AN INVESTIGATION ABOUT HEAVY METAL POLLUTION OF DUDEN AND GOKSU STREAMS (ANTALYA, TURKEY)

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Abstract. The cities are also expanding with growth in construction rapidly, depending on the population growth. This development causes a lot of environmental problems. Pollution in water is one of the main problems and the aim of this paper is to evaluate water pollution in the study area. There are some statistical methods developed for the measurement and evaluation of water pollution; heavy metal pollution index (HPI) is one of them. Antalya is, one of the big cities in Turkey, also growing fast; population and settlement in this city are increasing quickly. That is why two streams, Duden and Goksu, are selected to measure the heavy metal pollution. The 24 water samples from Duden Stream and 18 water samples from Goksu Stream were taken systematically in June 2018 and were analyzed by using HPI. The heavy metals, from the highest value to the lowest one, were Sr > Fe > Al > Mn > As > Ni > Cu > Pb > Cr > Se in Duden Stream; and Sr > Fe > Al > Ni > As > Cu > Mn > Pb > Cr > Se in Goksu Stream. The Sr and Al values have exceeded the standard permissible values in both of the streams. The heavy metal pollution index (HPI) was used to evaluate the potential risk. Regarding quality the water samples have been classified as “good” and “poor”, generally. On the other hand, some water samples had heavy metal pollution above standards. Especially, the water of D15 - D19 - D20 and G13 samples were determined as “very poor” according to the standards. As a conclusion, the anthropogenic factors and urbanization may be the cause of the pollution. Living creatures that use water may have health problems and ecological equilibrium may be hampered in these stations. Groundwater may be contaminated in these areas. So, the urbanization needs to be done more carefully.
Keywords: *heavy metal pollution index (HPI), urbanization, statistics, surface water, environment*

Introduction

The urbanization may cause pollution. This question becomes much more important, especially in industrial areas. The quality of environment has been influenced by the diffusion of pollutants in air, water and soil in large areas. The accumulation of pollutants has disturbed the ecological equilibrium, in time (Stoica and Baiulescu, 2008). The reason of the heavy metal pollution in water could be natural or anthropogenic (Zarazua et al., 2006; Mehrabi et al., 2015; Sobhanardakani, 2016). Bhuiyan et al. (2015) reported “The heavy metal evaluation index (HEI) showed strong correlations and provided better assessment of pollution levels with HPI.”

Duden Stream flows in the Lara Region of Antalya Bay and it is an example for pollution (Erdem and Topkaya, 2004). According to Yardimci et al. (2005), the other example is Goksu Stream which is the main source of Bogacay River. It feeds Bogacay River. So, Goksu Stream affects the water quality of the Bogacay River and the water quality changes temporally; the critical level of water quality was determined in summer because of the recreational activities. Cengiz et al. (2017) also evaluated the

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risk potential of metallic pollution in Bogacay River. According to this study, the samples from upstream showed lower risk potentials than those from downstream. Yalcin et al. (2016) also has investigated the contamination of the sediments by heavy metals along the banks of the Bogacay River. Demarco et al. (2018) and Uncumusaoglu et al. (2016) emphasized the importance of heavy metal pollution in streams in terms of environmental contamination and anthropogenic pollution. Besides, the heavy metal pollution in surface sediments has been also studied in the most recent papers (Ye et al., 2019; Sodrzeieski et al., 2018; Omwene et al., 2018).

Antalya, which is at the forefront of Turkey's major tourism centers and called the "Turkish Riviera", is quite rich in terms of water resources. The water is provided from underground waters. However, Antalya is located on tufa which has a karstic structure. Because of that, water moves frequently from the underground to the surface or from the surface to the underground. On the other hand, the population growth is remarkable in the 5th largest city of the country. Parallel to this, settlement areas are also expanding. The western part of the city is the best example of fast construction. The construction and also population growth continues on both sides of the city. Therefore, the protection of the existing water has become more important and the quality and/or quantity of water should be investigated to prevent pollution.

Although some studies have been made on this subject, no data has been obtained on heavy metal pollution in Duden and Goksu streams after the built-up and population growth. The surface water, which is coming out from the Kepez Hydroelectric Power Plant, reaches via two channels to the Mediterranean; one of them is Duden Falls in Lara tourist area, the other one is Bogacay River in Konyaalti district. However, the second one passes Goksu Stream before Bogacay River (Leventeli et al., 2017). In this study, heavy metal pollution in the surface water was investigated and analyzed statistical between Kepez Hydroelectric Power Plant and Duden Falls in Lara tourist area, called Duden Stream and also between Kepez Hydroelectric Power Plant and Bogacay River with Goksu Stream in Konyaalti district. The location map of the study area, including the sampling stations, is given in *Figure 1*.

Experimental

Study area

The study area is located in the city center of Antalya district which is one of the big cities in Turkey. The water which is coming out from the Kepez Hydroelectric Power Plant reaches via two channels to Mediterranean; one of them is Duden Falls in Lara tourist area, the other one is Goksu Stream with a part of the Bogacay River in Konyaalti district. There are agricultural, industrial and residential areas in the region.

Field sampling

The samples were collected from 42 locations in June 2018 based on morphological and land use properties of the study area. 1 L polythene containers are used for the collection according to standard procedures. Because of the dry season, surface water samples have been taken at this time. D in numbers of samples means "taken from Duden Stream", G means "taken from Goksu Stream". Goksu Stream has a 10.5 km length and Duden Stream has 28.5 km length. So, 24 samples were taken from Duden Stream and 18 samples from Goksu Stream. There are natural barriers like barbed wire,

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morass, prohibited agricultural areas and so on. The long symbols show the stations of Duden Stream and the round symbols show the stations of Goksu Stream (see *Fig. 1*).

