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Review

Principal Component Analysis of Integrated Metal Concentrations of Bogacayi Riverbank Sediments in Turkey

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Abstract

This research was carried out along the banks of the Bogacayi River in the western part of Antalya in Turkey. We investigated the concentration, average distribution, and level of contamination of the sediments by heavy metals for monitoring purposes. In this study, 25 sediment samples from different stations were collected and analyzed along the Bogacayi's banks. Heavy metals detected in order of abundance are Mg> Fe > Al > Ti> MN > Cr > Ni > Ba > V > Zr > Zn > Co > Cu > Pb > As > Mo > W > Cd > Sb > Ag. The average concentration of each heavy metal elements was compared to those of the earth crust, sandstone, ultrabasic rock, especially with the acceptable limit for Turkey, in order to determine their anomalies. The concentration of Cr in sample 24 was 19.85 times and Ni in sample 25 was 19.29-7.71 times higher than the acceptable limit for Turkey. In samples 24 (1.87 times) and 25 (1.85 times), Co was also higher than the acceptable limit for Turkey. As confirmed by the coefficient correlation analysis, the PCA, anthropogenic activities is thought to have possibly contributed most of the Sb, Mo, and Pb, and led to an increase in the quantities of elements such as: Fe, V, Mn, Co, Ni, Mg, Cr, and As. Most of the Al, Ti, Zr, Zn, W, Ba, and Cu, and a majority of the Fe, V, Mn, and Sn, potentially resulted from a natural source. Samples 24 (Zn, Co, Mn, Fe, V, Cr, Mg, and Ba) and 25 (Ni, Co, Fe, and Mg) contain several numbers of heavy metals, each showing high anomalous concentrations, which are related to anthropogenic sources. The ANOVA model summary reveals the high explanatory power of $R^2 = 100.00\%$, indicating that the number of samples used in this study was sufficient.

Keywords: heavy metals, river sediments, multivariate analysis, principal components analysis

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Introduction

The contamination of soils and sediments by heavy metals are known to be the most serious environmental problem and has significant implications for human health processes [1, 2]. "Heavy metals" refers to metallic elements with similar chemical properties that are toxic, persistent, non-biodegradable, and poisonous – even at lower concentrations [3-5]. They can either be introduced into the environment naturally (by chemical leaching of bedrocks, water drainage basins, and runoff from banks) and/or from anthropogenic sources (mining operations, disposal of industrial wastes, applications of biocides for pests, automobile exhausts, and combustion by-production from coal-burning power plants [6-10]. Most heavy metals introduced in the environment are usually known to be trapped in sediments by forming stable complexes with sediment organic matter, carbonates, and iron (Fe) – manganese (Mn) oxides [11, 12]. Human beings can easily be affected by heavy metals through body contact, inhalation of heavy metal-polluted dust, and intake of food [8, 13, 14]. An assessment of the distribution and contamination level of the soil, sediments, and water by these elements is of great importance to disaster risk reduction.

In this light, this study was carried out along the banks of the Bogacayi River in Antalya, which flows from the Mediterranean Sea, in order to determine the heavy metal content of its sediments. The study area which hosts villages close to the river banks will be a great tourist attraction in the near future, considering the mega touristic project that has to be established there. It is necessary and important to investigate the area for its potential of heavy metal threats to the ecosystem by investigating their distribution and sources, to mitigate environmental pollution and reduce exposure risk [9]. To do this, the multivariate statistical analysis which is the most commonly used method to explain the geogenic and anthropogenic source of heavy metal in sediments [15-18], will be used. Factor analysis is often used within this method [19-22].

Therefore, the purpose of this project is to evaluate the concentrations and average distributions of heavy metals by chemical analysis, assess the contamination level, and statistically analyze the heavy metals in Bogacayi riverbank sediments for monitoring purposes.

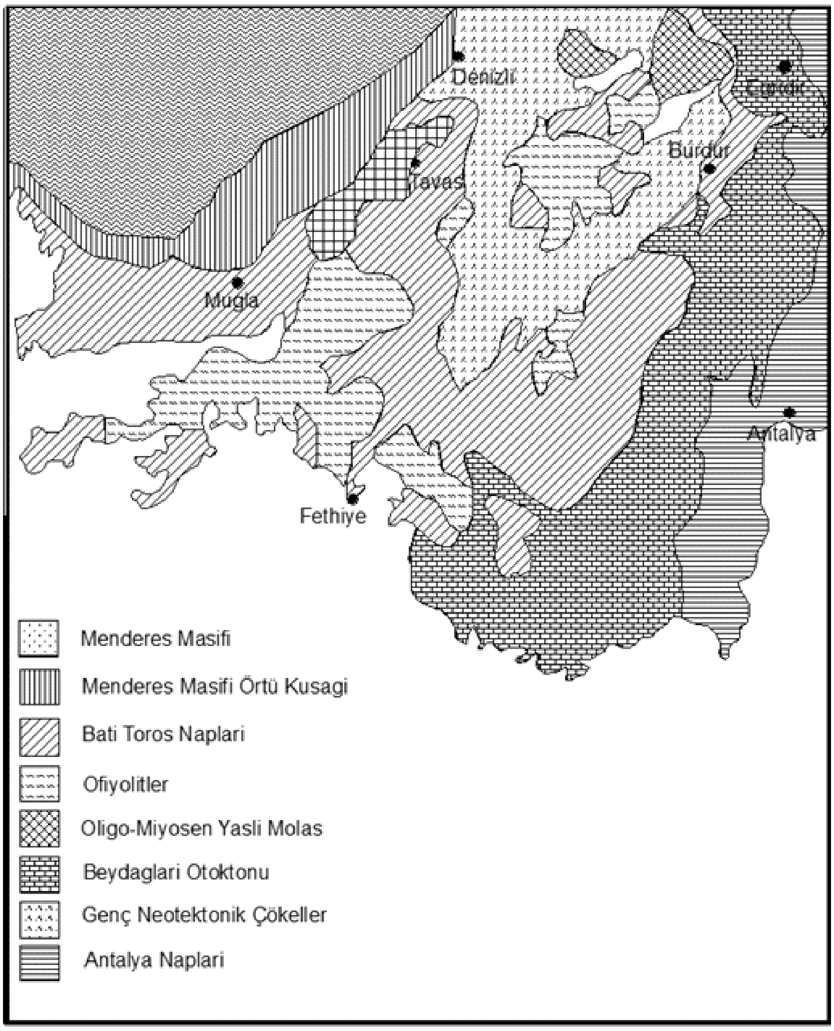

Fig. 1. View of the west Taurus Unit (Ersoy, 1990).

Geological Setting

Bogacayi riverbanks are located at the south end of the Taurus orogenic belt of the western Tantains, located near the Kemer and Konyaalti beach break in Korkuteli in the western part of Antalya. This area is covered with sediments.

The geology of the study area ranges from the Mesozoic to the Cenozoic time interval. The allochthonous formation is composed of exposed igneous and sedimentary rocks independent of each other. In this area dolomite, cherty dolomite, and dolomitic limestone represent the upper Triassic-Lower Jurassic, which seems older at the base of the Kayakoy formation, tectonically overlaid the upper Jurassic-lower cretaceous Babadag formation, which is composed of cherts nodules and micritic textured limestone.

Spilitic basaltic rocks overlie the upper cretaceous aged Covenliplateau formation that also overlies the Babadag formation tectonically. Harzburgite, dunite, serpentinite and pyroxene make up the upper cretaceous unit. All these are unconformably covered by dirty yellow, grayish colour conglomerate, clay stone, and sandstone formations forming the Pliocene unit and the quaternary alluvium, talus, and beach sands.

