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Application of multivariate statistical approach to identify heavy metal sources in bottom soil of the Seyhan River (Adana), Turkey

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Abstract In this study, freshly deposited soils were sampled from the Seyhan River (Turkey) from the exit of the Seyhan Dam to the Adana exit. Heavy metal contents were measured with X-ray fluorescence spectrometer. Multivariate statistical approach is used to identify the sources of heavy metals and other elements in soil samples. Considering the size of anomalies, metals are ranked as Co>Pb>Cr>Zn>Al. Based on the hierarchical cluster analysis results, three clusters were observed. P, Mg, Ti, Fe, Ca, Na, K, Al, Si, and Nb form the first cluster, Zn, Sr, Pb, and Cr associated as the second cluster, and Ba and Co form the third cluster. Three factors computed from principal component analysis are explained with a cumulative variance of 95%. The first factor is defined with "high background lithogenic factor" Co, the second factor with "local industrial factor" Pb, Cr, Ba, and Mg, and the third factor with "natural factor" Cr and Pb.

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Introduction

In the last century, the demand to water has been greatly increased. However, waters have not been sufficiently protected from the harmful materials. It is very important to determine heavy metal contents in wetlands. Some metals may show toxic effect and move via food chain. Heavy metal accumulation in environment has been attracting more and more attention of researchers and community because of their toxicity in the environment and subsequent accumulation in aquatic habitats (Facchinelli et al. 2001; Loska and Wiechula 2003; Upadhyay et al. 2006; Zhou et al. 2008). There are numerous routine studies on heavy metal contents in river soils and their sources (lithogenic or geogenic and anthropogenic sources). Chemical leaching of bedrocks, water drainage basins, and runoff from banks (Zhou et al. 2008); discharge of urban and industrial wastewater, combustion of fossil fuels, mining and smelting operations, processing and manufacturing industries, waste disposal including dumping, etc. (Klavins et al. 2000; Pardo et al. 1990; Yu et al. 2001; Yalcin et al. 2007, 2008); and the natural input of several heavy metals to soils due to pedogenesis

(Facchinelli et al. 2001) are the primary sources for the lithogenic and anthropogenic contribution of pollutions. It is subject to a multitude of anthropogenic impacts attributable to accelerated population growth (seven million) and development of small-scale and large-scale industries, expansion of harbors and tourism-related activities in the coastal zone, disposal of municipal wastes and industrial wastes, and numerous recreational and commercial activities that not only degrade the quality of coastal water but also pose a serious health hazard to marine biota and human (Capuzzo et al. 1985; Rama Devi et al. 1996; Williams 1996; Tran et al. 2002; Beiras et al. 2003; Shanmugam et al. 2007).

Methods commonly used for distinguishing between anthropogenic and geogenic sources of the potential toxic elements include element speciation, profile distribution, spatial distribution, information such as parent rock composition, and known anthropogenic loads (Boruvka et al. 2005; Zhou et al. 2008). Multivariable statistic analysis provides an alternative method to identify pollution sources, to apportion natural versus anthropogenic contribution and to give indications about transport processes and environmental conditions. Principal component analysis (PCA) and derivative methods have been widely used in geochemical applications to reach the objective (Boruvka et al. 2005; Facchinelli et al. 2001; Filgueiras et al. 2004; Manta et al. 2002; Qu and Kelderman 2001; Wang et al. 2005; Yu et al. 2000; Yalcin et al. 2008). Clustering analysis (CA) is often coupled to PCA to check results and provide grouping of individual parameters and variables (Facchinelli et al. 2001; Tariq et al. 2006; Wang et al. 2005). PCA in conjunction with CA provides a means for ensuring proper source identification for a given metal distribution pattern in soils/sediment (Jolliffe 1986; Upadhyay et al. 2006).

The Seyhan River flows throughout the city of Adana. Adana is the most developed and most rapidly growing industrial city in the southern part of Turkey. The study area where both mollase processes and anthropogenic factors are observed along the river bank was selected as an ideal location. The main objective of this study is to determine the average level and distribution of some heavy metals (Ti, Fe, Mn, Zn, Co, Nb, Ni, Pb, and Cr) in Seyhan river bottom soils in the city of Adana. Furthermore, this study seeks to define their natural or anthropogenic source and to identify their local or exotic source that cause contamination in Seyhan river bottom soils.