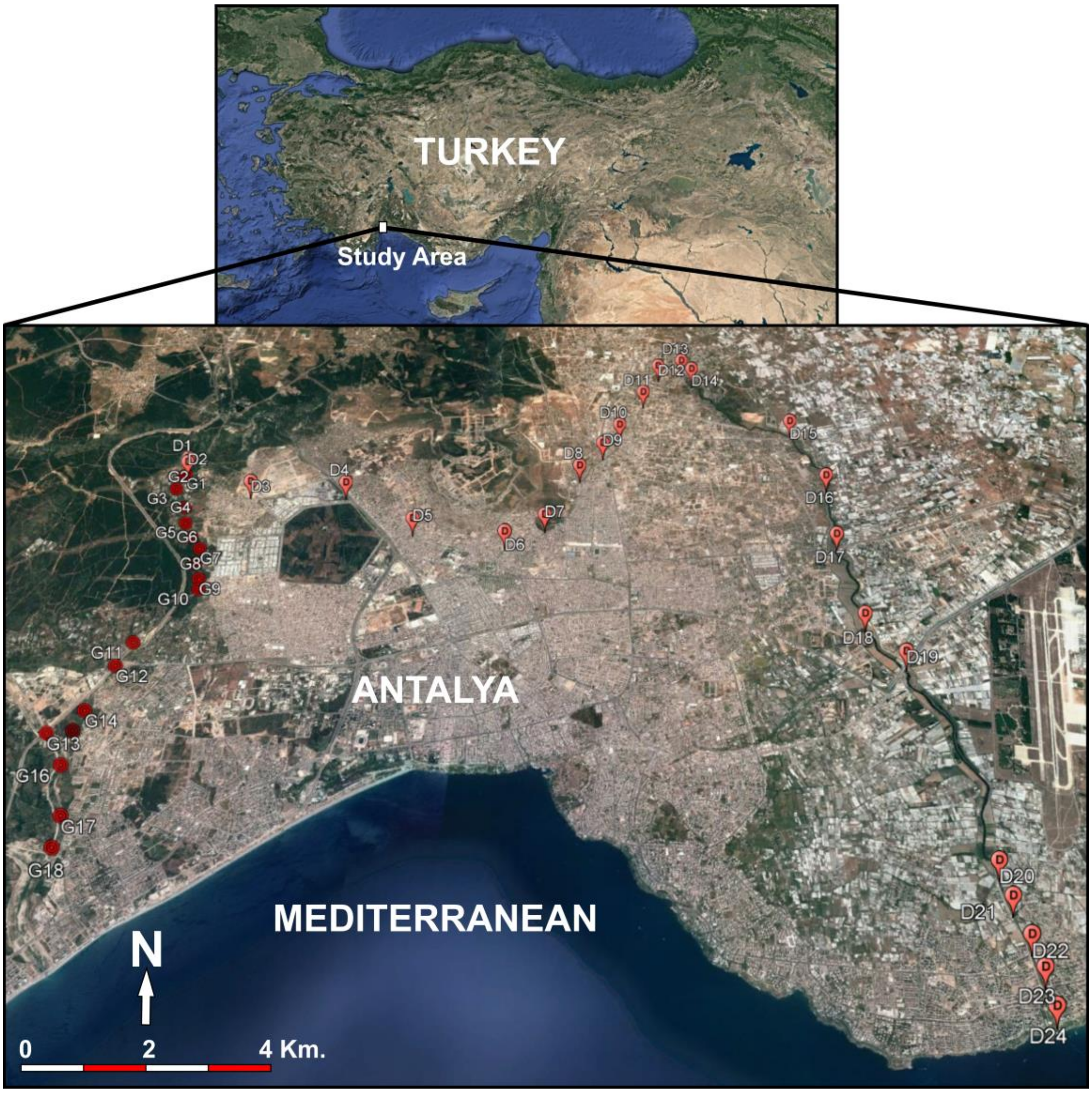

Figure 1. *The location map of the study area shows the sampling stations*

Laboratory methods

Preparation of samples

The experimental studies have been done in the Research Center Laboratory of Akdeniz University. Water samples acidified by adding 5 ml of nitric acid to 1 L polyethylene bottle ISOLAB mark tubes. The biological activities of microorganisms and bacteria that may be in the environment have been terminated in order to prevent the transformation of metals into other forms. The samples were kept in the refrigerator until analysis, and then they were filtered through the filter paper. 2 ml of nitric acid was added after pre-treatment to acidify the samples according to EPA 3005A (1992) method (Rohrbough et al., 1986; ASTM 1985). *Table 1* shows the device parameters of

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Inductively Coupled Plasma – Mass Spectrometer (ICP-MS). A certified standard (SPS-SW2 surface water) was used to verify method trueness.

Table 1. *Device parameters of ICP-MS (Perkin Elmer Elan DRC-e)*

Spectrometer	Elan DRC-e (Perkin Elmer SCIEX, Norwalk, CT, USA)
Sample Introduction	Scott Spray Chamber
RF Power	1000
Skimmer Cone	Nickel
Sampler Cone	Nickel
Gas flow rates (L min^{-1})	Nebulizer gas flow:0.81 Auxillary gas flow:1.20 Plasma gas flow:19
Scanning mode	Peak hopping
Reaction gas, CH_4(ml min^{-1})	Cell gas A 0.2; RPq 0.8 BEC (ppb) 0.1463 (As 74.9216)
Number of sweeps/reading	20
Number of readings/replicate	1
Number of replicates	3
Auto sampler	CETAX ASX-520
Dwell time per AMU (ms)	50
Sample flush	Time (50), speed (+/- rpm)-48
Read delay	Time (15), speed (+/- rpm)-20

Statistical methods and heavy metal pollution index (HPI)

The results of the analyses have been given below with calculations and also with assessments have been made using the Descriptive Analysis, Multivariate Statistics Analysis (Correlations, Principal Component, Component Matrix, Hierarchical Analysis) and Heavy Metal Pollution Index (HPI). Multivariate Statistics Analysis has been made using SPSS-23 software. Besides that, EXCEL 2016 software has been used for HPI calculations, according to similar works.