In this region basic and ultrabasic rocks are in contact with dykes along the fault zone and also in the massive peridotite crack and fracture are serpentinized [23].

Generally the study area is represented by the Antalya nappes (Fig. 1). Antalya nappes is divided into three different units: Cataltepe (clay, limestone, sandstone, and radiolarians), Alakircay-Ispartacayi (sandstone, limestone, radiolarians, ophiolitic rocks), and Tahtalidag (carbonates and sedimentary rocks) [24].

Material and Method

The first field work of this project was carried out in May 2013 around the Bogacayi riverbanks. Samples of 2 kg each were collected at depths of 10 cm from 25 different stations located about 500 m from each other. The samples were prepared at Akdeniz University's geology laboratory and analyzed for their heavical techniques at the ACME Laboratory Ltd., Canada.

The samples were carefully collected, avoiding gravel tracks with the use of a plastic shovel and stored in plastic bags for transportation. The GPS location of each sample was noted in an exercise book using a pen. Based on the U.S. EPA 1992, ASTM 2000 sampling requirements for sediment types, waiting time, and storage conditions, the collected samples were stored inside a freezer in plastic bags with pH < 2 adjusted with the use of HNO_3, to prepare them for analysis. Before the samples taken to the laboratory were analyzed, they were passed through processes of pH measurement, drying, grinding, sieving, weighing, and being stored with acid in parts.

Firstly, the pH value was evaluated. To do these, 20 grams of a sample were put in a 50 ml beaker and pure water was added at a ratio of 1:2.5. This was thoroughly shaken, kept for 10 minutes, and the beaker was stirred again, after which the pH was measured with the use of a pH meter.

The samples for chemical analysis were kept under normal conditions of room temperature for 24 hours. Using a precision weighing scale, 100 grams of the samples were measured, put on wet paper laid on the ground, labeled, and dried for 24 hours ian oven at 105ºC. After drying, sample weights were measured again using a precision scale.

100 g of the dried sample were taken and the amount of each sample remaining was passed through an oscillating mesh sieve and weight distribution of the particle sizes was calculated. Screening was carried out for 10 minutes per sample with sieve sizes of 2, 1, 0.5, 0.25, 0.125, and 0.065. During the experiment, sieve set, precision scale, brushes, and gloves were dried and washed after every measurement with a 1 mol L^{-1} HNO_3 to avoid contamination.

The Geochemical analyses of the samples were determined at the ACME Analytical Laboratories Ltd. Chemical analysis of content made with the Group 1EX (ICP-MS) and 3A01 (ICP-OES) method are given in mg/kg and percentage, for a total of 41 elements with reference numbr ANK13001068.

Geochemical data of the elements was then statistically analyzed using SPSS software.

Results

Data obtained from the Geochemical Analysis of the Bogacayi beach sand samples are presented in Table 1.

In orderabundance in ppm mg/kg, the heavy metals occur as follows with minimum, maximum, and mean values, respectively: Mg (81,600, 49,600), Fe (13,300, 42,500, 28,704), Al (14,100, 31,000, 24,772), Ti (1,130, 4,190, 2,957.60), Mn (593, 1,435, 1,044.36), Cr (159, 1,985, 404.84), Ni (172.9, 578.60, 368.16), Ba (68, 222, 127.36), V (12, 118, 64.56), Zr (26, 78.9, 51.84), Zn (27, 55, 41.40), Co (12.8, 37.3, 25.13), Cu (14.5, 31.6, 23.83), Pb (3.4, 11.4, 4.66), As (2, 8, 3.72), Mo (0.40, 0.80, 0.58), W (0.20, 0.50, 0.39), Cd (0.10, 0.40, 0.23), Sb (0.10, 0.40, 0.21), and Ag (0.10, 0.20, 0.112) Table 2.

The schematic presentation of the box plot (Fig. 2) reveals that some samples actually contain anomalous high concentrations of some elements, such as: sample 1 has a high anomalous concentration of Pb; sample 4 has a higher concentration of As; sample 5 shows an anomalously high concentration of As, and sample 10 has a higher concentration of Mn; sample 13 has a higher concentration of Ba; sample 15 higher concentrations of Ba and Zr; sample 16 shows a higher concentration of Ag; sample 18 has a higher concentration of Ag; sample 24 has higher concentrations of Zn, Co, Mn, Fe, V, Cr, Mg, and Ba; and sample 25 has higher concentrations of Ni, Co, Fe, and Mg.

Table 1. Results of chemical analysis of samples from Bogacayi riverbanks.

Samples	1	2	3	4	5	6	7	8	9	10	11	12	13
Au	4.4	5.2	2.7	2.7	2.1	1.9	1.9	2.8	3.5	1.9	2.7	1.3	1.6
Mo	0.8	0.4	0.6	0.7	0.4	0.6	0.5	0.5	0.6	0.6	0.7	0.4	0.4
Cu	14.5	22.5	23.8	22	22.8	23.5	26.2	22.4	25.6	23.3	31.6	21.5	26.9
Pb	11.4	5.6	4.8	4.7	4.3	4.4	4.1	4.1	5	4.4	4.4	3.9	5.2
Zn	27	44	44	41	34	44	41	42	40	43	41	43	42
Ag	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ni	172.9	334.1	351.1	321.6	353.4	425.4	344.3	440	440.2	350.6	438.5	354	375.4
Co	12.8	22.5	23.6	23.9	21.5	25.7	23.1	26.9	25.6	24.7	28.7	24.5	26.7
Mn	593	852	903	1030	885	1057	983	975	1006	1435	1122	1195	1003
Fe	13300	25200	26200	26900	23800	28500	28400	27100	28800	32000	31300	28100	29300
As	3	5	4	6	8	5	2	2	4	3	5	4	4
U	0.7	0.7	0.8	0.7	0.8	0.7	0.8	0.9	0.8	0.7	0.8	0.7	0.8
Th	3.4	2.4	2.1	1.8	1.3	2.2	2.1	2.1	2.5	2.1	2.3	1.8	2.8
Sr	206	192	191	190	177	201	193	196	203	207	200	208	184
Cd	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.4	0.2
Sb	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.4	0.2
Bi	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.6	0.2
V	12	54	58	68	54	57	66	56	56	83	71	71	67
Ca	199800	144200	140600	148500	151900	134100	129600	138500	136200	156100	125800	142700	101100
P	260	460	450	420	300	440	510	440	490	520	500	500	510
La	9.1	14	13.6	13.7	10	15.2	17.2	15.4	17.8	16	16.7	15.5	18
Cr	159	288	298	531	375	390	301	317	256	402	423	549	328
Mg	35800	44000	42900	41800	40900	52400	45900	51700	54100	47000	57300	47500	46400
Ba	68	127	118	101	95	122	128	117	143	129	130	122	145
Ti	1130	2720	2670	2680	1780	2740	3150	2600	2760	3390	3110	3250	3140
Al	0	0	0	0	0	0	0	0	0	0	0	0	0
Na	0	0	0	0	0	0	0	0	0	0	0	0	0
K	2800	4600	4600	4300	3200	5200	5300	4900	5700	4600	5400	4900	6200
W	0.2	0.3	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4
Zr	26	45.4	47.2	43.7	27.7	52.4	53.2	51.5	61.7	55.4	54.7	51.6	62.2
Ce	15	25	25	23	17	28	30	26	31	28	29	27	33
Sn	0.5	0.6	0.6	0.4	0.4	0.6	0.5	0.5	0.6	0.7	0.5	0.7	0.7
Y	7.7	11	10.9	11.3	9.4	11.6	12.4	11	12.1	12.4	12.2	11.8	13
Nb	4.9	9.6	9.9	9.1	5	11.9	11.7	11.5	14.2	12.9	12.3	11.9	13.1
Ta	0.3	0.6	0.6	0.5	0.3	0.7	0.7	0.7	0.9	0.8	0.8	0.7	0.8
Sc	5	9	8	9	8	8	8	8	8	10	9	9	8
Li	10.2	13.8	14.7	12.3	10.9	13	14.5	12.9	14.2	13	14.6	12	17.6
Rb	12.3	16.8	16.3	16	13.9	16.3	17.1	15	19.2	15.9	17.2	14.6	21.1
Hf	0.6	1.1	1.2	1.1	0.7	1.4	1.4	1.4	1.7	1.5	1.5	1.3	1.5
In	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Te	2	3.1	2.4	5	5.2	4.3	3.1	4.8	5.5	5.7	1.9	3.3	4