The study area

The study area with coordinates of 36° 33′–39° 12′ N and 34° 24′–36° 56′ E is located in the Seyhan River basin in the territories of Adana city at south of Turkey (Fig. 1a). Topographically, Adana and its surroundings are composed of two landforms: mountainous and plain areas. The northwest, north, and northeastern parts of the city are surrounded by the Central Taurus Mountains while the southern part hosts plains and flat areas. The reception basin of Seyhan River is formed from Middle Taurus Mountain limestones and ultrabasic rock (Pozantı-Karasantı ophiolitic massive). The Pozantı-Karsantı ophiolitic massive is formed from metamorphic mélange, metamorphic slice, and ophiolitic rocks (Parlak 2000) Carbonate-hosted Pb–Zn deposits are common in the Taurus Mountain Belt, which runs from west to east in the south of Turkey and is geographically subdivided into three parts: the western, the middle, and the eastern Taurus Mountains. The boundary between the middle and the eastern part is known as Aladaglar or the Zamanti Pb–Zn Province (Koptagel et al. 2007). The Seyhan River cuts throughout the city of Adana. River is divided into two sections by the Seyhan Dam constructed at the central part.

The study area is located in the downstream part of the Seyhan River where industrialization and urbanization are intense (Fig. 1b). This area has an elevation of 25 m above sea level and has a typical Mediterranean climate (semi-arid) with an average 600-mm rainfall (Irvem et al. 2006). Annual average temperatures in the upper and lower basin are 8°C and 18°C, respectively (Topaloglu 1999; Anonymous 1974). The lower Seyhan River to which contaminated waters are discharged has a length of 94 km from the dam to the Mediterranean Sea (Yuceer and Inkayali 2004; Fig. 1c).