Results and discussions

Chemical data, statistical surveys

The water samples were taken at the same time from the streams to investigate the existence of iron (Fe), lead (Pb), arsenic (As), copper (Cu), manganese (Mn), nickel (Ni), aluminum (Al), cobalt (Co), strontium (Sr), chromium (Cr), selenium (Se), antimony (Sb), mercury (Hg) and cadmium (Cd) elements. The amount of heavy metal elements obtained is given in *Table 2* in ppb (µg / L). However; antimony (Sb), mercury (Hg) and cadmium (Cd) were not detected in any samples. Cobalt (Co) values were below reporting limit. Chromium (Cr) and selenium (Se) values were below reporting limit generally, excepting some samples; Cr values are 1.7 in G1, 2.5 in G2, 1.2 in G3, 4.7 in G9, 4.3 in G10, 2.1 in D12 and 2.9 in D13; Se values are 0.4 in G7, 0.5 G9, 0.3 G10, 2.1 in D12 and 2.9 in D13.

Descriptive statistics of metal concentration are presented in *Table 3*. The heavy metals were arranged from the highest value to the smallest one as Sr > Fe > Al > Mn > As > Ni > Cu > Pb > Cr > Se in Duden Stream. On the other hand, the order of the metal values from the highest value to the smallest one for Goksu Stream was as Sr > Fe

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> Al > Ni > As > Cu > Mn > Pb > Cr > Se. Among these metals, the Sr and Al values have exceeded the standard permissible values in both of tributaries. The values of the other metals were far below standard values.

Table 2. *The heavy metal values (ppb)*

NO	Coordinates		Pb	As	Cu	Fe	Mn	Al	Ni	Sr
D1	36S 0288246	4090629	N.D.	10	4.5	185	2.6	9	5.4	202
D2	36S 0288254	4090520	N.D.	9.9	3.4	183	1.3	5.9	4.3	317
D3	36S 0289513	4090059	2.2	9.6	4.9	212	1.8	7.5	23.5	421
D4	36S 0291260	4090070	8.1	8.9	30.7	254	7.9	13.3	9	298
D5	36S 0292577	4089230	5.5	9.1	4.7	189	1.3	6.8	24.6	309
D6	36S 0294242	4088960	1.5	9.2	6.3	198	1.6	16	18	305
D7	36S 0294935	4089369	2.9	9.6	4.9	248	3.2	9.3	5.2	336
D8	36S 0295524	4090582	N.D.	10.6	3.2	234	1.6	8.8	5	331
D9	36S 0295941	4091168	5.1	8.3	43.6	238	9.2	26.5	5.6	329
D10	36S 0296251	4091657	1.1	9.4	5.6	232	4.4	11.3	4.9	311
D11	36S 0296696	4092554	1.5	9.5	5.8	241	4.2	6	5.9	305
D12	36S 0296991	4093304	4.5	12.3	5.1	176	7.7	3.6	7.1	298
D13	36S 0297453	4093464	N.D.	12.1	30.6	156	9	3.7	5.1	285
D14	36S 0297650	4093229	N.D.	11.8	3.2	195	3.1	2.9	4	328
D15	36S 0299490	4091819	1.9	10.6	6.5	218	84.9	52.2	9.9	478
D16	36S 0300061	4090432	N.D.	11	5.1	185	30.8	9.9	4.5	425
D17	36S 0300127	4089027	N.D.	10.7	5	174	12.5	12.1	4.7	319
D18	36S 0300445	4087284	N.D.	11.6	3.5	151	15.5	6	4.1	357
D19	36S 0301044	4086519	2.3	7.8	3.8	221	85.4	81.3	18.8	365
D20	36S 0301940	4082808	4.3	9.7	4.8	213	82.5	78.4	19.4	325
D21	36S 0302046	4082257	N.D.	8.9	4.1	142	13.4	7.1	3.8	302
D22	36S 0302210	4081680	N.D.	10.2	3.1	168	12.9	16.7	3.2	298
D23	36S 0302310	4081209	N.D.	8.4	3.7	161	13.6	15.2	2.4	256
D24	36S 0302363	4080662	1.5	9.6	3.2	159	19	24.9	3.07	201
G1	36S 0288231	4090522	N.D.	9	3.8	238	1.2	3.5	11.2	299
G2	36S 0288179	4090460	1.9	8.3	3.7	227	1.4	5.8	4.5	301
G3	36S 0288131	4090151	0.7	9.4	4.1	239	1.4	3.5	12.8	322
G4	36S 0288388	4089712	N.D.	9.4	3.5	265	1.1	7.8	6.4	500
G5	36S 0288477	4089340	1	8.4	3.8	260	1	5.3	8	511
G6	36S 0288663	4089014	4.5	6.3	2.7	167	N.D.	1.2	8.1	455
G7	36S 0288862	4088752	N.D.	6.5	3.1	198	1	N.D.	5.2	361
G8	36S 0288854	4088410	N.D.	6.6	2.9	190	N.D.	2.6	6	358
G9	36S 0288992	4088071	N.D.	6.4	5.9	205	1	4.8	12.4	363
G10	36S 0289033	4087849	N.D.	6.3	4	185	1.1	6.2	7.3	353
G11	36S 0288180	4086714	N.D.	6.2	2.9	166	N.D.	2.6	4.9	357
G12	36S 0288003	4086239	3.7	6.4	3.6	157	N.D.	1.2	3.6	401
G13	36S 0287235	4084938	4.2	1.1	7.3	148	24	54	15	399
G14	36S 0287727	4085368	N.D.	6.7	3.5	182	N.D.	N.D.	2.9	420
G15	36S 0287639	4084992	2.4	7	17.4	174	N.D.	2.4	6.4	398
G16	36S 0287624	4084370	N.D.	6.9	5	164	6	14.4	8	366
G17	36S 0287869	4083497	N.D.	6.5	3.6	165	2.2	1.1	3.7	356
G18	36S 0287884	4082971	2.8	6.2	3.7	155	3.5	17.1	3.3	302