Continued

Samples	14	15	16	17	18	19	20	21	22	23	24	25
Au	2.3	2.1	2	1.6	0.8	0.8	2	2.3	1.8	0.5	0.5	1.6
Mo	0.6	0.6	0.7	0.8	0.6	0.4	0.5	0.5	0.7	0.5	0.7	0.7
Cu	23.4	23.2	25	28.7	19.1	22	24	20.5	26.1	20.1	27.8	29.3
Pb	4.2	5.3	5	5.2	3.4	3.9	4	3.4	4.3	3.6	4.1	3.8
Zn	41	47	43	47	35	37	38	35	45	40	55	46
Ag	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Ni	403.5	181.8	380.5	318.6	370.3	402	333.7	385.4	343.2	335.3	469.5	578.6
Co	25	17.1	25.3	26	23.7	26.7	24.5	25.3	25.8	24.3	37.3	37
Mn	1052	997	1015	1002	1056	1016	1142	1103	1285	1017	1350	1035
Fe	29000	26800	29000	30300	26900	28100	30100	28200	32300	28000	42500	37500
As	2	2	3	4	3	3	2	3	4	3	5	4
U	0.8	0.9	0.9	0.8	0.8	1	0.8	0.9	0.8	0.9	0.9	0.8
Th	2.3	3.5	2.8	2.9	1.6	2.2	1.9	1.9	2.4	2.3	2	2.2
Sr	192	210	189	192	234	201	212	221	205	198	188	168
Cd	0.1	0.1	0.2	0.3	0.2	0.2	0.4	0.2	0.2	0.1	0.4	0.2
Sb	0.2	0.2	0.2	0.4	0.2	0.1	0.4	0.1	0.2	0.1	0.4	0.2
Bi	0.2	0.2	0.2	0.6	0.1	0.1	0.6	0.2	0.1	0.1	0.5	0.2
V	67	62	64	71	58	54	69	64	76	59	118	79
Ca	117700	154600	104500	101900	155500	123400	144200	146100	130900	128400	122100	104500
P	480	770	530	560	490	460	470	490	530	480	490	500
La	16	23.3	16.9	18.7	15.3	15.6	15.9	15.4	17.9	16.6	15.5	16
Cr	281	174	229	254	242	261	280	315	487	301	1985	695
Mg	51100	27000	48500	46200	50000	56100	48800	53400	51300	49500	68800	81600
Ba	122	165	129	136	123	121	123	124	132	125	222	117
Ti	2910	4050	2960	3470	2880	2640	3240	2800	3550	2890	4190	3240
Al	0	0	0	0	0	0	0	0	0	0	0	0
Na	0	0	0	0	0	0	0	0	0	0	0	0
K	5400	6600	6400	6500	4900	5100	5200	4800	5600	5200	4800	5300
W	0.4	0.5	0.5	0.4	0.3	0.4	0.4	0.3	0.5	0.4	0.4	0.4
Zr	52.9	78.9	59.2	59.2	47.4	49.3	51.5	46.9	57.5	53.5	52.7	54.4
Ce	29	40	32	33	27	28	27	27	32	29	27	28
Sn	0.4	0.8	0.7	0.7	0.5	0.5	0.7	0.4	0.6	0.5	0.6	0.5
Y	12	15.5	13.1	13.3	11.9	11.7	12.6	11.4	13.1	13.2	12.6	11.5
Nb	11.3	17.9	12.1	12.6	10.4	10.6	11.3	10.1	12.8	10.7	12.6	11.6
Ta	0.7	1.1	0.8	0.8	0.6	0.7	0.7	0.6	0.8	0.7	0.8	0.7
Sc	8	7	8	9	9	8	11	9	10	9	11	10
Li	14.6	16.2	17.7	17.6	13	12.9	13.8	12	14.1	13.1	14.2	15.3
Rb	17.3	23.1	21.8	22.5	14.8	17.1	15.6	14.5	17.9	15.7	14.7	17
Hf	1.2	2	1.7	1.7	1.2	1.3	1.3	1.3	1.6	1.2	1.4	1.4
In	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Te	3.4	3.8	1.9	3.9	4.5	3.4	2.2	2.5	1.9	2.1	3.1	2.9

Table 2. Results of heavy metal statistical parameters computed using the chemical data.

	Au	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As
Std. Error of Mean	,2	,0	,7	,3	1,1	,1	16,3	1,0	32,9	997,9	,3
Std. Deviation	1,2	,1	3,6	1,5	5,4	,4	81,4	4,8	164,6	4989,4	1,4
Minimum	,8	,4	14,5	3,4	27,0	,1	172,9	12,8	593,0	13300,0	2,0
Maximum	5,2	,8	31,6	11,4	55,0	1,0	578,6	37,3	1435,0	42500,0	8,0
	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg
Std. Error of Mean	,1	2,7	,0	,0	,0	3,4	4318,8	17,8	,5	70,3	2044,9
Std. Deviation	,5	13,6	,2	,1	,2	17,2	21594,2	88,9	2,7	351,3	10224,4
Minimum	1,3	168,0	,1	,1	,1	12,0	101100,0	260,0	9,1	159,0	27000,0
Maximum	3,5	234,0	1,0	,4	,6	118,0	199800,0	770,0	23,3	1985,0	81600,0
	Ba	Al	Na	K	W	Zr	Ce	Sn	Y	Nb	Ta
Std. Error of Mean	5,3	695,3	136,8	176,1	,0	2,1	1,0	,0	,3	,5	,0
Std. Deviation	26,4	3476,3	683,9	880,3	,1	10,3	4,9	,1	1,4	2,6	,2
Minimum	68,0	14100,0	2520,0	2800,0	,2	26,0	15,0	,4	7,7	4,9	,3
Maximum	222,0	31000,0	5980,0	6600,0	,5	78,9	40,0	,8	15,5	17,9	1,1
	Li	Rb	Hf	In	Te	U	Ti	Sc			
Std. Error of Mean	,4	,5	,1	,3	,2	,0	123,5	,3			
Std. Deviation	1,9	2,7	,3	1,6	1,2	,1	617,4	1,3			
Minimum	10,2	12,3	,6	,1	1,9	,7	1130,0	5,0			
Maximum	17,7	23,1	2,0	5,0	5,7	1,0	4190,0	11,0			

Regression

According to the Model Summary in Table 3, the explanatory power of the data of the chemical elements on Al, $R^2 = 100\%$, indicate a high degree of accuracy of chemical analysis. According to the ANOVA, the 24 descriptive variables (Te, Au, Sr, Sn, Mo, Sc, In, Ag, As, Ba, W, Cd, Ni, U, Sb, Cu, Mn, P, Th, Na, Bi, Li, La, and

