Carpathian Journal of Earth and Environmental Sciences, February 2020, Vol. 15, No. 1, p. 145 - 156; DOI:10.26471/cjees/2020/015/117

GEOCHEMICAL AND ANTHROPOGENIC FACTORS CONTROLING THE HEAVY METAL ACCUMULATION IN THE SOILS OF SARAYONU LADIK LINK ROADS

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Abstract: In this study, the geological, geochemical and anthropogenic distribution of heavy metal and toxic elements in the soil on the link roads and agricultural lands on the railroads of Sarayonu (Konya), which dates back to 4000 years ago, was examined. According to the results of the soil samples taken at 5, 25 and 50 meters perpendicular to the roadsides, $As_{Igeo,}$ and Hg_{Igeo} elements were found as "unpolluted to moderately polluted", EF_{Zn}, $EF_{As,}$ and EF_{Hg} were found as "moderate enrichment" and contamination factor (Cf) was found as "pollution" at locations 1, 7 and 8. According to geochemical and statistical evaluations, the elements were divided into 3 groups as Ophiolite, Oxide, and Geo-anthropogenic. According to the evaluations, geochemical events and geological factors, as well as anthropogenic factors played an important role in the accumulation of heavy metals on agricultural lands.

Keywords: Sarayonu, Soil pollution, Heavy metal, Anthropogenic, Geoaccumulation index

1. INTRODUCTION

Mining activities in many parts of the world are among the most polluting human activities that significantly affect environmental parameters. Large scale environmental pollution has been identified during the operation and production of mineral deposits due to the geological and geochemical properties of the operating mineral deposit and the chemicals used during production. (Krüger & Gröngröft, 2003; Yokel & Delistraty, 2003; Camm et al., 2004; Fordyce, 2004; Komatina, 2004; Selinus et al., 2004; Smedley & Kinniburgh, 2004; Donkor et al., 2005; Getaneh & Alemayehu, 2006; Romero et al., 2007; El Hamiani et al., 2010; Moore et al., 2011; Ispas et al., 2018). Mercury deposits around Lâdik, operated and abandoned uncontrollably, close to the study area within the boundaries of Konya Province, are important in particular due to the pollution that heavy metals, including mercury, can spread to the environment (Abu-Rukah, 2001; Abboat et al., 2003; Eisler, 2004; Chang et al., 2005; Abderahman & Abu-Rukah, 2006; Diawara et al., 2006; Hu et al., 2013) (Fig. 1). The mercury deposits are located in the south-southwest of the research area. Although many kinds of research on mercury and other heavy metals in the mercury deposit in Ladik and its environment have been examined in Konya and its surrounding (Doğan, 1975; Akçay, 1998; Horasan, 2005; Horasan & Temur, 2006; Ateş, 2014), the relationship of pollution and the agricultural lands of the Sarayonu district, which is one of the most important regions of wheat and other agricultural products, has not been examined. In this context, this study was carried out in order to examine the distribution of heavy metal and toxin elements in the soil on agricultural lands on the link road and railroad of the Sarayonu district dating back approximately 4000 years ago, which is one of the most important agricultural lands in the region, to determine the relation of source rock according to the geochemical features of the soil and to identify, model and interpret the pollution caused as a result of anthropogenic and mining-related heavy metal distribution in the soils. The studies on pollution caused by urbanization that is becoming widespread in the world have been conducted, interpretations of the studies have been made and many countries' governments have completed the regulations on pollution sources as a result of these studies (Kabata-Pendias & Pendias, 2001; Komatina, 2004; Selinus et al., 2004; Mirsal, 2008; Berkowitz et al., 2008; Kurt, 2018; Horasan & Arık, 2019).