N.D. Not detected

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Table 3. *Descriptive statistics of water sample*

Parameter μg/l	Duden Stream n = 24				Goksu Stream n = 18				Std. permissible value (Nasrabadi, 2015; Prasad and Bose, 2001)
	Min	Max	Mean	Std. dev.	Min	Max	Mean	Std. dev	
Pb	0	8.1	1.766667	2.243961	0	4.5	1.177778	1.632593	50
As	7.8	12.3	9.95	1.19855	1.1	9.4	6.866667	1.837518	50
Cu	3.1	43.6	8.304167	10.5732	2.7	17.4	4.694444	3.364079	1000
Fe	142	254	197.2083	33.28661	148	265	193.6111	37.16599	1000
Mn	1.3	85.4	17.89167	26.55961	0	24	2.494444	5.572355	300
Al	2.9	81.3	18.1	21.66478	0	54	7.416667	12.50309	10
Ni	2.4	24.6	8.394583	6.853334	2.9	15	7.205556	3.560812	20
Sr	201	478	320.875	61.13301	299	511	379	61.98102	50
Cr	0	2.9	.2083333	.7156126	0	4.7	.8	1.527012	10
Se	0	2.9	.2083333	.7156126	0	.5	.0666667	.157181	10

Significant correlation coefficients between 10 heavy metal behaviours in river water in 42 different stations are shown in *Table 4*. Positive correlation was determined between Pb and Fe, Cu, Ni; between As and Cr, Se; between Mn and Al; between Cr and Se in Duden Stream. The highest correlation between these metals was determined between Mn and Al (0.923 *). The positive high correlation between Mn and Al showed that their potential sources may be the same in Duden Stream. There is a positive correlation between As and Fe; between Mn and Al, Ni; between Cr and Se, between Al and Ni in Goksu Stream. High positive correlation between Mn and Al is determined (0.974 *). Besides, there is a high negative correlation relationship between As and Mn (-0.748*), As and Al (-0.715*) in Goksu Stream. These correlations showed that Mn and Al may be from the same source. However, it can be said that As has a different source than Mn and Al in Goksu Stream.

According to the total variance of heavy metal content, the statistical evaluation of the chemical analysis results was high and calculated as 79.460 % (*Table 5*). The explained total variance analysis is evaluated in two parts. One of them is “Initial Eigenvalues”; the other one is “Extraction Sums of Squared Loadings”. The percentage of explanations of each factor is given in order; the cumulatively highest value gives percentage of explanations of the used data. The numerical data of this ratio, which reaches 100, explain its explanatory rate. Therefore, the cumulative value obtained as 79.460% was stated to be high in the factor analyzes of the article. A total of 4 factors were determined by factor analysis. The first factor was explained by Al, Mn, Ni, Pb. The second, third and fourth factors were respectively represented by Cu, As and Fe (*Table 6*). Factors indicate possible sources. Metals within the same factor can be of similar origin in the first factor except other factors.

From the results of the hierarchical analysis, it is understood that three groups were formed among locations (*Fig. 2*). The first group of locations includes 28, 29 and 15 numbers. The second group of locations includes 1, 24 and 23 numbers. The third one includes total of the all numbers. These groups show similarities between the locations Excessive differences between locations show the excess of natural and anthropogenic factors acting on the streams. The analysis results are consistent with factor analysis and with the Principal Component Analysis.

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Table 4. *Relationships between behaviour of heavy metals*

		Pb	As	Cu	Fe	Mn	Al	Ni	Sr	Cr	Se
DUDEN	**Pb**	1									
	As	-.331	1								
	Cu	.483*	-.126	1							
	Fe	.533*	-.358	.282	1						
	Mn	.118	-.147	-.113	.107	1					
	Al	.249	-.383	-.024	.248	.923*	1				
	Ni	.483*	-.327	-.076	.262	.314	.425	1			
	Sr	.041	.129	-.047	.305	.446	.259	.314	1		
	Cr	.016	.566*	.332	-.299	-.107	-.202	-.108	-.151	1	
	Se	.016	.566*	.332	-.299	-.107	-.202	-.108	-.151	1*	1
GOKSU	**Pb**	1									
	As	-.470	1								
	Cu	.240	-.167	1							
	Fe	-.426	.764*	-.177	1						
	Mn	.403	-.748*	.162	-.328	1					
	Al	.437	-.715*	.168	-.299	.974*	1				
	Ni	.102	-.190	.182	.222	.541*	.513*	1			
	Sr	.163	.009	.054	.223	-.000	.005	-.018	1		
	Cr	-.268	.117	-.023	.238	-.133	-.101	.341	-.364	1	
	Se	-.324	-.112	-.027	.049	-.118	-.138	.191	-.138	.656*	1

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

Table 5. *Total variance of heavy metal content*

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	2.452	30.649	30.649	2.452	30.649	30.649
2	1.441	18.007	48.656	1.441	18.007	48.656
3	1.305	16.311	64.967	1.305	16.311	64.967
4	1.159	14.493	79.460	1.159	14.493	**79.460**
5	.763	9.540	89.000			
6	.474	5.920	94.920			
7	.365	4.568	99.488			
8	.041	.512	100.000			

Extraction method: principal component analysis

Table 6. *Component matrix[a]; extraction method: principal component analysis*

	Component			
	1	2	3	4
Pb	**.600**	.483	-.317	-.316
As	-.073	.379	**.706**	.469
Cu	.217	**.788**	-.089	-.254
Fe	.310	.414	-.170	**.734**
Mn	**.800**	-.304	.421	.023
Al	**.880**	-.246	.268	-.150
Ni	**.698**	-.046	-.191	.103
Sr	.204	-.341	-.619	.450