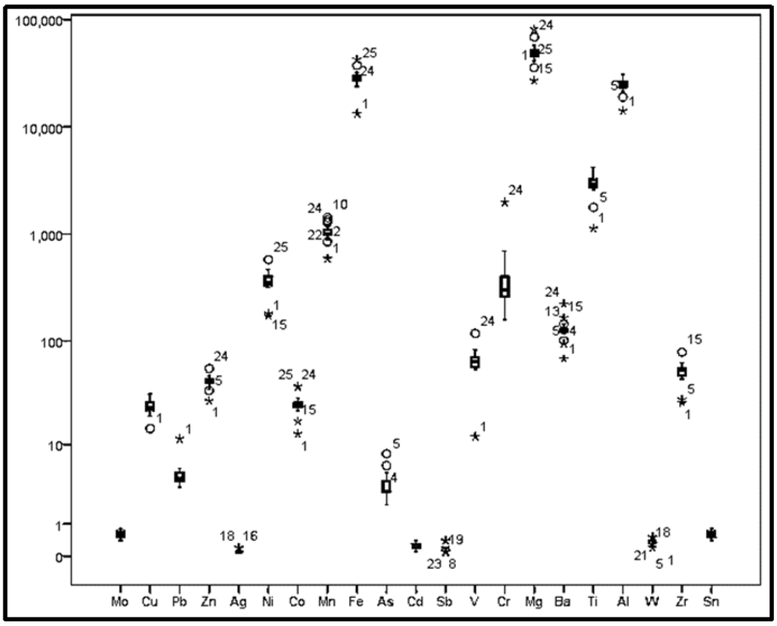

Fig. 2. Concentrations of heavy metals in Bogacayi riverbank sediments.

Table 3. Data regression of sample content of Bogacayi riverbank sediments using model summary (a) and ANOVA (b).

Model Summary (a)						
Model		R	R Square	Adjusted R Square	Std. Error of the Estimate	
1		1.000[a]	1.000			
ANOVA (b)						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	290030400.000	24	12084600.000	.	.[b]
	Residual	.000	0	.		
	Total	290030400.000	24			

a. Dependent Variable: Al

b. Predictors: (Constant), Te, Au, Sr, Sn, Mo, Sc, In, Ag, As, Ba, W, Cd, Ni, U, Sb, Cu, Mn, P, Th, Na, Bi, Li, La, Mg

Mg) on Al have high explanatory power, suggesting that a sufficient number of samples and heavy metal from the study area were used in the analysis [17, 25, 26].

Correlation Analysis

Results of the Pearson correlation coefficient are presented in Table 4. The Pearson correlation coefficient, which is a statistical measurement of the strength of the linear relationships between the variance of the same element (e.g., Al) and another type of element (e.g., Sb) within the samples, indicates a very strong or that a strong positive relationship exists between Cu and Zn, Co, Fe, V, Ti, Al, and W; between Zn and Co, Fe, V, Ba, Ti, Al, W, and Zr; between Ni and Co, Fe and Mg; between Co and Fe, V, Cr, and Mg; between Mn and Fe, V and Ti; between Fe and V, Cr, Mg, Ba, Ti and Al; between Cd and Sb; between V and Cr, Ba, Ti, and W; between Cr and Ba; between Ba and Ti, Al and Zr; between Ti and Al, W, and Zr; between Al and W and Zr; between W and Zr; and between Zr and Sn. There is a moderate positive relationship between Cu and Ni, Ba, Zr, Mn and Mg; between Zn and Mn, Cr and Sn; between Ni and V and Cr; between Co and Mn, Ba, Ti, Cd and Al; between Mn and Cu, Mg, Al, Cd, Cr, Ba, W and Zr; between Fe and Cd, W and Zr; between Cd and Cr and V; between Sb and V, Cr and Sn; between V and Mg, Al and Zr; between Cr and Mg and Ti; between Ba and W and Sn; between Ti and Sn; between Al and Sn; and between W and Sn.

A strong negative relationship exists between Pb and Mn, and Fe and V. A moderate negative relationship exists between Pb and Ni, Co, Ti, Mg, Al and W; and between As and Zr.

Cluster Analysis

Cluster analysis between groups carried out to examine the similarity or homogeneity of the sample reveals six principal cluster groups as shown in Fig. 3. The clusters include samples as follows: Cluster 1 (S 13, 17, and 16), cluster 2 (S 24 and 25), cluster 3 (S 12, 20, 21, 2, 3, 4, 10, 18, and 5), cluster 4 (S 11, 19, 14, 6, 9, 8, 7, 23, and 22), cluster 5 (S 15), and cluster 6 (S 1).

Between the groups, cluster analysis also was carried out on the elements to evaluate the closeness in their relationship to each other as shown in Fig. 4. From the dendrogram, the elements are divided into three cluster groups, cluster 1 (Ti-Ag), cluster 2 (Fe, Al, and Mg – which are the most abundant common elements in the earth's crust) [27], and er 3 (Ca). This Theclusters are is thought to indicate a similar source of the elements.

Factor Anaysis

The results of the principal component analysis (PCA) of the elements as shown in Tables 5 and 6 indicates that the six components retained have a good representation of all the elements. The six components provide 83.949% of the

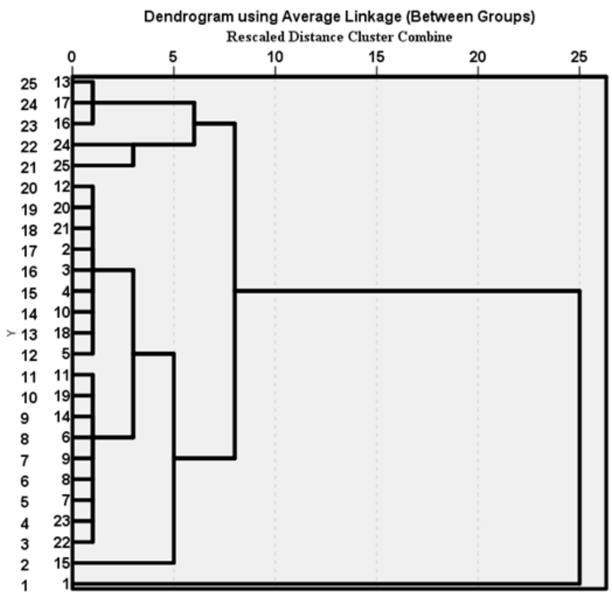

Fig. 3. Hierarchical cluster analysis dendrogram of Bogacayi riverbank samples.

Table 4. Coefficient correlation between the 41 elements in the riverbank sediments of Bogacayi.