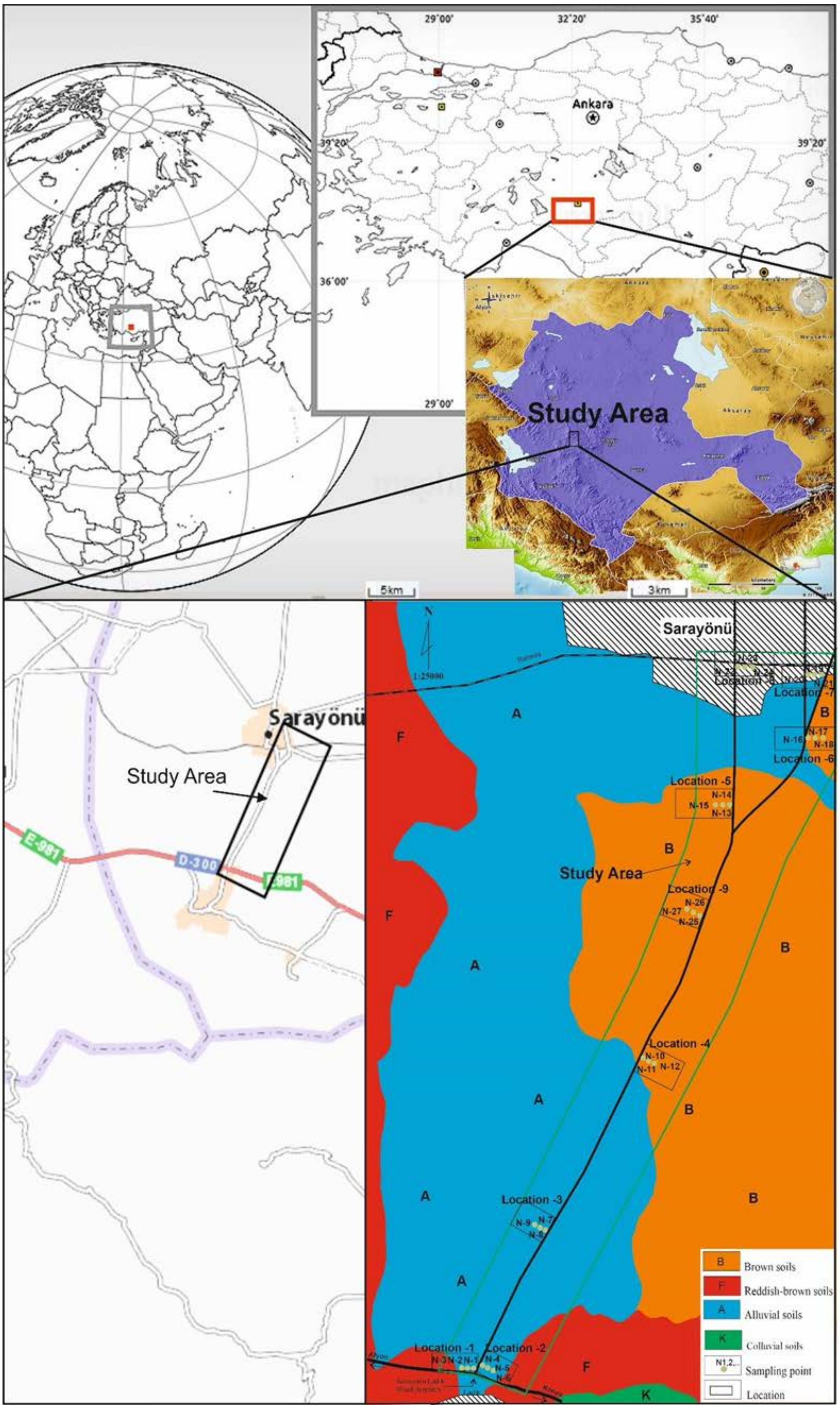

Figure 1 Location and geological map of the study area

2. MATERIALS AND METHODS

All studies prepared in previous years related to Konya and its surroundings (Eren, 1993; Kurt, 1994; Horasan, 2005; Horasan & Temur, 2006; Arık & Öztürk, 2011; Öztürk & Baykal, 2012; Horasan, 2014; Ateş, 2014; Horasan & Arık, 2019) were examined in detail. The geology of the region was reviewed, updated and mapped. The soil map of the study area was mapped by the General Directorate of Rural Services (KHGM, 1987) in previous years and the land borders were checked and updated by using this map. In the field studies, 9 locations on the 6 km long Sarayonu - Ladik link road, where the vehicle traffic slowed, accelerated, stopped were identified based on the railway passing through the district center. At each location, samples were collected from 5, 25 and 50 meters perpendicular to the highway. A total of 27 samples were collected, The section covered with leaves, garbage and dry grass in the 1-2 cm parts from the surface was cleaned and approximately 5 kg samples were taken from the depth of 20 cm. The samples were dried for 24 hours in an oven at 60 °C. The samples removed from the oven were crushed with the help of plastic mallet and the grain size was reduced to -80 mesh size. These samples were put into 300 g packages and stored as witness samples. The prepared solution sample was scanned in the Perkin Elmer branded Inductively Coupled Plasma - Mass Spectrometer (ICP - MS) device within Selçuk University Advanced Technology Research Application Center - İLTEK. Mg, Al, P, K, Ca, Ti, V, Cr Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Cd, Sn, Sb, Ta, Tl, Pb, U, Se, Ba, Mo and Hg concentrations of ICP-MS device were examined. In 2016, vehicle count, average speed and vehicle classification by using portable air pressure hose for at least 7 days 24 hours in all seasons in Turkey's 1818 spots were applied by General Directorate of Highways (KGM, 2017), on the main road that connects the district where this study is carried out to the Konya province. The error rate in system vehicle counts is ± 5%. According to daily data of KGM, a total of 3098 vehicles including 2494 cars with an average speed of 69 km / h, 171 medium loaded commercial vehicles with an average speed of 67 km / h, 6 buses with an average speed of 64 km / h, 236 trucks with an average speed of 64 km / h and 191 trailers, towing vehicles, semi-trailers with an average speed of 58 km / h used the link road daily. In this study, the values measured by KGM were also used. The chemical analysis results of the study were evaluated by using statistical analysis. Cluster analyses were performed to determine the relationship between the elements. For the components with high correlation, the significance of regression and regression analysis with correlation coefficients were determined.