[a]4 components extracted

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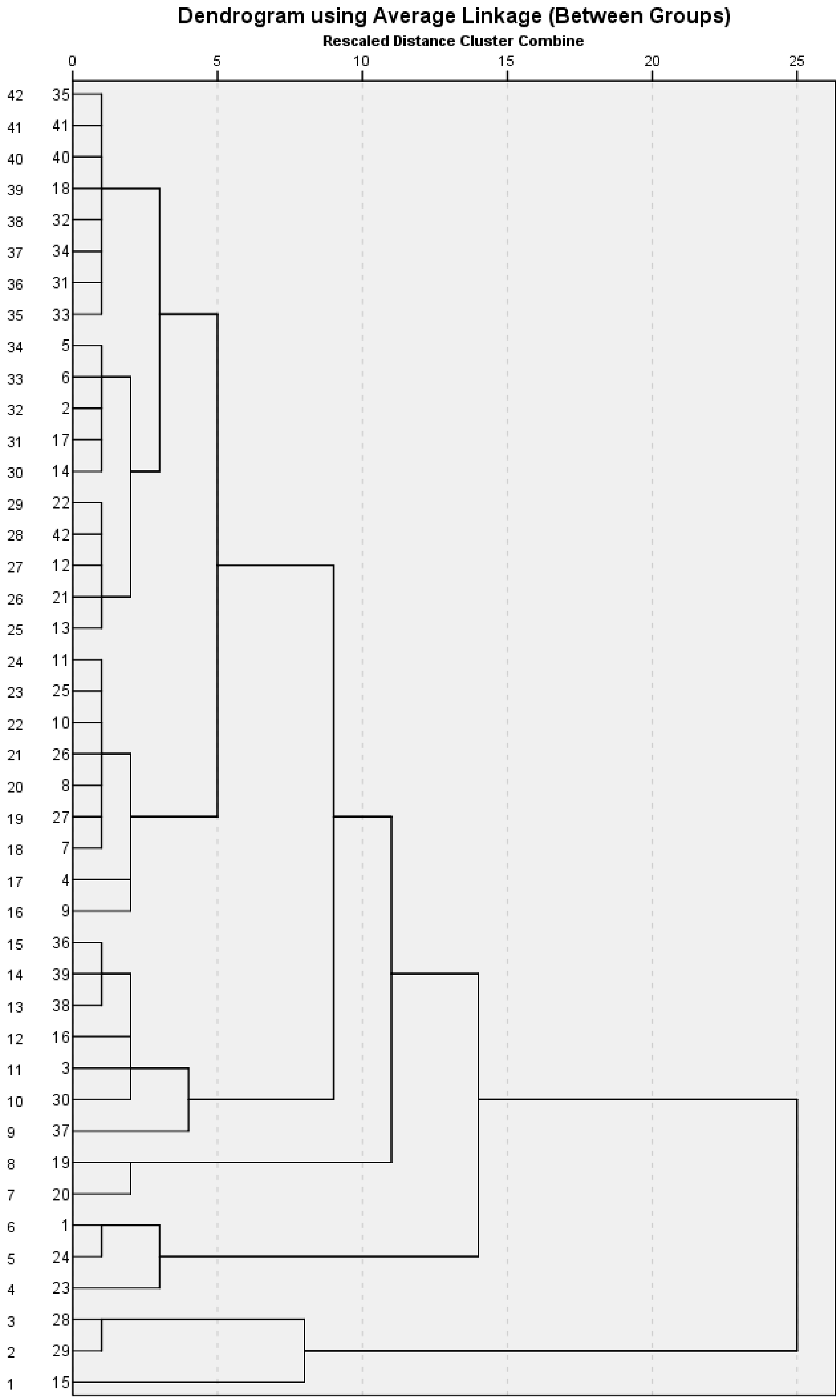

Figure 2. *Dendrogram of the results*

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Heavy metal pollution index (HPI)

The pollution indexes are used to estimate the pollution of the water. Generally, heavy metal pollution index (HPI), heavy metal evaluation index (HEI) and degree of contamination (*Cd*) are used to evaluate water for drinking as well as irrigation purposes (Brraich and Jangu, 2015). Mehrabi et al. (2015) have also used heavy metal pollution index (HPI) to evaluate the level of contamination both in groundwater and in soil in Ahangaran mining area, Iran. They reported that HPI values were less than the critical index limit. Bhuiyan et al. (2015) have studied in Buriganga River, Bangladesh. The results showed that most of the samples exceeded the critical limit and "the intensity of pollution gradually decreased from the source to the downstream part of the river". Yang et al. (2015) have studied during the period 2008-2012 to understand the contamination in terms of heavy metal pollution and also used HPI for that. They had the following result: "The general trend of reduction in HPI appears not to have a seasonal variation and most likely resulted from the continued improvement in heavy metal pollution control strategies implemented by local environmental, agencies combined with a significant improvement in wastewater treatment capacities."

Prasad and Bose (2001) proposed the heavy metal pollution index (HPI) (Nasrabadi, 2015). The analysis results were interpreted based on these papers, in this study. Based on the weighted arithmetic average method, HPI shows the total quality of water compared to heavy metals (Horton, 1965; Mohan et al., 1996). The Heavy Metal Pollution Index (HPI) and the sub-index of each parameter (Qi) are calculated using the following correlations (*Eq. 1*).

$$Q_i = \sum_{i=1}^{n} \frac{(M_i - I_i)}{(S_i - I_i)} \text{x}100 \qquad HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \qquad \text{(Eq.1)}$$

Wi is the unit weight of the i-th parameter, and Qi is the sub-index of the i-th parameter. n is the number of parameters considered. Mi is the measured value of the parameter i. Ii and Si give the ideal and standard values of the i-th parameter. The HPI calculations are shown in *Table 7*. The average of HPI is 80.38833 for Duden Stream, 60.13997 for Goksu Stream. The graphical representations of the results are presented in *Table 8* with heavy metal pollution index (HPI) values. All values, except values of D15 - D19 - D20 - G13 samples, are below the 100.