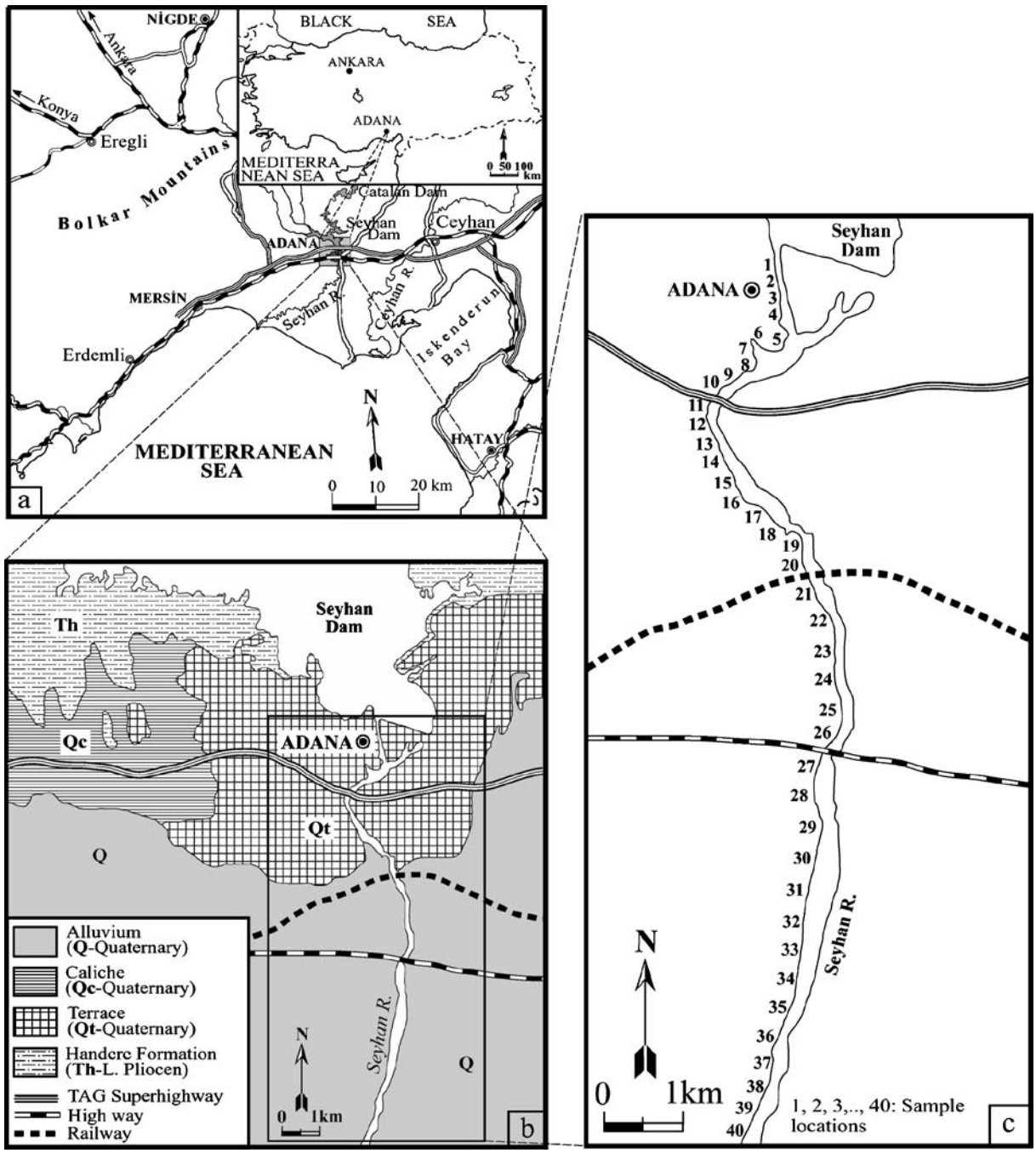


Fig. 1 Sketch map of study area (**a**), geological map (modified from Cobanoglu 2005; **b**), and sampling sites (**c**) from the Seyhan River in Adana City

Regional geology

In the southern part of the Adana Basin, old Quaternary terrace–caliche layers and early Miocene and Pliocene formations can be seen in undisturbed positions. The geological structures (Cobanoglu 2005) are comprised by three formations (Fig. 1b).

Handere formation

This formation was first named by Schmidt (1961). It is composed of gray-colored gravel, gravel sandstone, sandstone, siltstone, and cross-bedded claystone-marl with lensed gypsy forms. Handere formation is out of the study area.

Terrace–caliche

There are two kinds of terrace materials in the Adana Basin. The first one is the alluviums covered with terraces and the second one is the Çakıt stream outside of the study area. It shows changeable parallel distributions as wide and also as long as in the Seyhan river bed. The terrace–caliche formation changes from gravel sandstones to gray-colored cross-layers with gravel-coarse sandstones at the bottom and continue with gravels in block forms at the top.

Alluvial deposits

In the region, the old alluviums bed forming Adana plain and young alluviums developed in the riverbeds (Yetis and Demirkol 1986; Sivrikaya et al. 2008). Terrace and recent alluvium deposits are of aquifer character. In the study area, groundwater is found at depths between 2 and 40 m. Groundwater level gets shallower from north to south and from east to west and even is manifested at the surface (Cobanoglu 2005).

Materials and methods

Sampling

A total of 40 topsoil samples (1–5-cm-deep top layer) from the bottom of lower Seyhan River were collected manually with a stainless steel spatula at May 2007 (Fig. 1c). Samples collected from the lower Seyhan River with a spacing of about 300 m were cleaned manually for foreign matter and carried within zip-mouthed polyvinylchloride packages. In order to minimize the contamination from plastic bags, samples were washed with 6 mol l^{-1} HNO_3 and rinsed with distilled water and heated at 70°C. Coordinates of samples were determined with GPS-12CX (Garmin brand) and marked on 1/25,000 scaled topographic map. In order to reduce the possibility of random influence of urban waste in areas of polluted discharge, bulk sample soils were collected from three different points and pooled.

Chemical analyses

Following the drying of soil samples at open air, they were homogenized in an agate mortar and pulverized to >2-mm grain size. The mortar was washed with 6 mol l^{-1} HNO_3 and rinsed with distilled water and dried before each sample process. Grinded samples were heated at 90°C for 12 h. Four-gram samples were then prepared for chemical analysis. Prior to analysis, all the samples were transformed to double-sided film tablets in 32-mm diameter and analyzed for their heavy metal and other element contents (K, Ti, P, Na, Mg, Fe, Ca, Si, Al, Zn, Ba, Co, Nb, Rib, Sr, Ni, Pb, Cr) with Spectro Xepos Bechtop X-ray fluorescence spectrometer. Detection System is a drift detector with Peltier cooling, energy resolution full width at half maximum < 170 eV, measured for the Mn Kα line with an input count vote of 10,000 pulses, microprocessor-controlled detector, and electronics. Results are given as milligram per kilogram.