	Au	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Th	Sr	Cd	Sb	Bi	V
Au	1																	
Mo	.073	1																
Cu	-.204	.211	1															
Pb	.605**	.387	-.395	1														
Zn	-.290	.185	.664**	-.389	1													
Ag	-.145	.060	-.242	-.180	-.262	1												
Ni	-.287	-.049	.556**	-.585**	.350	.049	1											
Co	-.465*	.091	.682**	-.588**	.614**	-.028	.892**	1										
Mn	-.560**	.026	.416*	-.632**	.543**	.031	.380	.568**	1									
Fe	-.558**	.129	.735**	-.653**	.777**	-.051	.691**	.903**	.782**	1								
As	.108	-.009	.200	-.015	.075	-.190	.178	.168	-.043	.053	1							
U	-.462*	-.147	.115	-.350	.107	.272	.190	.268	.074	.271	-.339	1						
Th	.299	.404*	.013	.650**	.087	-.131	-.468*	-.354	-.355	-.256	-.373	.076	1					
Sr	-.058	-.040	-.486*	-.023	-.360	.451*	-.374	-.397*	.184	-.254	-.437*	.013	-.025	1				
Cd	-.276	-.134	.297	-.335	.386	-.118	.300	.425*	.527**	.466*	.064	-.147	-.428*	.037	1			
Sb	-.178	.187	.283	.037	.384	-.163	-.007	.218	.309	.332	.109	-.224	.021	.014	.610**	1		
Bi	-.043	.062	.104	.119	.247	-.172	-.134	.081	.079	.142	.051	-.217	.023	-.027	.617**	.875**	1	
V	-.546**	.098	.654**	-.625**	.791**	-.056	.509**	.780**	.840**	.944**	.118	.169	-.314	-.203	.535**	.410*	.243	1
Ca	.440*	.004	-.753**	.522**	-.582**	.001	-.611**	-.699**	-.301	-.664**	-.007	-.368	-.012	.512**	-.151	-.128	-.056	-.540**
P	-.314	.063	.419*	-.380	.603**	.090	-.049	.153	.434*	.454*	-.415*	.321	.365	.187	.014	.136	.020	.450*
La	-.337	.057	.488*	-.380	.561**	.008	.021	.193	.410*	.461*	-.443*	.364	.405*	.147	.011	.092	-.016	.410*
Cr	-.358	.196	.347	-.205	.598**	-.153	.431*	.685**	.507**	.702**	.321	.104	-.265	-.278	.472*	.410*	.314	.757**
Mg	-.353	.137	.497*	-.433*	.334	.038	.910**	.911**	.403*	.732**	.079	.218	-.334	-.300	.287	.107	-.007	.535**
Ba	-.408*	.049	.516**	-.373	.780**	-.029	.261	.541**	.579**	.749**	-.060	.388	.093	-.025	.344	.389	.230	.776**
Ti	-.502*	.106	.604**	-.535**	.826**	-.047	.217	.522**	.742**	.804**	-.219	.245	.071	.043	.381	.398*	.236	.832**
Al	-.397*	.122	.693**	-.467*	.680**	.090	.273	.477*	.408*	.647**	-.164	.334	.259	-.197	.075	.179	.089	.575**
Na	-.593**	-.096	.496*	-.697**	.493*	.245	.300	.441*	.464*	.586**	-.200	.499*	-.038	.064	.136	.123	.037	.513**
K	-.329	.094	.578**	-.376	.557**	.114	.160	.289	.316	.467*	-.381	.367	.403*	-.001	.032	.149	.044	.374
W	-.345	.170	.658**	-.435*	.628**	-.136	.212	.351	.514**	.548**	-.148	.304	.182	-.154	.104	.072	-.118	.510**
Zr	-.300	.073	.517**	-.358	.635**	-.025	.098	.253	.435*	.503*	-.417*	.315	.420*	.074	.041	.120	-.023	.442*
Ce	-.351	.048	.507**	-.390	.578**	.063	.064	.218	.405*	.470*	-.426*	.367	.411*	.109	-.008	.083	-.044	.408*
Sn	-.091	.041	.243	.088	.477*	-.114	-.263	-.058	.266	.187	-.235	-.061	.483*	.114	.337	.559**	.412*	.221
Y	-.485*	.026	.480*	-.488*	.623**	.049	.010	.244	.536**	.551**	-.348	.374	.264	.124	.087	.173	.042	.548**
Nb	-.294	.080	.516**	-.370	.665**	-.060	.133	.291	.525**	.551**	-.402*	.263	.356	.143	.153	.179	.015	.502*

Ta	-.292	.095	.545**	-.343	.658**	-.066	.142	.305	.511**	.557**	-.406*	.340	.403*	.108	.120	.185	.006	.493*
Sc	-.426*	-.021	.472*	-.666**	.512**	.008	.498*	.700**	.782**	.801**	.127	.029	-.526**	-.015	.579**	.408*	.281	.813**
Li	-.183	.219	.675**	-.166	.591**	.060	.153	.313	.135	.436*	-.221	.260	.470*	-.311	-.014	.219	.099	.367
Rb	-.080	.171	.519**	-.072	.457*	.012	-.085	.038	.041	.216	-.183	.249	.598**	-.188	-.179	.088	.009	.163
Hf	-.273	.182	.589**	-.355	.635**	.066	.159	.304	.479*	.535**	-.348	.327	.383	.088	.151	.147	-.007	.465*
In	-.099	.364	.284	.074	.218	-.075	-.127	.038	-.054	.067	.041	-.021	.257	-.096	.168	.419*	.467*	.078
Te	.003	-.194	-.057	-.167	.020	-.148	.096	-.023	.116	-.009	.257	-.226	-.265	-.021	.143	-.101	-.144	.048

	V	Ca	P	La	Cr	Mg	Ba	Ti	Al	Na	K	W	Zr	Ce	Sn	Y	Nb	Ta	Sc	Li	Rb	Hf	In	Te
Bi																								
V	1																							
Ca	-.540**	1																						
P	.450*	-.389	1																					
La	.410*	-.493*	.954**	1																				
Cr	.757**	-.206	-.004	-.052	1																			
Mg	.535**	-.533**	-.046	.009	.555**	1																		
Ba	.776**	-.435*	.617**	.604**	.672**	.297	1																	
Ti	.832**	-.509**	.842**	.804**	.457*	.271	.830**	1																
Al	.575**	-.821**	.782**	.833**	.114	.255	.612**	.779**	1															
Na	.513**	-.755**	.662**	.724**	.047	.253	.542**	.681**	.865**	1														
K	.374	-.714**	.843**	.922**	-.098	.109	.533**	.711**	.925**	.827**	1													
W	.510**	-.579**	.690**	.737**	.099	.136	.461*	.687**	.700**	.622**	.748**	1												
Zr	.442*	-.521**	.935**	.976**	.001	.058	.635**	.807**	.831**	.686**	.922**	.776**	1											
Ce	.408*	-.571**	.939**	.985**	-.066	.033	.602**	.789**	.876**	.775**	.957**	.754**	.976**	1										
Sn	.221	-.155	.600**	.566**	-.008	-.239	.440*	.544**	.461*	.289	.558**	.433*	.634**	.581**	1									
Y	.548**	-.528**	.926**	.946**	.068	.005	.672**	.869**	.861**	.815**	.885**	.771**	.926**	.943**	.582**	1								
Nb	.502*	-.445*	.919**	.950**	.097	.099	.691**	.842**	.762**	.627**	.860**	.754**	.981**	.939**	.639**	.892**	1							
Ta	.493*	-.487*	.901**	.945**	.098	.123	.708**	.825**	.777**	.651**	.876**	.778**	.976**	.940**	.647**	.895**	.986**	1						
Sc	.813**	-.375	.231	.201	.543**	.566**	.468*	.629**	.401*	.472*	.189	.297	.204	.186	.120	.368	.257	.251	1					
Li	.367	-.758**	.673**	.716**	-.013	.103	.493*	.595**	.884**	.656**	.871**	.628**	.751**	.777**	.557**	.705**	.661**	.693**	.130	1				
Rb	.163	-.588**	.737**	.791**	-.235	-.161	.377	.502*	.829**	.609**	.878**	.639**	.796**	.831**	.584**	.737**	.703**	.730**	-.080	.892**	1			
Hf	.465*	-.530**	.890**	.934**	.026	.114	.622**	.785**	.822**	.678**	.909**	.793**	.955**	.939**	.632**	.871**	.951**	.956**	.237	.743**	.796**	1		
In	.078	-.322	.183	.223	-.089	-.069	.068	.173	.373	.297	.331	.024	.149	.218	.240	.196	.107	.130	.060	.398*	.425*	.245	1	
Te	.048	.120	-.028	-.003	-.033	-.133	.013	-.049	-.093	-.121	-.093	-.145	.027	-.041	-.025	-.043	.084	.015	-.044	-.148	.023	.045	.081	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