Figure 3 shows the distribution of the heavy metal pollution index (HPI) values at the stations in the study area. The critical pollution index value is 100; this and above this value should be considered unacceptable (Prasad and Kumari, 2008; Prasad and Mondal, 2008; Reza and Singh, 2010; Ojekunle et al., 2016). According to Sirajudeen et al. (2014) the status categories of HPI are given in *Table 9*. According to the table there is no water in "very good" category. 14 water samples have been classified as "good" (D1 - D2 - D11 - D14 - D21 - G1 - G3 - G7 - G8 - G11 - G12 - G14 - G15 - G17); 20 water samples as "poor" (D3 - D4 - D5 - D7 - D8 - D10 - D12 - D13 - D16 - D18 - D22 - D23 - G2 - G4 - G5 - G6 - G9 - G10 - G16 - G18) and 8 water samples as "very poor (unsuitable for drinking)" (D6 - D9 - **D15** - D17 - **D19** - **D20** - D24 - **G13**). The HPI values of D15 - D19 - D20 and G13 samples were well above the limit.

The high HPI values were due to industrial waste waters, domestic sewage and landfill leachate (Milivojevic et al., 2016).

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Table 7. *HPI calculations for both of the streams*

				DUDEN n = 24			GOKSU n = 18		
Heavy metals	S_i	I_i	W_i	M_i	Q_i	$W_i x Q_i$	M_i	Q_i	$W_i x Q_i$
As	50	10	0.02	9.95	-0.125	-0.0025	6.8666	-7.8335	-0.15667
Cr	10	-	0.1	0.2083	2.083	0.2083	0.8	8	0.8
Mn	300	100	0.003333	17.8916	-41.0542	-0.13685	2.4944	-48.7528	-0.16251
Fe	1000	100	0.001	197.2083	10.80092	0.010801	193.6111	10.40123	0.010401
Ni	20	-	0.05	8.3945	41.9725	2.098625	7.2055	36.0275	1.801375
Cu	1000	50	0.001	8.3041	-4.38904	-0.00439	4.6944	-4.76901	-0.00477
Se	10	-	0.1	0.2083	2.083	0.2083	0.0666	0.666	0.0666
Al	10	-	0.1	18.1	181	18.1	7.4166	74.166	7.4166
Pb	50	-	0.02	1.7666	3.5332	0.070664	1.1777	2.3554	0.047108
Sr	50	-	0.02	320.875	641.75	12.835	379	758	15.16
Total			0.415333	Total		33.38795	Total		24.97814
HPI values				80.38833			60.13997		

Table 8. *The values of heavy metal pollution index (HPI)*

DUDEN		GOKSU	
Station	**HPI**	**Station**	**HPI**
D1	43.99435	G1	47.56614
D2	46.92572	G2	51.28629
D3	72.53699	G3	49.65717
D4	66.4472	G4	70.34977
D5	60.97661	G5	66.32724
D6	78.40037	G6	51.17769
D7	57.75208	G7	46.7238
D8	55.7768	G8	43.55147
D9	98.8178	G9	65.68706
D10	59.78249	G10	63.56285
D11	47.09795	G11	42.73846
D12	52.10245	G12	43.20092
D13	53.28856	G13	**176.502**
D14	40.82054	G14	41.40662
D15	**177.8917**	G15	47.44171
D16	67.32998	G16	73.99047
D17	93.24475	G17	38.35314
D18	51.15154	G18	71.67112
D19	**242.1338**		
D20	**232.0681**		
D21	47.98676		
D22	70.51553		
D23	62.16189		
D24	80.9329		

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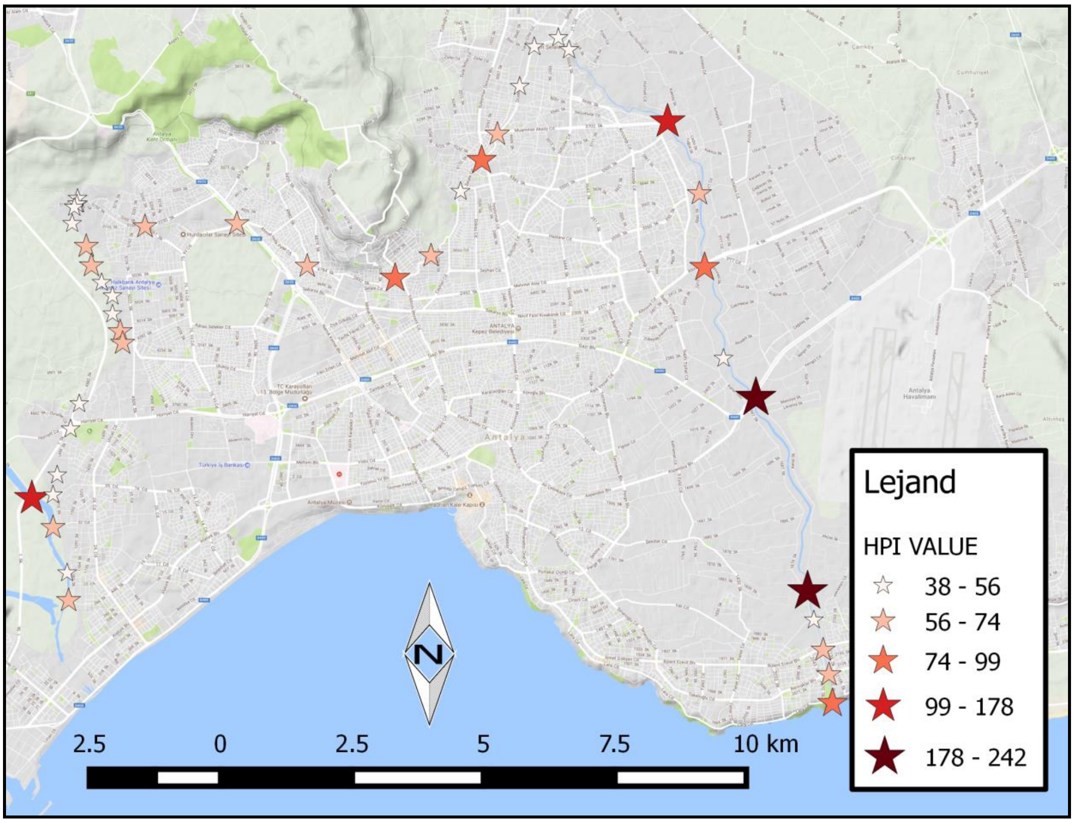