Statistical analysis

First, using the raw data of chemical analyses, simple statistical processes were carried out with the use of MS Excel program and heavy metal ratios were evaluated. However, the data are not sufficient to indicate if their source has a natural or anthropogenic origin. Since surface soils/sediments show partial differences with depth, their explanation requires geochemical evaluations (Facchinelli et al. 2001). Multivariate data analysis techniques can be used to assess the complex eco-toxicological processes by showing the relationship and interdependency among the variables and their relative weights (Bartolomeo et al. 2004). Therefore, multivariate data analysis techniques were utilized for geochemical evaluations (PCA and CA). PCA is a multivariate method mainly used

Table 1 Statistical summary in the Seyhan River and abundance of elements in soil, earth crust, and their acceptable limits

	Seyhan River					Soils (Wedepohl 1969–1978; C)	Variation of average concentration in soil (fold; A/C)	Variation of maximum concentration in soil (fold; B/C)	Earth crust (mg/kg; Krauskopf 1979; D)	Variation of average concentration in earth crust (fold; A/D)	Acceptable limit for Turkey (mg/kg; TKKY 2005; E)	Variation of average concentration in TKKY (fold; A/E)
	Mean (A)	Minimum	Maximum (B)	SD	Skewness							
Fe	1.6574	0.47	1.93	0.23977	−3.442	2.1×10^4	–	–	5.4×10^4	–	–	–
Pb	91.4250	10.00	200.00	51.62482	0.880	17	5.37	11.76	12.5	7.3	50	1.83
Zn	70.7000	29.00	130.00	19.62816	0.063	36	1.96	3.6	70	1.01	150	−0.47
Cr	136.1000	101.00	199.00	34.45830	0.799	43	3.16	4.62	100	1.36	100	1.36
Co	354.2750	75.00	498.00	139.52814	−0.787	10	35.42	49.8	20	17.714	20	17.7
Ti	0.7913	0.60	1.06	0.10248	0.312	–	–	–	5	−0.15	–	–
Al	6.2145	2.95	7.17	0.98147	−2.147	14.7 (Brooks 1972)	0.42	0.48	8.1×10^4	−0.76	–	–
Si	28.0864	24.87	31.13	2.18031	−0.142	–	–	–	28.2×10^4	−0.99	–	–
Ca	1.3305	0.81	2.85	0.44029	1.530	–	–	–	4.1×10^4	−0.32	–	–
Mg	0.4249	0.00	2.27	0.40150	2.433	–	–	–	2.3×10^4	−0.18	–	–
Na	2.4128	0.76	3.73	0.62148	−0.451	–	–	–	2.4×10^4	1.005	125	−0.02
K	4.5408	3.77	5.43	0.36593	0.571	–	–	–	2.1×10^4	2.16	–	–
P	0.1712	0.06	0.24	0.03161	−0.632	–	–	–	1.1	−0.15	–	–
Ba	394.7250	302.00	498.00	54.41671	−0.059	–	–	–	500	−0.8	200	1.97
Nb	43.1000	3.00	67.00	18.92333	−0.309	–	–	–	20	2.155	–	–
Sr	79.7000	63.00	117.00	12.39355	1.043	–	–	–	375	−0.2	–	–

Sediment (mg/kg, $n = 40$); Valid N (listwise) 40

for data reduction (Zhou et al. 2008). PCA aims at finding a few components that explain the major variation within the data (Danielsson et al. 1999). In our PCA, factors which represent more than 85% of the total variation are chosen (Facchinelli et al. 2001). PCA analysis is performed on the correlation or covariance matrix between the variables, followed by varimax rotation in order to make the components more interpretable (Jolliffe 1986). CA can be used for grouping of objects with similar kind (Yalcin et al. 2007).

In order to determine the variations in heavy metal contents in the lower Seyhan River soils and their natural or anthropogenic sources, "multivariate data analysis techniques" were utilized with the use of SPSS software. Relevant maps were constructed using the Corel Draw.

Results and discussion

Metal concentration

The Seyhan River flowing through Adana city is polluted by industrial wastes and its waters are intensely used for agriculture in the basin. Starting from the Seyhan Dam where samples are collected, the Seyhan River flows through its natural channel and it is in close contact with the soil. The river is cut by two small sets which were built for irrigation and inland lake. In the period when river water is cut down from the dam and there were no inland lake waters, samples were systematically collected from the river bed.