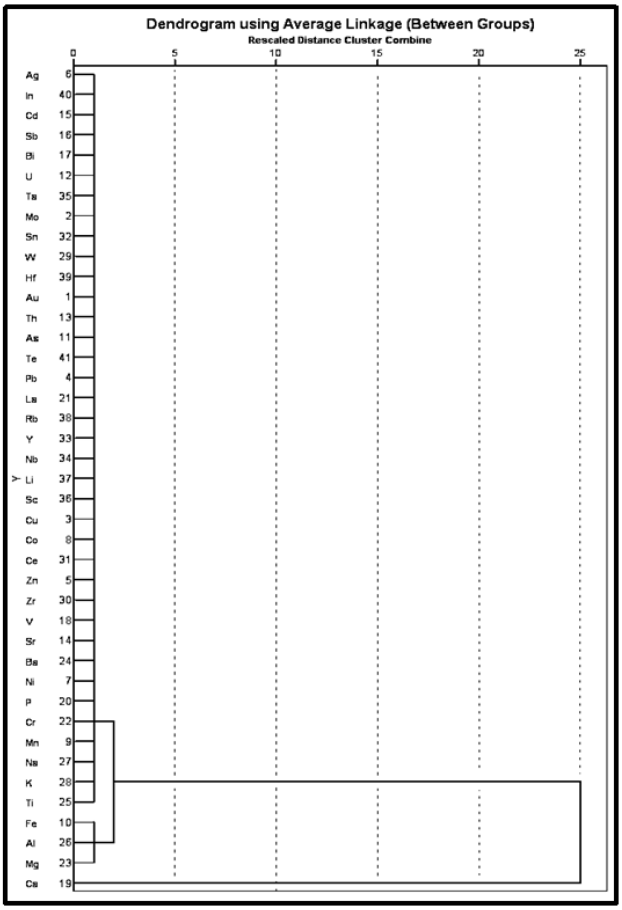

Fig. 4. Elements dendrogram of Bogacayi riverbank sediments.

variables' variance of 41 elements with lowest eigenvalue > 1.5. Ti (0.927), Al (0.919), Zr (0.901), Zn (0.799), W (0.799), Fe (0.788), Ba (0.777), V (0.736), Cu (0.722), and Mn (0.632) show their strongest positive correlational relationship in the first component (Factor 1), and the component explains 42.404% of the total variance with eigenvalue of 17.386. The second component (Factor 2) has the highest indicator values for Co (0.730), Ni (0.697), Mg (0.710), Cr (0.722), Cd (0.546), and As (0.470), and explains 16.906% of the variance with eigenvalue of 6.931. The third component (Factor 3) has the strongest indicator

Table 5. Explanation of total variance on elements in Bogacayi riverbank sediments.

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	17.386	42.404	42.404
2	6.931	16.906	59.310
3	3.510	8.561	67.872
4	2.988	7.289	75.160
5	1.866	4.551	79.711
6	1.738	4.238	83.949

values for Sb (0.782) and Pb (0.499), and explains 8.561% of the variance with eigenvalue of 3.510. Component 4 explains 7.289% of the variance with eigenvalue of 2.988 and Te, Sr and Ca (non heavy metal elements) show their highest values in this component. Component 5 explains 4.551% of the variance with an eigenvalue of 1.866, and Ag (0.545) has it highest indicator value in this component. While component 6 explains 4.238% of the variance with an eigenvalue of 1.738, and Mo (0.527) has its highest indicator value in this component. A visual representation of this can be seen on the scree plot in Fig. 5.

Cluster analysis (CA) is the most suitable method for determining correlation between the variables [28]. Although CA is not significantly different from PCA, PCA is an alternative method used for justification of the results [15, 17].

The mean values of the heavy metal concentration were compared to those of the earth crust [29], sandstone [30], ultrabasic rocks [30] and acceptable limit for Turkey [31] values to evaluate the quantitative level in the beach sand as shown in Table 7.

When compared to the average concentration in the earth crust, average concentration for M (591.52 times), Mn (1.04 times), Cr (4.05 times), Ni (4.91 times), Co (1.26 times), Cd (1.52 times), As (2.07 times), Ag (1.6 times), and Sb (1.04 times) were greater. Compared to the sandstone average concentration, Fe (2.93 times), Mg (7.09 times), Ti (1.97 times), Mn (11.6 times), Cr (11.57 times), Cu (2.65 times), Ni (184.08 times), Co (83.76 times), Zn (2.59 times), Cd (2.53 times), As (3.72 times), Ag (1.24 times), Mo (2.9 times), Sb (2.31 times), and V (3.23 times) had higher average concentrations. Average concentrations of Al (1.24 times), Ti (9.86 times), Cu (2.38 times), Pb (4.66 times), As (3.72 times), Ag (1.87 times), Mo (1.93 times), Sb (2.08 times), Sn (1.14 times), and V (1.61 times) were greater than thoseltrabasic. and wWhen compared to the acceptable limit for Turkey, Cr (4.05 times), o (1.26 times), and Ni (12.27-4.91 times) had greater concentrations.

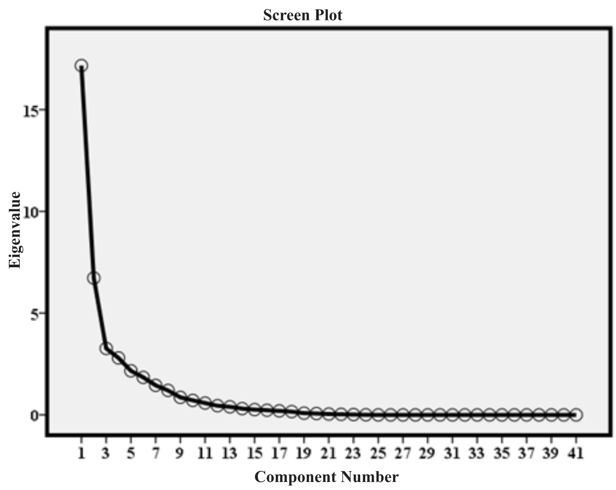

Fig. 5. Screen plot showing visual representation of factor analysis of elements in the Bogacayi riverbank sediments.

Table 6. Result of factor analysis of heavy elements in Bogacayi riverbank sediments (component matrix[a]).

	Component					
	1	2	3	4	5	6
Ti	.927	.104	.129	.236	-.071	.100
Al	.919	-.123	-.051	-.219	.149	-.132
Y	.911	-.272	-.075	.186	-.014	-.050
Ta	.905	-.293	-.006	.104	-.181	.111
Hf	.902	-.310	-.020	.033	-.096	.026
Zr	.901	-.368	-.053	.060	-.156	.027
Ce	.898	-.403	-.121	.047	-.027	-.027
Nb	.895	-.283	.000	.160	-.229	.074
K	.890	-.362	-.087	-.113	.139	-.109
La	.882	-.405	-.091	.105	-.071	-.010
P	.851	-.385	-.042	.200	-.079	.035
Na	.816	-.014	-.290	.035	.332	-.249
Zn	.799	.241	.292	-.122	-.229	.077
W	.799	-.121	-.103	-.106	-.203	.042
Fe	.788	.585	-.015	-.032	-.038	.140
Li	.780	-.301	.099	-.401	.166	-.079
Ba	.777	.196	.154	.155	-.098	.235
V	.736	.589	.112	.116	-.088	.083
Cu	.722	.275	.125	-.454	-.098	-.079
Rb	.704	-.558	.069	-.329	.021	-.197
Mn	.632	.459	-.024	.443	-.152	.066
Co	.570	.730	-.112	-.254	.052	.126
Sn	.552	-.375	.522	.229	-.048	-.067
Sc	.514	.671	.056	.255	.086	-.057
U	.370	-.055	-.517	-.027	.316	.212
Ni	.341	.697	-.333	-.323	-.018	.010
Mg	.330	.710	-.209	-.274	.144	.273
Sb	.298	.239	.782	.201	.286	-.064
Cr	.298	.722	.282	.026	-.103	.398
Cd	.277	.546	.428	.371	.072	-.218
In	.251	-.145	.454	-.233	.451	-.352
Th	.172	-.772	.307	-.296	.012	.364
Bi	.127	.181	.784	.182	.390	-.153
Mo	.108	-.087	.345	-.299	.151	.527
Ag	-.001	-.080	-.424	.239	.545	.099
Te	-.040	.084	-.017	.128	-.514	-.509
Sr	-.082	-.300	-.142	.806	.200	.129
As	-.232	.470	.213	-.326	-.248	-.311
Au	-.497	-.327	.253	-.256	-.283	.056
Pb	-.554	-.463	.499	-.235	-.011	.354
Ca	-.728	-.206	.159	.499	-.231	.214

Extraction Method: Principal Component Analysis.
a. 6 components extracted.