Cluster analysis was performed with elements that had a meaningful correlation. Cu, Pb, Zn, Mn, Fe, As, Cd, Cr, Al and Hg elements were evaluated according to I_{geo}, EF and Cf factors. The I_{geo} (Geoaccumulation index) value was calculated and evaluated using the formula (1) (Muller, 1969)

$$I_{geo} = \left[\frac{C_n}{1.5 \times B_n}\right] \quad (1)$$

The Igeo values proposed by (Muller, 1969) were interpreted as $I_{geo} \leq 0$—*uncontaminated*; $0 < I_{geo} \leq 1$— *Unpolluted to moderately polluted*; $1 < I_{geo} \leq 2$— *Moderately polluted*; $2 < I_{geo} \leq 3$ — *Moderately polluted to highly polluted*; $3 < I_{geo} \leq 4$— *Highly polluted*; $4 < I_{geo} \leq 5$— *Highly polluted to very highly polluted*; $I_{geo} > 5$ — *Very highly polluted*.

EF (Enrichment Factor) was calculated and evaluated by the formula (2) (Zoller et al., 1974).

$$EF = \frac{\left(\frac{C_i}{C_{ie}}\right)s}{\left(\frac{C_i}{C_{ie}}\right)RS} \quad (2)$$

EF<2; *Depletion to mineral encrichment*, 2<EF<5; *Moderate enrichment*, 5<EF<20; *Significant enrichment*,20 <EF<40; *Very high enrichment*, EF>40; *Extremely enrichment*. (AbdulqaderIsmaeel and Kusag, 2015).

C_f (Contamination Factor) was calculated and evaluated by the formula (3) (Hakanson, 1980)

$$C_f = \frac{C_{Heavy\ metal}}{C_{background}}$$ and

$$PLI = (C_{f1} \times C_{f2} \times C_{f3} \ldots \times C_{fn})_{\frac{1}{n}} \quad (3)$$

$PLI \leq 1$ *No Pollution*, $PLI \geq 1$ *Pollution* (Tomlinson et al., 1980).

According to the results, the size of the accumulation of heavy metals occurring in agricultural soil was evaluated by comparing pollution limit values used in Turkey and the World.

3. RESULTS AND DISCUSSION

Sarayonu district is one of the oldest settlements dating back 4000 years (Kurt, 2014). The district, which is located on the link road between Konya and Afyon, is in the typical continental climate zone with its cold and rainy weather in winters and hot and dry weather in summers. The income source of the district which has a dynamic population is provided by agriculture and livestock. Therefore, the agricultural lands are quite large and the agricultural product pattern is quite high. Agricultural products used as human nutrients, as well as fodder crops used in breeding, are important (Karakurt, 2007). One of Turkey's largest farms where agricultural research is carried out, agricultural products are developed and produced is also in this region whose wheat production plays an important role for Konya and Turkey.