Concentrations of heavy metals and other elements (Fe, Pb, Zn, Cr, Co, Al, Si, Ca, Mg,

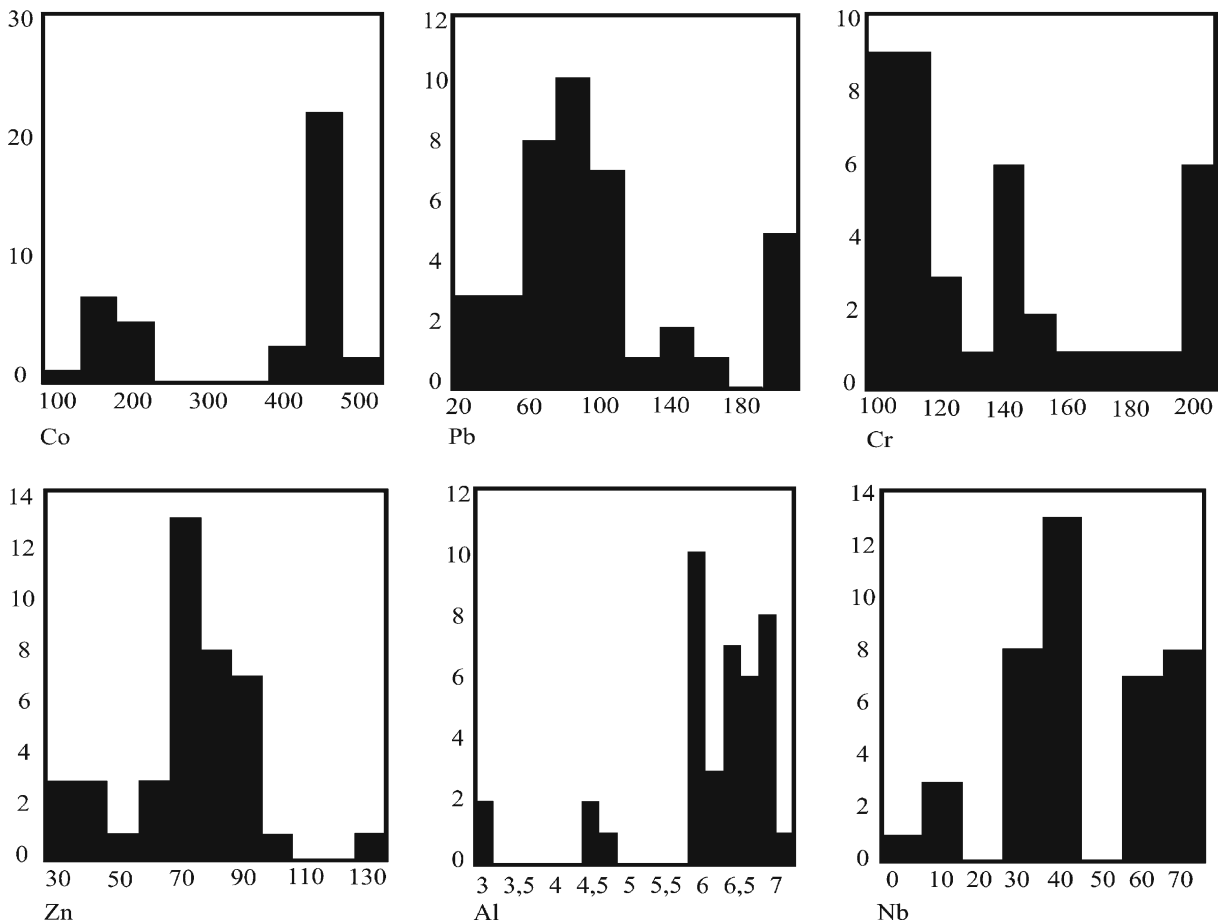


Fig. 2 Frequency histograms of Co, Pb, Cr, Zn, Al, and Nb in bottom soils of the Seyhan River (Adana)