Figure 3. *The distribution of the heavy metal pollution index (HPI) values at the stations in the study area*

Table 9. *Status categories of HPI*

HPI	Quality of water (Sirajudeen et al., 2014)	Stations of study area (Duden and Goksu Streams)
0-25	Very good	---
26-50	Good	D1, D2, D11, D14, D21, G1, G3, G7, G8, G11, G12, G14, G15, G17
51-75	Poor	D3, D4, D5, D7, D8, D10, D12, D13, D16, D18, D22, D23, G2, G4, G5, G6, G9, G10, G16, G18
Above 75	Very poor (unsuitable for drinking)	D6, D9, **D15**, D17, **D19**, **D20**, D24, **G13**

Conclusions

The metal pollution ratio between the Kepez Hydroelectric Power Plant and the Karpuzkaldiran waterfall, which is defined as the “Lower Duden of the Duden Stream” in Lara and also surface water between Kepez Hydroelectric Power Plant and Bogacay River in Konyaaltı district, named Goksu Stream, were investigated using the HPI method. Firstly, aluminum (Al), lead (Pb), arsenic (As), copper (Cu), manganese (Mn), iron (Fe), nickel (Ni), cobalt (Co), strontium (Sr), chromium (Cr), selenium (Se), antimony (Sb), mercury (Hg) and cadmium (Cd) elements were investigated. Antimony (Sb), cadmium (Cd) and mercury (Hg) were undetectable and cobalt (Co) remained below the reporting limit.

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The mean values of aluminum (Al) and strontium (Sr) concentrations exceeded the permitted standard values, while the concentration of other metals remained well below the permissible standard, according to the descriptive statistics of the metal concentration of Duden Stream. When the relations between 10 heavy metal behaviours in stream water in 24 different stations were examined by multivariate analyses; the correlation between Cu and Pb, Fe and Pb, Ni and Pb, As and Cr, As and Se, Mn and metals were positively correlated, respectively, Cr and Sr have the same values and are highly correlated. The HPI critical value is set at 100 according to the literature. Accordingly, it has been determined that the calculated HPI value in water samples D15, D19 and D20 is well above the predicted critical value. The HPI value was consistent with multivariate statistical analyses.

4 factors influenced to the streams at high level with 79.460%. This value shows that the data used in the statistical analyzes are sufficient to explain the factors. The cumulative value calculated by SPSS shows that the percentage of explanations is high and adequate for 4 different factors.

The chemical similarities between the sampling stations show that there are 3 different locations in the region. According to the hierarchical analysis; 28, 29 and 15 samples have formed their dendrogram among themselves; 1, 24 and 23 samples have formed their dendrogram among themselves and all remaining samples have formed their dendrogram among themselves. The main reason of this grouping is the natural and anthropogenic effects.

The Goksu samples, according to the descriptive statistics of the metal concentration of the surface water, only the mean values of the concentration of strontium (Sr) exceeded the allowable standard values, while the concentration of other metals was far below the permissible standard. When the relationship between 10 heavy metal behaviours in stream water at 18 different stations was examined, it was found that there was a positive correlation between As and Fe, As and Mn, As and Al, Mn and Al, Mn and Ni, Al and Ni, Cr and Se metals respectively. It has been determined that the calculated HPI value in the case of water number G13 is above the predicted critical value.

There is no water in “very good” category. 14 water samples have been classified as “good” 20 water samples as “poor” and 8 water samples as “very poor (unsuitable for drinking)”. The HPI values of D15, D19, D20 and G13 samples were well above the limit. So, it is understood that the main source of pollution is anthropogenic.

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REFERENCES

[1] ASTM (1985): Standard specification for reagent water. Annual Book of ASTM Standards 11(01): D1193-77.

[2] Bhuiyan, M. A., Dampare, S. B., Islam, M. A., Shigeyuki, S. (2015): Source apportionment and pollution evaluation of heavy metals in water and sediments of Buriganga River, Bangladesh, using multivariate analysis and pollution evaluation indices. – Environ Monit Assess 187: 4075.