Table 7. Comparison of average concentrations of heavy metals in Bogacayi riverbank sediments to those of the earth crust, sandstone, ultrabasic rock, their acceptable limit in Turkey, and to the beach sand sediments of Kizkalesi, Susanoglu, Iskenderun Bay, Mersin Bay, Silifke, and Alanya-Manavgat.

	Bogacay mean	Earth crust (mg/kg) [29] (B)	Variation of average concentration in Earth crust (fold) (A/B)	Sanstone [30] (C)	Variation of average concentration in Sanstone (fold) (A/C)	Ultrabasic [30] (D)	Variation of average concentration in Ultrabasic (fold) (A/D)	Acceptable limit for Turkey (mg/kg) [31] (E)	Variation of average concentration in TKKY (fold) (A/E)	Kizkalesi Beachsediman Mean [26] (F)	Variation of average concentration in Kizkalesi Beach dune (A/F)	Susanoglu Beach sediman Mean [9] (G)	Variation of average concentration in Susanoglu Beach dune (A/G)	İskenderun Bay Beach sediman Mean [35])(H)	Variation of average concentration in İskenderun Bay (A/H)	Mersin Bay Beach sediman Mean [10] (I)	Variation of average concentration in Mersin Bay (A/I)	Silifke-Alanya Beach sediman Mean [33] (J)	Variation of average concentration in Silifke-Alanya Beach (A/J)	Alanya-Manavgat, Mean [34] (K)	Variation of average concentration in Alanya-Manavgat beach sand (A/K)
Al	**24772.00**	**81000**	**0.31**	**25000**	**0.99**	**20000**	**1.24**	-	-	**8267**	**3.00**	**11924**	**2.08**	**26648**	**0.93**	**30485**	0.81	20908	1.18	12747	1.94
Fe	28704.00	54000	0.53	9800	2.93	94300	0.30	-	-	18803	1.53	13909	2.06	45312	0.63	34078	0.84	15751	1.82	14784	1.94
Mg	49600.00	23000	2.16	7000	7.09	204000	0.24	-	-	34993	1.42	15624	3.17	93500	0.53	42370	1.17	19998	2.48	19038	2.61
Ti	2957.60	5650	0.52	1500	1.97	300	9.86	-	-	813	3.64	736	4.02	2414	1.23	2773	1.07	947	3.12	699	4.23
Mn	1044.36	1000	1.04	90	11.60	1620	0.64	-	-	585	1.79	333	3.14	1166	0.90	7666000	0.00	355	2.94	387	2.70
Cr	404.84	100	4.05	35	11.57	1600	0.25	100.00	4.05	553	0.73	428	0.95	1187	0.34	15124138	0.00	16	24.66	113	3.59
Cu	23.83	50	0.48	9	2.65	10	2.38	50-140	0.48-0.17	10	2.38	12	1.99	16	1.49	158517	0.00	9	2.74	10	2.37
Ni	368.16	75	4.91	2	184.08	2000	0.18	30-75	12.27-4.91	186	1.98	145	2.54	646	0.57	2790917	0.00	15	23.78	19	19.86
Co	25.13	20	1.26	0	83.76	150	0.17	20.00	1.26	28	0.90	21	1.20	43	0.58	281217	0.00	5	4.67	6	4.55
Pb	4.66	13	0.37	7	0.67	1	4.66	50-300	0.09-0.02	4	1.17	5	0.93	15	0.31	102300	0.00	9	0.51	7	0.63
Zn	41.40	70	0.59	16	2.59	50	0.83	150-300	0.28-0.14	19	2.18	17	2.44	89	0.47	525500	0.00	30	1.37	22	1.92
Cd	0.23	0	1.52	0	2.53	1	0.25	1.0-3.0	0.23-0.08	4	0.06	4	0.06	0	0.76	2127	0.00	0	1.63	0	1.68
As	3.72	2	2.07	1	3.72	1	3.72	20.00	0.19	24	0.16	19	0.20	10	0.38	88833	0.00	9	0.41	11	0.35
Ag	0.11	0	1.60	0	1.24	0	1.87	-	-	4	0.03	4	0.03	0	1.12	-	-	0	1.09	-	-
Mo	0.58	2	0.39	0	2.90	0	1.93	10.00	0.06	25	0.02	27	0.02	1	0.83	-	-	1	1.10	2	0.36
Sb	0.21	0	1.04	0	2.31	0	2.08	-	-	5	0.04	5	0.04	0	0.52	-	-	2	0.14	1	0.39
Sn	0.57	3	0.23	1	0.63	1	1.14	20.00	0.03	8	0.07	7	0.08	1	0.47	-	-	1	0.96	0	1.19
V	64.56	110	0.59	20	3.23	40	1.61	-	-	63	1.02	38	1.70	122	0.53	-	-	28	2.30	23	2.79
W	0.39	1	0.33	2	0.25	1	0.51	-	-	7	0.06	6	0.07	1	0.28	-	-	0	1.70	0	1.34

Table 8. Comparison of high anomaly concentrations of some elements in the sample with earth crust, sandstone, ultrabasic rock, and acceptable limits for Turkey.

Sample No	Element under test	Concentration of Elements / ppm (A)	Earth crust (mg/kg) [29] (B)	Variation with average concentration in Earth crust (fold) (A/B)	Sanstone [30] (C)	Variation with average concentration in Sanstone (fold) (A/C)	Ultrabasic [30] (D)	Variation with average concentration in Ultrabasic (fold) (A/D)	Acceptable limit for Turkey (mg/kg) [31] (E)	Variation with average concentration in TKKY (fold) (A/E)
1	Pb	11.4	2.5	4.56	7	1.63	1	11.40	50-300	<1
10	Mn	1435	1000	1.44	90	15.94	1620	0.89	-	-
24	Mn	1350	1000	1.35	90	15.00	1620	0.83	-	-
4	As	6	1.8	3.33	1	6.00	1	6.00	20	0.30
5	As	8	1.8	4.44	1	8.00	1	8.00	20	0.40
16	Ag	0.2	0.07	2.86	0.09	2.22	0.06	3.33	-	-
18	Ag	0.2	0.07	2.86	0.09	2.22	0.06	3.33	-	-
24	Co	37.3	20	1.87	0.3	124.33	150	0.25	20	1.87
25	Co	37	20	1.85	0.3	123.33	150	0.25	20	1.85
24	Fe	42500	54000	0.79	9800	4.34	94300	0.45	-	-
25	Fe	37500	54000	0.69	9800	3.83	94300	0.40	-	-
24	V	118	110	1.07	20	5.90	40	2.95	-	-
24	Cr	1985	100	19.85	35	56.71	1600	1.24	100	19.85
24	Mg	68800	23000	2.99	7000	9.83	204000	0.34	-	-
25	Mg	81600	23000	3.55	7000	11.66	204000	0.40	-	-
25	Ni	578.6	75	7.71	2	289.30	2000	0.29	30-75	19.29-7.71