Na, K, P, Ba, Nb, and Sr) in soil samples are given in Table 1. Their respective concentrations are 0.47–1.93, 10.00–200.00, 29.00–130.00, 101.00–199.00, 75.00–498.00, 0.60–1.06, 2.95–7.17, 24.87–31.13, 0.81–2.85, 0.00–2.27, 0.76–3.73, 3.77–5.43, 0.06–0.24, 302.00–498.00, 3.00–67.00, and 63.00–117.00 mg/kg. Arithmetical averages of metals are found as 1.65, 91.42, 70.7, 136.1, 354.27, 0.79, 6.21, 28.08, 1.33, 0.42, 2.41, 4.54, 0.17, 394.72, 43.1, and 79.7 mg/kg, respectively. Based on the results of chemical analyses, maximum concentrations of heavy metals and other elements exceed acceptable limits of the abundance in the soil (Pb, Zn, Cr, Co, Al), abundance in the earth crust (Pb, Zn, Cr, Co, Na, K, Nb), and the Turkish Soil Contamination Control Regulation (Pb, Cr, Ba; Wedepohl 1969–1978; Brooks 1972; Krauskopf 1979; TKKY 2005). Considering their concentration ranges, metals are ranked as Co>Pb>Cr>Zn>Al (Table 1).

Examination of frequency histograms of anomalous elements reveals that there are some differences in heavy metal contents (Fig. 2). Particularly, Cr and Pb show wide distributions in the histograms. Cr, for example, has the highest concentration in the first part of histogram and decreases to the central section and stays stable and then tends to increase in the last section. Pb is more abundant in the first part of histogram and tends to increase in the final section. In the second part of the histogram, it decreases before the final section. In general, it shows similarities to Cr. Zn is concentrated in the central part and decreased in the final section. Nb content is very low in the first part of histogram and concentrated in the central part and observed in the last part. Al is significantly concentrated in the last part. Although Co is observed with a little extent in the first part, it is concentrated in the last part.

Interelement relationships

With reference to the correlation matrix (Table 2) which indicates the correlation among different elements, the positive high relationship (r^2 = less than 0.10) on soil vs. contaminated elements (between Cr and Pb, Cr and Mg; between Na and K; between Co and Na; between Pb and Mg) and the positive low relationship (r^2 = less than 0.50) on soil vs. contaminated elements (between Pb and K, between Pb and Al, between Pb and Ba) indicates the presence of these elements on soil layers. The association of these elements (Cr, Pb, Mg) is absorbed from local industrial factor on soil. The above correlation of elements clearly indicates that they are derived from different sources or industrial input/activities of pollution in the study area. The negative high relationship

Table 2 Coefficient correlation between the elements on soils in the Seyhan River

	K	Ti	P	Na	Mg	Fe	Ca	Si	Al	Zn	Ba	Co	Nb	Sr	Pb	Cr
K	1															
Ti	−0.020	1														
P	0.238	0.222	1													
Na	−0.582[a]	0.011	−0.092	1												
Mg	0.223	−0.023	0.105	−0.353[b]	1											
Fe	0.089	0.239	−0.113	−0.186	0.081	1										
Ca	−0.096	0.081	0.307	0.103	−0.186	0.102	1									
Si	−0.121	0.005	0.017	−0.017	0.014	−0.043	0.231	1								
Al	0.194	0.016	−0.199	−0.131	−0.001	0.045	0.091	−0.050	1							
Zn	0.027	0.023	0.017	−0.086	0.188	−0.026	−0.084	0.281	−0.112	1						
Ba	0.173	−0.314[b]	−0.188	−0.134	0.281	0.081	−0.345[b]	−0.162	0.082	0.219	1					
Co	0.299	0.050	0.126	−0.471[a]	0.123	0.175	0.254	0.158	0.252	0.198	−0.062	1				
Nb	0.215	−0.182	−0.025	−0.216	0.166	−0.050	−0.179	−0.010	0.199	0.294	0.253	0.239	1			
Sr	0.107	−0.118	0.035	0.146	0.031	−0.021	0.055	−0.166	0.276	0.008	0.230	−0.175	0.180	1		
Pb	0.313[b]	−0.100	−0.025	−0.359[b]	0.445[a]	0.202	−0.109	−0.211	0.378[b]	0.131	0.337[b]	0.167	0.262	0.235	1	
Cr	0.248	−0.019	−0.100	−0.386[b]	0.409[a]	0.036	−0.242	−0.139	0.150	0.132	0.206	0.111	0.156	0.047	0.702[a]	1

[a]Correlation is significant at the 0.01 level (two-tailed)
[b]Correlation is significant at the 0.05 level (two-tailed)