3.1 General Geology

The study area is located within Anatolides according to (Ketin, 1966), Bolkardağı zone in Taurides according to (Özgül, 1976), largely Afyon - Bolkardağı zone according to (Okay, 1986), Kütahya - Bolkardagı zone according to (Özcan et al., 1988). In the researches conducted in and near the study area (Özcan et al., 1988; Eren, 1993; Kurt, 1994; Kurt, 1996) there is no common view on the stratigraphic development of the region. Ladik metamorphics in the region consist of the Sızma group at the bottom and the Ardıçlı group overlying this group unconformably. Silurian (?) - Devonian Permian aged Sızma group consists of Bozdağ formation which is composed of dolomitic limestone, recrystallized limestone and dolomites at the bottom, Bağrıkurt formation which is composed of schist, phyllite, recrystallized limestone, metachirt, metacestode, and metal carbonate olistoliths and Montenegro metamathematics, partly observed as intermediate level and partly as dikes. The Ardıçlı group located with an angular unconformity over this group consists of Bahçecik formation represented by a small amount of recrystallized limestone, phyllite, metacestode, metachonglomera, and metal carbonate, a metaplastic form of Ertuğrul formation. These units are overlain unconformably by the Quaternary aged alluvial unguided units observed excessively in the research area (Eren, 1993). The entire research area consists of alluvials.

3.2 Classification of soils

The soil cover formed in the study area is classified as A (Alluvial soils), B (Brown soils), F (reddish-brown soils), K (colluvial soils) depending on the geological structure and characteristics of the region. An (Alluvial soils) forms a very large area in the Konya Plain. It consists of sediments with stream and lake with A and C horizons. The sediments brought into the storage environment by the streams create a few layers according to the characteristics of the sediments depending on the wave motion at different times. (Fig. 1) (Tuncez & Candan, 2008). In most of the study area, brown soils (B) with low thickness mostly used in dry farming have been identified. The reddish-brown soils (F) are ABC profile soils observed in the west and south of the study area (Fig. 1) (Tuncez and Candan, 2008). The colluvial soils (K) are not suitable for agriculture and their formation continues. They were seen in a local area at the Sarayonu junction on the Istanbul road of the study area. (Fig. 1) (Kaya & Kılcı, 2011).

3.3 Soil Geochemistry

9 locations were identified in the study area and 3 samples were collected from each. There are 27 samples in total, and chemical analysis of 22 elements including Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, P, Pb, Sb, Sn, Sr, Ti, V, Zn, and Hg were carried out (Table 1). In scientific studies in the fields of environmental geology and soil geochemistry, some of these elements are considered necessary for living organisms. However, the negative effects of some of these elements are said to be unproven (Sparks, 2005; Wilson, 2012). For the heavy elements considered to be harmful in the researches all over the world, each country has defined the limit values within its own or its local regions and the values below these limit values are considered to be safe (Horowitz et al., 1988; Lottermoser et al., 1998; Iskandar and Birkham, 2001; Kabata-Pendias & Pendias, 2001; Krüger & Gröngröft, 2003; Komatina, 2004; Selinus et al., 2004; Essington, 2005; La Blanco et al., 2006; De Vivo et al., 2008; Mirsal, 2008; Horasan & Arık, 2019).

The results obtained from this study have also been compared with pollution limit values of Turkey (MOEF 2001) and different countries (Kabata-Pendias & Pendias, 2001). It has been found that As average is higher than the values of the countries except for Austria (Table 2) and the Hg average is higher than that of Turkey (Table 2). As a result of evaluations, As, Ba and Hg elements existing as minerals or compounds in different rock groups in geological processes in the study area may change as a result of different events that may occur during geological processes. The events, such as hydrothermal alteration, oxidation, and solution transfer cause the elements to be transformed into different mediums or different forms from their original position (Akçay, 2002).

Firstly, correlation analyses were performed in order to determine the simple relations between the elements analyzed in the samples collected from the study area, (Table 3). There is a very strong positive correlation between Cu and Zn, Cd, Sn, Sb, Pb, Zn and Sb, Pb, Cd and Sn, Sb, Pb, Ti and Sb, Pb, Sb and Pb, Pb and Hg; There is a strong positive correlation between Ti and Sr, Ba, Mg and Ca, Al and K,

Table 1**.** Parametrical statistical results of major elements and some trace elements in soils compiled from the study area (N: Number of elements, Mean: Arithmetic Mean, Std. Sap: Standard Deviation, Std. A.L: Lower Limit, U.L: Upper limit).