When the anomaly concentrations of these elements in the mentioned samples were compared to the mean value of the earth crust, Pb (4.56-fold) in S1, Mn (1.44-fold) in S10, Mn (1.35 fold) in S24, As (3.33-fold) in S4, As (4.44-fold) in S5, Ag (2.86-fold) in S16 and S18, Co (1.87-fold) in S24, Co (1.85-fold) in S25, V (1.07-fold) in S24, Cr (19.85-fold) in S24, Mg (2.99-fold) in S24, Mg (3.55-fold) in S25, and Ni (7.71-fold) in S25 have higher concentrations. When compared to their mean values in Sandstone, Pb (1.63-fold) in S1, Mn (15.94-fold) in S10, Mn (15-fold) in S24, As (6-fold) in S4, As (8-fold) in S5, Ag (2.22-fold) in S16 and S18, Zn (3.44-fold) in S24, Co (124.33-fold) in S25, Co (123.33-fold) in S25, Fe (4.34-fold) in S24, Fe (3.83-fold) in S25, V (5.90-fold) in S24, Cr (56.71-fold) in S24, Mg (9.83-fold) in S24, Mg (11.66-fold) in S24, and Ni (289.3-fold) S25. When compared to their mean values in Ultrabasic, Pb (11.4-fold) in S1, As (6-fold) in S4, As (8-fold) in S5, Ag (3.33-fold) in S16 and S18, Zn (1.10-fold) in S24, V (2.95-fold) in S24, and Cr (1.24-fold) in S24. When compared to their acceptable limit for Turkey, Co (1.87-fold) in S24, Co (1.85-fold) in S25, and Cr (19.85-fold) in S24 and Ni (19.29-7.71-fold) are greater. Reference values for Ba and Zr were not available (Table 8).

Discussion

From the comparison in Table 8, it is worth noting the very high anomaly concentration of Cr in sample 24 is 19.85 times and Ni in sample 25 is 19.29-7.71 times higher than the acceptable limits in Turkey. These proportions are very high and confirm the need for a close study of heavy elements around the localities of samples 24 and 25, alongside Co, which is 1.87- and 1.85-fold greater than the acceptable limit for Turkey in samples 24 and 25, respectively. The acceptable Turish limits for (Mn, Ag, Fe, V, and Mg) were not available.

According to the box plot analyzed above, samples 24 and 25 have high anomalous concentrations of some heavy metal elements that are both grouped in the second cluster in the Hierarchical Cluster analysis. Some samples in other clusters do have anomalies in identical heavy metal elements such as cluster 3 (S 4 and 5) with high As anomaly and cluster 4 (S 8, 19, and 23) with low Sb anomaly. This is thought to be an indicator to confirm the similarities of the samples.

Both the coefficient correlation and PCA confirm the negative relationship of Pb and As with the other elements under investigation (Mg, Fe, Al, Ti, Mn, Cr, Ni, Ba, V, Zr, Zn, Co, Cu, Mo, W, Cd, Sb, and Ag) in Component 1. This is further confirmed by the box plot. In sample 1, Pb has an anomalous high concentration whereas there's a corresponding decrease in Cu, Zn, Ni, Co, Mn, Fe, V, Ba, Ti, Al, W, and Zr in the same sample. Similarly, in sample 5, as As increases, Zn, Ba, Ti, W, Zr, and Al decrease. Mg, Fe, Al, Ti, Mn, Cr, Ni, Ba, V, Zr, Zn, Co, Cu, Mo, W, Cd, and Sb show a positive relationship with each other. From this analysis, metals that have strong positive correlation are thought to be of the same source, while those of strong negative correlations are thought to be of a different origin.

According to [9, 32-35], component 1 is usually allocated to be the geogenic source, component 2 the anthropogenic activities related, and component 3 the anthropogenic source. Most of the Ti, Al, Zr, Zn, W, Ba, and Cu, and the majority of Fe, V, MN, and Sn are thought to have come from a natural source. Most of the Ni, Mg, Cr, and As, and the majority of the Co and Cd are thought to have resulted from both natural and anthropogenic-related activities, implying no clear distinction of a particular source by the PCA. Most of the Sb, Mo, and Pb are believed to have come from anthropogenic activities. Though the majority of the Fe, V, MN, and Sn are thought to have come from a natural source, and Co and Cd from natural and anthropogenic-related activities, a considerable quantity of the elements are also thought to have been contributed from other sources such as: natural (Co), natural and anthropogenic-related activities (Fe, V, MN, and Sn), and anthropogenic activities (Sn and Cd).

The heavy metal elements (Sb, Mo, and Pb) that are well loaded in component 3 do not show a good correlational relationship according to Pearson's correlation, whereas those with high values (well loaded) in the first component demonstrate either a strong or stronger correlational relationship among themselves, and to some in the second component such as Fe, V, and Mn, according to Pearson's correlation. Base on this, such elements are thought to have a possible related source.

Samples 24 (Zn, Co, Mn, Fe, V, Cr, Mg, and Ba) and 25 (Ni, Co, Fe, and Mg) contain several numbers of heavy metals, each showing high anomalous concentrations, that are related to anthropogenic sources based on the PCA (Table 6).

Conclusion

From the results and discussion above, it can be concluded that the abundance of the elements under investigation are as follows: Mg > Fe > Al > Ti > Mn > Cr > Ni > Ba > V > Zr > Zn > Co > Cu > Pb > As > Mo > W > Cd > Sb > Ag.

A sufficient number of samples and elements from the study area were used in this analysis based on the high explanatory power R^2 = 100.00% of 24 descriptive elements on Al, according to the ANOVA model summary.

Anthropogenic activities contributed most of the Sb, Mo, and Pb, and led to an increase in the quantities of elements such as Fe, V, Mn, Co, Ni, Mg, Cr, and As.

Samples 24 (Zn, Co, Mn, Fe, V, Cr, Mg, and Ba) and 25 (Ni, Co, Fe, and Mg) contain several numbers of heavy metals, each showing high anomalous concentrations that are related to anthropogenic sources. The concentration of Cr in sample 24 is 19.85 times and Ni in sample 25 is 19.29-7.71 times higher than the acceptable limits for Turkey. These proportions are very high and confirm the need for a close study of heavy elements around the localities of samples 24 and 25; alongside Co this is 1.87- and 1.85-fold greater than the acceptable limits for Turkey in samples 24 and 25, respectively.

In comparison to the average concentration in the earth's crust, average concentrations for Mg (2.16 times), Mn (1.04 times), Cr (4.05 times), NI (4.91 times), Co (1.26 times), Cd (1.52 times), As (2.07 times), Ag (1.6 times), and Sb (1.04 times) were greater. Compared to the sandstone average concentration, Fe (2.93 times), Mg (7.09 times), Ti (1.97 times), Mn (11.6 times), Cr (11.57 times), Cu (2.65 times), Ni (184.08 times), Co (83.76 times), Zn (2.59 times), Cd (2.53 times), As (3.72 times), Ag (1.24 times), Mo (2.9 times), Sb (2.31 times), and V (3.23 times) had higher average concentrations. Average concentrations of Al (1.24 times), Ti (9.86 times), Cu (2.38 times), Pb (4.66 times), As (3.72 times), Ag (1.87 times), Mo (1.93 times), Sb (2.08 times), Sn (1.14 times), and V (1.61 times) were greater than those of ultrabasic, and when compared to the acceptable limit for Turkey, Cr (4.05 times), Co (1.26 times), and Ni (12.27-4.91 times) had greater concentrations.

Six (6) factors were retained by factor analysis and they represent a very high proportion of 83.949% of the variables' variance of analyzed elements.

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