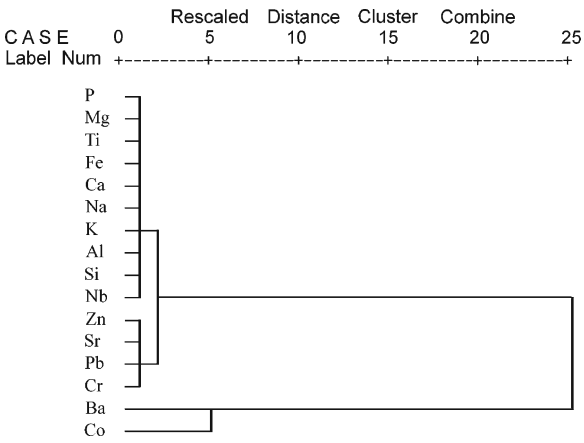


Fig. 3 Hierarchical cluster analysis dendogram for soil samples from Seyhan River

(r^2 = less than 0.10) on soil contaminated elements (between Na and K; between Co and Na) and the negative low relationship (r^2 = less than 0.50) on soil contaminated elements (between Ba and Ti, between Ba and Ca; between Pb and Na; between Cr and Na) indicate the presence of these elements on soil layers,

The positive association between Cr and Pb and between Cr and Mg (r^2 = less than 0.10) indicates that they are anthropogenic and are mainly due to the effluent or industrial input/activities and come from different sources of pollution in the study area.

Hierarchical cluster analysis

Three clusters are observed from the dendrograms (Fig. 3) for the metals and other elements in topsoil with significant linkage distance, indicating relatively high independency for each cluster. For topsoil samples, P, Mg, Ti, Fe, Ca, Na, K, Al, Si, and Nb are very well correlated with each other and form a cluster which association with Zn, Sr, Pb and Cr is shown in Fig. 3. Ba–Co cluster joined only much later. P, Mg, Ti, Fe, Ca, Na, K, Al, Si, and Nb form the first cluster; Zn, Sr, Pb, and Cr associated as the second cluster and Ba and Co form the third cluster.

Principal component analysis

PCA was applied to chemical analysis data on soils from the Seyhan river bed. To quantitatively evaluate the clustering behavior, PCA with varimax normalization (PCA-V) is applied, and the results are given in Table 3 for soil samples. Three factors originate with a cumulative variance of 95% for the topsoil samples.

The overwhelming 72% of total variance is contributed by PC1, showing higher loadings for

Table 3 Total variance explained matrixes (three factors selected)

Component	Initial eigenvalues (a)			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	19,626.368	72.195	72.195	19,626.368	72.195	72.195
2	4,235.041	15.578	87.773	4,235.041	15.578	87.773
3	2,067.723	7.606	95.379	2,067.723	7.606	95.379
4	481.656	1.772	97.151			
5	392.107	1.442	98.593			
6	254.040	0.934	99.527			
7	123.250	0.453	99.981			
8	3.879	0.014	99.995			
9	0.678	0.002	99.998			
10	0.289	0.001	99.999			
11	0.129	0.000	99.999			
12	0.106	0.000	100.000			
13	0.070	0.000	100.000			
14	0.050	0.000	100.000			
15	0.008	2.915E-05	100.000			
16	0.001	2.171E-06	100.000			

Extraction method: principal component analysis

Table 4 Component matrixes (three factors selected)

	Rescaled Component		
	1	2	3
K	0.306	0.280	0.045
Ti	0.049	−0.238	0.205
P	0.124	−0.148	0.097
Na	−0.480	−0.288	−0.112
Mg	0.137	0.457	0.108
Fe	0.178	0.136	0.028
Ca	0.249	−0.323	0.122
Si	0.153	−0.238	−0.065
Al	0.261	0.250	0.150
Zn	0.204	0.219	−0.149
Ba	−0.058	0.780	−0.621
Co	0.999	−0.023	−0.022
Nb	0.248	0.313	−0.092
Sr	−0.169	0.291	−0.016
Pb	0.197	0.831	0.474
Cr	0.137	0.660	0.508

Extraction method: principal component analysis

Co, evidencing the main metal contribution coming from the influence of widespread regional high Co background anomaly (Cheng et al. 2005a; Table 4). The high Cd background anomaly in sediment and soil is distributed along with both the riversides of the Yangtze River (Cheng et al. 2005a). The source of Cd could be from weathering of Co-rich bedrocks accompanied by anthropogenic input at some local area (Cheng et al. 2005b), whereas the specific forming mechanism and ecological effect of this anomaly have not yet been carefully revealed (Ma et al. 2004). This factor could be identified as the "high background lithogenic factor".