	Unit	**Mean**	**N**	**Std. Dev.**	**Min.**	**Max.**
Mg	%	6134	27	1830	4084	13780
Al	%	25321	27	4915	12696	34018
P	%	711	27	224	386	1207
K	%	5827	27	893	3217	6934
Ca	%	62097	27	40692	12684	148277
Ti	%	280	27	89	94	471
V	ppm	57	27	12	31	86
Cr	ppm	61	27	9.8	46	101
Mn	%	1013	27	332	476	1487
Fe	%	33005	27	5900	20843	42523
Co	ppm	8.03	27	1.6	5.06	10
Cu	ppm	20	27	29	0.0001	89
Zn	ppm	135	27	173	0.00015	449
As	ppm	31	27	8.3	16	47
Sr	ppm	161	27	149	39	575
Cd	ppm	0.10	27	0.14	0.001	0.40
Sn	ppm	0.60	27	0.37	0.13	1.5
Sb	ppm	11	27	17	0.00045	41
Pb	ppm	17	27	12	7.0	41
Se	ppm	2.8	27	2.6	0.01	10
Ba	ppm	287	27	65	161	378
Hg	ppm	3.6	27	3.12	0.81	10

Table 2. The comparison of maximum limit values given for certain elements in the soils of Turkey (MOEF, 2001) and other countries (Kabata-Pendias and Pendias, 2001) with the values obtained.

		Austria	Poland		Germany		E.U	Russia	England	USA		*Turkey*	This Study		
		1977	1977	1993	1984	1992	1986	1986	1987	1988	1993	*2001*	Mean	Min	Max
As	ppm	50	-	30	20	-	-	2	10	14	-	***20***	31	16	47
B	ppm	100	-	-	25	-	-	-	-	-	-				
Be	ppm	10	-	10	-	-	-	-	-	-	-				
Cd	ppm	5	1	3	3	1.5	1–3	-	3–15	1.6	20	***1***	0.10	0.001	0.39
Co	ppm	50	-	50	-			-	-	20		***20***	8.0	5	10
Cr	ppm	100	80	50	100	100	50–150	0.05	-	120	1500	***100***	61	46	101
Cu	ppm	100	70	30	100	60	50–140	23	50	100	750	***50***	20	0.0001	89
F	ppm	500	-	-	200	-	-	-	-	-	-				
H	ppm		-	5	2	1	1–1.5	2.1	-	0.5	8				
Mo	ppm	10	-	10	-	-	-	-	-	4	-	***10***			
Ni	ppm	100	75	30	50	50	30–75	35	20	32	210	***30***			
Pb	ppm	100	150	70	100	100	50–300	20	500-2000	60	150	***50***	17	7	41
Se	ppm	10	-	10	10	-	-	-	-	1.6	-	***5***			
V	ppm	-	-	150	-	-	-	150	-	-	-		57	31	86
Zn	ppm	300	300	100	300	200	150-300	110	130	220	1400	***150***	135	0.00015	449
Ba	ppm											***200***	287	161	378
Hg	ppm											***1***	3.6	0.81	9.9
Sn	ppm											***20***	0.59	0.13	1.4
Tl	ppm											***1***			

V, Cr, K and V, Ca and Ba, Fe and Co, Cu and As, Zn and As, Hg, Zn and Cd, Sn, Sb, As and Cd, Sn, Pb, Hg, Cd and Hg, Ti and Hg. There is a very strong negative correlation between Cu and Zn, Cd, Sn, Sb, Pb, As and Sb, Pb, Cd and Sn, Sb, Pb, Pb and Hg. There is a strong negative correlation between Al and Zn, Cd, Sb, Pb, Ca and Fe, Ti and Co, As, Mn and Sr.

The dendrograms were prepared according to the common correlations obtained by cluster analysis in order to determine the association of elements that show a strong and very strong positive correlation (Fig. 2).

There are 3 groups in the dendrogram (Fig. 2). Group 1 is the Ophiolite group represented by Al, V, K, Cr and Mn, Fe, Co subgroups with a strong positive correlation. Lithologically, these elements are found in the Ophiolite rocks (Kurt, 2018). It is thought that the basic and ultrabasic rocks belonging to the emerging ophiolite in the south-southwest of the study area are eroded by the effect of the block faults and climate at the border of the plain in the geological process and form these elements (Fig. 2).