[3] Brraich, O. S., Jangu, S. (2015): Evaluation of water quality pollution indices for heavy metal contamination monitoring in the water of Harike Wetland (Ramsar Site), India. – International Journal of Scientific and Research Publications 5(2): 2250-3153.
[4] Cengiz, M. F., Kilic, S., Yalcin, F., Kilic, M., Yalcin, M. G. (2017): Evaluation of heavy metal risk potential in Bogacayi River water (Antalya, Turkey). – Environmental Monitoring and Assessment 189(6): 248.
[5] Demarco, C. F., Afonso, T. F., Pieniz, S., Quadro, M. S., Camargo, F. A., Andreazza, R. (2018): In situ phytoremediation characterization of heavy metals promoted by Hydrocotyle ranunculoides at Santa Bárbara stream, an anthropogenic polluted site in southern of Brazil. – Environmental Science and Pollution Research 25(28): 28312-28321.
[6] EPA 3005A (1992): Acid Digestion of Waters for Total Recoverable or Dissolved Metals for Analysis by FLAA or ICP Spectroscopy. – EPA, Washington, DC.
[7] Erdem, A., Topkaya, B. (2004): Determination of land pollutants carried into the Mediterranean coastal zone by the Duden River, Antalya. – Fresenius Environmental Bulletin 13(11B): 1339-1343.
[8] Horton, R. K. (1965): An index system for rating water quality. – J Water Pollut Control Federation 3: 300.
[9] Leventeli, Y., Yalcin, F., Kilic, M. (2017): Statistical investigation of heavy metal pollution between Kepez HPP and Bogacay (Antalya-Turkey). – World Multidisciplinary Earth Sciences Symposium 11-15.09.2017, Prague, Czech Republic.
[10] Mehrabi, B., Mehrabani, S., Rafiei, B., Yaghoubi, B. (2015): Assessment of metal contamination in groundwater and soils in the Ahangaran mining district, west of Iran. – Environ Monit Assess 187: 727.
[11] Milivojevic, J., Krstic, D., Smit, B., Djekic, V. (2016): Assessment of heavy metal contamination and calculation of its pollution index for Ugljesnica River, Serbia. – Bull. Environ. Contam. Toxicol. 97: 732-742.
[12] Mohan, S. V., Nithila, P., Reddy, S. J. (1996): Estimation of heavy metal in drinking water and development of heavy metal pollution index. – J. Environ. Sci. Health A31(2): 283.
[13] Nasrabadi, T. (2015): An index approach to metallic pollution in river waters. – J. Environ. Res. 9(1): 385-394.
[14] Prasad, B., Bose, J. M. (2001): Evaluation of the heavy metal pollution index for surface and spring water near a limestone mining area of the lower Himalayas. – Environmental Geology 41: 183-188.
[15] Prasad, B., Kumari, S. (2008): Heavy metal pollution index of ground water of an abandoned open cast mine filled with fly ash: A case study. – Mine Water Environ. 27(4): 265-267.
[16] Prasad, B., Mondal, K. K. (2008): The impact of filling an abandoned opencast mine with fly ash on ground water quality: A case study. – Mine Water Environ. 27(1): 40-45.
[17] Reza, R., Singh, G. (2010): Heavy metal contamination and its indexing approach for river water. – Int. J. Environ. Sci. Tech. 7(4): 785-792.
[18] Rohrbough, W. G. et al. (1986): Reagent Chemicals, American Chemical Society Specifications, 7th Ed. – American Chemical Society, Washington, DC.
[19] Sirajudeen, J., Arulmanikandan, S., Manivel, V. (2014): Heavy metal pollution index of groundwater of Fathima Nagar Area near Uyyakondan Channel Tiruchirappalli District, Tamil Nadu, India. – World Journal of Pharmacy and Pharmaceutical Sciences 4(1): 967-975.
[20] Sobhanardakani, S. (2016): Evaluation of the water quality pollution indices for groundwater resources of Ghahavand Plain, Hamadan Province, Western Iran. – Iranian Journal of Toxicology 10(3): 35-40.
[21] Sodrzeieski, P. A., Andrade, L. C. D., Tiecher, T., Camargo, F. A. D. O. (2018): Physico-chemical variability and heavy metal pollution of surface sediment in a non-channelled

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DOI: http://dx.doi.org/10.15666/aeer/1702_24232436

section of Dilúvio Stream (Southern Brazil) and the influence of channelled section in sediment pollution. – Revista Ambiente & Água 14(1).
[22] Stoica, A., Baiulescu, G. E. (2008): Global pollution. – Proceedings of Ecopole 2(1): 119-121.
[23] Ojekunle, O. Z., Ojekunle, O. V., Adeyemi, A. A., Taiwo, A. G., Sangowusi, O. R., Taiwo, A. M., Adekitan, A. A. (2016): Evaluation of surface water quality indices and ecological risk assessment for heavy metals in scrap yard neighbourhood. – SpringerPlus 5: 560.
[24] Omwene, P. I., Öncel, M. S., Çelen, M., Kobya, M. (2018): Heavy metal pollution and spatial distribution in surface sediments of Mustafakemalpaşa stream located in the world's largest borate basin (Turkey). – Chemosphere 208: 782-792.
[25] Uncumusaoglu, A. A., Sengul, U., Akkan, T. (2016): Environmental Contamination of Heavy Metals in the Yaglidere Stream (Giresun), Southeastern Black Sea. – Fresen. Environ. Bull. 25(12): 5492-5498.
[26] Yalcin, F., Kilic, S., Nyamsari, D. G., Yalcin, M. G., Kilic, M.,(2016): Principal component analysis of integrated metal concentrations of Bogacayi riverbank sediments in Turkey. – Polish Journal of Environmental Studies 25(2): 471-485.
[27] Yang, X., Duan, J., Wang, L., Li, W., Guan, J., Beecham, S., Mulcahy, D. (2015): Heavy metal pollution and health risk assessment in the Wei River in China. – Environ Monit Assess 187: 111.
[28] Yardimci, A., Muhammetoglu, A., Oguz, H. (2005): A Fuzzy Logic Application to Environment Management System: A case Study for Goksu Streams Water Quality Assessment. – In: Reusch, B. (ed.) Computational Intelligence, Theory and Applications. Advances in Soft Computing, Vol. 33. Springer, Berlin, Heidelberg, pp. 327-338.
[29] Ye, C., Butler, O. M., Du, M., Liu, W., Zhang, Q. (2019): Spatio-temporal dynamics, drivers and potential sources of heavy metal pollution in riparian soils along a 600 kilometre stream gradient in Central China. – Science of the Total Environment 651: 1935-1945.
[30] Zarazua G, Avila-Perez P, Tejeda S, Barcelo-Quintal I, Martinez, T. (2006): Analysis of total and dissolved heavy metals in surface water of a Mexican polluted river by total reflection X-ray fluorescence spectrometry. – Spectrochim Acta B 61: 1180-4.

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