PC2 loaded by Pb, Ba, Cr, and Mg indicates the likely influence from local industrial effluent and these PCs could be considered to be dominated by the "local industrial factor" (Table 4). The producing progress of industrials, accompanied by the drainage of untreated effluent like acid wash and plating liquid, results in the tremendous enrichment of Pb, Ba, Cr, and Mg in the polluted soils and could be the factor that control these two PCs. Pb and Cr may be controlled by different industrial sources.

PC3 with high contribution of Cr and Pb accounting for 7% of the total variance is controlled by the "natural factor" of the lithogenic process during weathering progress of natural parent materials such as rocks and soils (Table 4). The mean concentration of the two elements in topsoil samples as well as the polluted soils was not substantially higher or even a bit lower than the background value (Table 1), indicating that these metals were not influenced by anthropogenic factors.

Pb and Cr emerges at both PC2 and PC3, showing that this metal has a mixed source. Although many of the same control factors are observed in soil samples, their relative importance is different. For example, the "high background lithogenic factor" stands as the first most important factor (PC1) in the third place for soils. The "local industrial impacts factor" is a more significant controlling factor for soil samples (PC2) than for soil samples (PC3).

This would be presumably due to the characteristic that heavy metals resulting from anthropogenic contamination are either associated with the soils, adsorbed on hydrous oxides, or precipitated as hydroxide, sulfides, and carbonates (Forstner 1985). Anthropogenic released metals (Cr and Pb) tend to reside in solid phase rather than dissolved phase in soil interface.

Conclusions

According to the results of chemical analyses, concentrations of heavy metals such as Pb, Zn, Cr, Co, and Al exceed acceptable limits of the abundance in the soil; concentrations of Pb, Zn, Cr, Co, and Nb are anomalous with respect to their abundance in the earth crust and concentrations of Pb and Cr exceed acceptable limits of the Turkish Soil Contamination Control Regulation. Variations of these metals are ranked in the order of their abundance as Co>Pb>Cr>Zn>Al.

Based on frequency histograms, Cr concentrations are mostly derived from nearby areas; however, Cr inputs from intermediate to distal areas should not also be discarded. Pb is observed to be generally originated from close by to intermediate distances and from distal sources with a lesser extent. Pb and Cr show similar source characteristics. Zn originates from nearby to intermediate

distances, Al from distal sources, Nb from nearby to intermediate distances, and Co from nearby to distant sources. In this respect, heavy metal sources impacting the study area are thought to be derived from nearby/intermediate/distant sources. Quaternary alluvium deposits in the area are underlain by terrace–caliche units.

Alluvial deposits, the old alluviums bed forming Adana plain and young alluvions developed in riverbeds, exist. Terrace–caliche changes from gravel sandstones to gray-colored cross-layers with gravel-coarse sandstones at the bottom and continue with gravels in block forms at the top. In addition, there is no mining site in the vicinity of study area.

Multivariable statistic approaches (PCA-V and CA) are used as a tool to distinguish sources of heavy metal elements in Seyhan River (Adana) bottom soil in Adana city. Natural and anthropogenic inputs of heavy metals in the soil samples are distinguished. Present research suggests that:

Distributions of Co in soil all are controlled by the "high background lithogenic factor", that means, they are regional and affected by input from upstream areas; Cr and Pb representing "natural factor" of the lithogenic process seem to be originated from parent material in soils. Potential origin of these heavy metals consists of the carbonates that form the Taurus Mountain which is within the reception area of Seyhan River and the ultrabasic (Pozantı-Karsantı ophiolite) rocks.

Pb, Ba, Cr, and Mg in soil samples have a majority of contribution from the industrial extraction of wastewater, which can be concluded as the "local industrial factor"; the pattern of distribution for Cr and Pb is affected by a mixed source. The result indicates that the element clustering behavior is similar in soil samples, revealing that the metal contents in the some kinds of samples are controlled by the same sources. However, the relative importance of each of the factors of soil samples is different. The river on which the study is conducted is interconnected through four different bridges on both sides. There are asphalt roads on the riverbank and small industrial areas in the region. These form the "local industrial factors."

The result agrees with discussion based on the background value and field survey on point-source pollutant-affected soil samples. The results also reconfirmed that multivariable statistic method (principal component analysis and cluster analysis) of a small set of data together with other information can provide valuable insight in the context of the sources of soil pollutants.

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