The second group is the Oxide group, which is represented by Ti, Sr, Ca and Ba, between which there is a strong positive correlation (Fig. 2). This group is represented by the elements that emerge by alteration and transport of the carbonated rocks in the region. In the dendrogram, Group 3 is called Geo-anthropogenic and represented by Mg, P, As, Hg and Zn, Cu, Pb, Cd, Sn subgroups between which there is a very strong positive correlation (Fig. 2).

In order to reveal the significance of the correlation between components, simple regression analyses were applied to the components having a strong and very strong correlation. There was a strong positive correlation between Hg and As, and according to the regression analysis results, it was understood that the alignment of points to the regression line was significant. The alignment between Mg and P which have a weak positive correlation was understood to be insignificant. In addition, it was determined that the alignment of the points to the regression line between Ba-Ca, Ti-Sr, Fe-Co, and Al-V with a strong positive correlation was significant. When the values of the elements of Cu, Pb, Zn, Mn, Fe, As, Cd, Cr, Al, and Hg selected from 22 elemental analyzes made from 27 samples collected from the study area (Table 1) are evaluated according to the I_{geo} (Geoaccumulation Index) index (Table 4).

According to the arithmetic mean value of I_{geo}, the pollution value was found to be Zn <Cu <Cd <Al <Cr <Fe <Pb <Mn <As <Hg (Table 5).

Cu_{Igeo} was calculated as “Unpolluted to moderately polluted” in locations 7 and 8, Pb_{Igeo} was calculated as “Unpolluted to moderately polluted” in locations 1, 7 and 8, Zn_{Igeo} was calculated as “Unpolluted to moderately polluted” in location 6, “moderately polluted” in locations 1, 2, 7 and 8, Mn_{Igeo} was calculated as “Unpolluted to moderately polluted” in locations 2, 3, 4, 6 and 8, As_{Igeo}, was calculated as “Unpolluted to moderately polluted” in locations 2, 3, 4, 6 and 9, “moderately polluted” in locations 1, 7 and 8, and Hg_{Igeo} was calculated as “Highly polluted” in locations 1, 7 and 8, “Moderately polluted to highly polluted” in locations 2 and 4, “Moderately polluted” in locations 3 and 6, “ Unpolluted to moderately polluted” in 5 and 9. According to the Igeo index, there is a remarkable accumulation in locations 1, 2, 7 and 8.

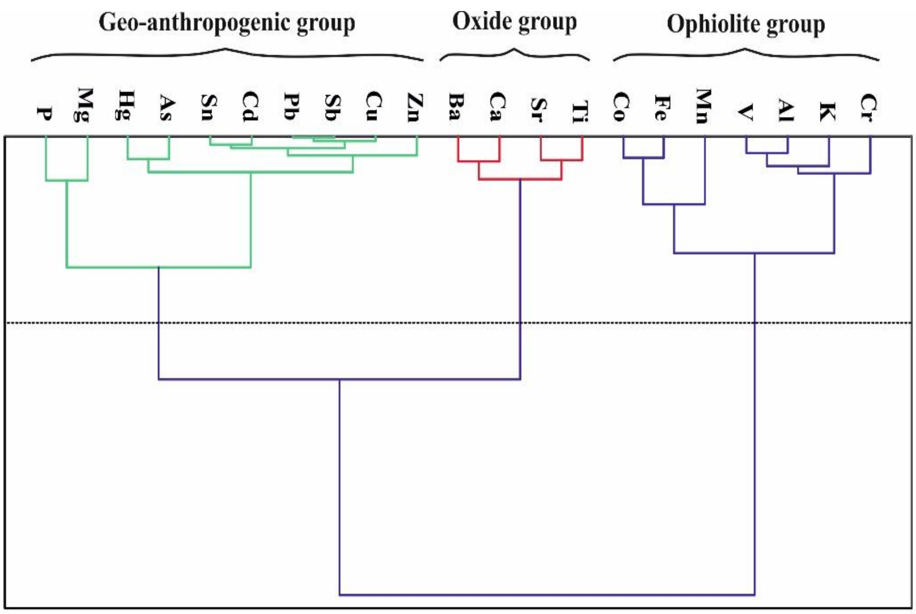

Figure 2. Cluster analysis based on simple correlation coefficients in soil samples.

