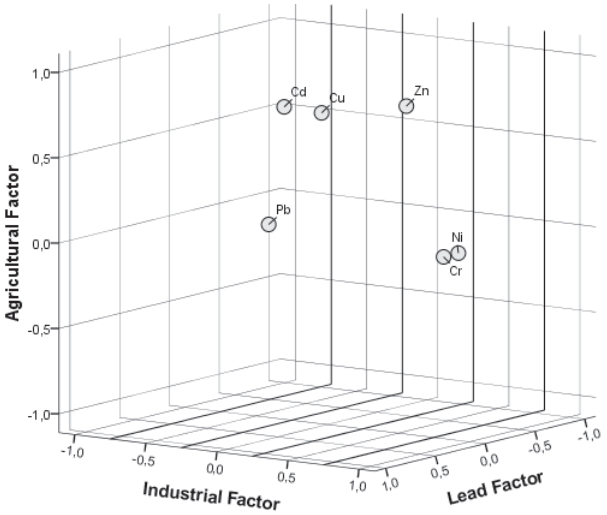

Fig. 4. Component plot of FA.

The highest Cd accumulations were detected at the P3 and P11 Stations (0.5 mg kg^{-1} and 0.56 mg kg^{-1}, respectively). Cd accumulations detected at the P6, P7, P10, and P14 Stations were below the detection limits and Cd concentrations in sediments of the entire basin were below the limit value, according to TEC [20].

The highest Pb accumulations were detected at the P10 and P11 Stations (56.14 mg kg^{-1} and 50.77 mg kg^{-1}, respectively). Pb accumulations detected at the P1 Station were below the detection limits, and Pb concentrations in sediments of the entire basin (except for the P10 and P11 Stations, which were higher than the limit value) were below the limit value, according to TEC [20].

Cr and Ni levels of sediment samples collected from downstream of the basin were significantly higher than those detected upstream. The highest Cr and Ni accumulations were recorded as 325.53 mg kg^{-1} and 751.66 mg kg^{-1}, respectively, at the P14 Station. According to TEC [20], Cr and Ni concentrations exceeded the limit values in the entire basin in general.

Factor Analysis (FA)

FA was used to detect the effective varifactors on the Porsuk Stream Basin by using correlated variables. A total of six variables (Zn, Cu, Pb, Cd, Ni, and Cr levels in sediment samples) were used to detect the varifactors. Eigenvalues higher than 1 were taken as criterion for evaluating the principal components required to explain the sources of variance in the dataset. According to rotated cumulative percentage variance, three factors explain 81.56% of total variance (Fig. 3).

The parameter loadings (>0.5) for three components before and after rotation are given in Table 3. Liu et al. [21] classified the factor loadings as "strongly loaded (>0.75)," "moderately loaded (0.75-0.50)," and "weakly loaded (0.50-0.30)" according to loading values. The component plot in the rotated space that shows the related variables of three effective factors is given in Fig. 4.

First factor (F1), named "industrial factor," explains 32.36% of total variance and is related to the variables of nickel and chromium values of sediment. All parameters are strongly positively loaded with this factor.

The second factor (F2), named "agricultural factor," explains 28.03% of total variance and is related to the variables of copper, cadmium, and zinc values of sediment. Copper parameter are positively strong, while cadmium and zinc parameters are moderate positively loaded with this factor.

Table 3. Component matrix before and after rotation.

Parameters	Components (Before rotation)			Parameters	Components (After rotation)		
	F1	F2	F3		F1 (Industrial factor)	F2 (Agricultural factor)	F3 (Lead factor)
Cr	.859			Ni	.945		
Ni	.822			Cr	.932		
Cd		.777		Cu		.792	
Cu	.604	.655		Cd		.734	
Pb			-.708	Zn		.688	
Zn			.684	Pb			.877

The third factor (F3), named "lead factor," explains 21.16% of total variance and is related to the variable of lead values of sediment. The lead parameter is strong positively loaded with this factor.

Discussion and Conclusion

Nickel and chromium that occur naturally in the earth's crust may enter the water environment as a result of anthropogenic activities in general. The most significant sources of nickel and chromium in surface sediments are industrial activities [22-23]. There are many industrial enterprises in Kütahya and Eskişehir provinces, and the highest Cr-Ni accumulations were detected in the output stations of these cities. Also, nickel and chromium were found to be "industrial factor" components with strong parameter loadings. In a study performed in Ergene River that is known as one of the most polluted lotic ecosystems of Turkey, toxic metal accumulations in sediment samples were investigated [24]. If we compare the results of this study with the present investigation, recorded Cr and Ni data in Porsuk Stream Basin sediment were significantly higher than the recorded values in the Ergene River. In other studies performed in a significant chromium mine basin in Turkey (Emet Stream Basin) and in one of the most inorganically polluted wetlands in Turkey (Meriç River Delta), Cr and Ni levels were investigated [25-26]. According to the results of these studies, Cr and Ni concentrations in sediments of the Emet Stream Basin and Meriç River Delta were found to be at extremely high levels and exceed the limit values significantly. In the present study, recorded Cr and Ni data detected in sediment of almost all the stations except source regions of Porsuk Stream were significantly higher than the recorded values in Emet Stream Basin and Meriç River Delta sediment. These results indicate that the Porsuk Basin is significantly affected by industrial contamination.

Fertilizers have a significant impact on zinc and copper transitions to soil and sediment and pesticides (especially herbicides) containing significant amounts of zinc [27-28]. Cadmium is also known as another agricultural origin toxic metal that can be emitted to the soil and water by applying phosphate fertilizers [29]. In the present study, Zn, Cu, and Cd elements were found to be "agricultural factor" components with strong-to-moderate parameter loadings. As with many lotic ecosystems, there are many agricultural lands around the Porsuk Stream Basin. The high Zn levels detected in sediment across the entire basin indicates that this significant aquatic ecosystem is intensively under the effect of agricultural pressure. In a study performed in the Thrace Region of Turkey, sediment quality of Gala Lake was evaluated using FA. According to rotated cumulative percentage variance, two factors explain 86% of total variance. Similar to the present study, "agricultural factor" explained 48% of total variance and was an effective component on sediment quality of Gala Lake, and Zn-Cu elements were strong positively loaded with this factor [25].

Lead is another industrial origin toxic metal commonly found in soil, water, and sediment – especially near roadways, industrial sites, and hazardous waste sites [30]. The highest Pb accumulations in sediment of Porsuk Stream Basin, which were found to be "Pb factor: components with strong parameter loadings, were recorded in the output stations of Kütahya District, which are known as significantly under the effect of the organized industrial zone of Kütahya. In a study performed in a Felent Stream Basin, which is one of the most significant branches of Porsuk Stream in Kütahya Province, Arslan et al. [31, 32] reported that lead concentrations in sediments of Yedigöller Region were found to be at quite high levels and exceed the limit values. In the present study, recorded Pb data in the output stations of Kütahya District (P10 and P11) were significantly higher than the recorded values in Yedigöller Region sediment. These results indicate that the organized industrial zone of Kütahya contaminates the system more than the organized industrial zone of Eskişehir in terms of lead concentrations. In another study performed in Beyşehir and Mogan Lakes in the Central Anatolia Region of Turkey, which are known as being under industrial pressure lakes, toxic metal concentrations in biotic and abiotic components of the lakes were investigated. According to the results of this study, Pb accumulations were found as the highest levels among the investigated toxic metals [33].

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