Table 3. Correlation coefficients of the elements analyzed in soil samples

	Mg	Al	P	K	Ca	Ti	V	Cr	Mn	Fe	Co	Cu	Zn	As	Sr	Cd	Sn	Sb	Pb	Ba	Hg
Mg	1.000	-0.520	0.413	-0.397	0.603	0.184	-0.221	-0.209	-0.417	-0.496	-0.384	0.166	0.429	0.152	0.138	0.311	0.384	0.412	0.258	0.114	0.097
Al		1.000	-0.354	0.699	-0.495	0.331	0.784	0.609	0.184	0.333	0.202	-0.515	-0.694	-0.490	-0.077	-0.626	-0.510	-0.677	-0.608	-0.014	-0.339
P			1.000	-0.164	-0.070	-0.499	-0.090	-0.286	0.129	0.119	0.139	-0.020	0.189	0.407	-0.344	0.186	0.149	0.184	0.117	-0.537	0.262
K				1.000	-0.340	0.274	0.612	0.448	0.131	0.409	0.213	0.012	-0.206	-0.136	0.042	-0.092	-0.107	-0.152	-0.075	0.219	0.169
Ca					1.000	0.488	-0.460	-0.219	-0.385	-0.698	-0.803	0.407	0.490	-0.023	0.509	0.505	0.557	0.558	0.422	0.664	0.210
Ti						1.000	0.139	0.203	-0.572	-0.407	-0.630	-0.164	-0.139	-0.642	0.677	-0.198	-0.076	-0.129	-0.201	0.668	-0.224
V							1.000	0.662	0.191	0.307	0.336	-0.289	-0.485	-0.089	-0.247	-0.267	-0.165	-0.423	-0.365	-0.145	-0.073
Cr								1.000	0.188	0.045	0.097	-0.160	-0.243	-0.072	-0.112	-0.237	0.030	-0.246	-0.215	-0.024	-0.056
Mn									1.000	0.170	0.349	0.050	-0.069	0.324	-0.628	-0.028	-0.069	-0.096	-0.006	-0.352	0.191
Fe										1.000	0.719	-0.191	-0.344	0.150	-0.429	-0.144	-0.336	-0.274	-0.203	-0.372	-0.045
Co											1.000	-0.010	-0.217	0.413	-0.484	-0.073	-0.134	-0.137	-0.011	-0.517	0.099
Cu												1.000	0.815	0.675	0.141	0.890	0.852	0.931	0.960	0.514	0.798
Zn													1.000	0.616	0.135	0.746	0.766	0.871	0.856	0.338	0.645
As														1.000	-0.349	0.681	0.662	0.671	0.732	-0.154	0.701
Sr															1.000	0.126	0.179	0.189	0.129	0.539	0.051
Cd																1.000	0.890	0.912	0.890	0.390	0.765
Sn																	1.000	0.897	0.884	0.428	0.706
Sb																		1.000	0.973	0.473	0.800
Pb																			1.000	0.447	0.815
Ba																				1.000	0.280
Hg																					1.000

Correlation matrix (Pearson (n)): (-0.800)-(-0.999): Very strong negative correlation (-0.600)-(-0.799): Strong negative correlation (0.600)-(0.799): Strong positive correlation (0.800)-(0.999): Very strong positive correlation

Table 4. Geoaccumulation index and Enrichment Factor results

	Igeo	Cu		Pb		Zn		Mn		Fe		As		Cd		Cr		Al		Hg	
	EF		Cu		Pb		Zn		Mn		Fe		As		Cd		Cr		Al		Hg
1.	N1	-0.2	2.4	0.3	3.4	1.4	7.5	-0.3	2.2	-1.5	1.0	1.3	6.9	-0.6	1.9	-1.1	1.3	-2.8	0.4	2.5	15
	N2	-1.9	0.9	-0.5	2.4	0.9	6.4	-1.1	1.6	-1.8	1.0	0.8	5.8	-1.0	1.7	-1.5	1.2	-3.2	0.4	2.2	16
	N3	-8.3	0.0	-1.1	0.9	-19	0.0	-0.1	1.8	-1.0	1.0	1.0	4.1	-8.8	0.0	-1.2	0.9	-2.3	0.4	3.8	27
2.	N4	-19	0.0	-1.6	0.8	1.3	5.8	-0.6	1.5	-1.2	1.0	0.7	3.9	-8.8	0.0	-1.0	1.2	-2.3	0.5	1.8	8.4
	N5	-2.9	0.3	-1.4	0.8	0.9	3.8	-0.1	2.0	-1.0	1.0	0.8	3.5	-8.8	0.0	-1.5	0.7	-2.7	0.3	0.6	3.2
	N6	-2.5	0.4	-1.5	0.7	-19	0.0	0.0	2.1	-1.0	1.0	0.9	3.8	-1.1	1.0	-1.2	0.9	-2.1	0.5	3.2	19
3.	N7	-3.8	0.2	-1.3	0.8	-19	0.0	-0.1	2.0	-1.1	1.0	0.4	2.9	-8.8	0.0	-1.4	0.8	-2.4	0.4	0.6	3.3
	N8	-3.9	0.1	-1.4	0.7	-19	0.0	0.1	2.0	-0.9	1.0	0.7	3.0	-8.8	0.0	-1.2	0.8	-2.1	0.4	1.9	6.8
	N9	-2.6	0.3	-1.4	0.6	-19	0.0	0.2	2.0	-0.8	1.0	0.9	3.2	-8.8	0.0	-1.1	0.8	-1.9	0.4	1.9	6.5
4.	N10	-3.8	0.1	-1.7	0.7	-19	0.0	-0.2	1.8	-1.1	1.0	0.6	3.3	-8.8	0.0	-0.4	1.6	-1.8	0.6	2.6	12
	N11	-3.2	0.2	-1.5	0.7	-19	0.0	0.1	2.0	-0.9	1.0	0.7	3.2	-3.0	0.2	-1.0	0.9	-2.0	0.5	2.3	9.4
	N12	-4.9	0.1	-1.6	0.6	-19.9	0.0	0.2	2.1	-0.9	1.0	0.9	3.4	-8.8	0.0	-1.0	0.9	-2.1	0.4	2.3	8.9
5.	N13	-19	0.0	-1.9	0.7	-19	0.0	-1.4	0.9	-1.3	1.0	-0.1	2.3	-8.8	0.0	-1.2	1.1	-2.0	0.6	0.6	3.7
	N14	-19.4	0.0	-1.9	0.7	-19	0.0	-1.3	1.1	-1.4	1.0	-0.2	2.3	-8.8	0.0	-1.1	1.2	-2.1	0.6	0.9	4.8
	N15	-19	0.0	-2.0	0.7	-19	0.0	-1.3	1.1	-1.4	1.0	-0.2	2.4	-8.8	0.0	-1.2	1.1	-2.2	0.6	0.8	4.7
6.	N16	-4.8	0.1	-1.7	0.7	0.1	2.7	-0.2	2.1	-1.3	1.0	0.3	2.9	-8.8	0.0	-1.1	1.1	-2.0	0.6	1.7	7.9
	N17	-3.8	0.2	-2.0	0.6	-19	0.0	-0.2	2.3	-1.3	1.0	0.1	2.6	-8.8	0.0	-1.2	1.1	-2.0	0.6	1.3	6.3
	N18	-4.3	0.1	-2.1	0.6	-19	0.0	0.2	2.7	-1.3	1.0	0.0	2.4	-8.8	0.0	-1.0	1.2	-2.1	0.6	0.8	4.3
7.	N19	-0.6	1.2	0.2	2.1	1.3	4.6	-0.4	1.4	-0.9	1.0	1.0	3.7	-0.4	1.4	-1.3	0.7	-2.6	0.3	3.9	26
	N20	0.2	2.1	0.1	2.1	1.4	5.2	-0.3	1.5	-1.0	1.0	0.9	3.7	-0.2	1.7	-1.2	0.9	-2.6	0.3	3.9	29
	N21	0.1	2.1	0.4	2.7	1.5	5.8	-1.2	0.9	-1.0	1.0	1.0	4.0	-1.0	1.0	-1.4	0.8	-2.3	0.4	3.7	26
8.	N22	0.0	2.2	0.4	2.8	1.1	4.5	-0.3	1.7	-1.1	1.0	1.0	4.4	-0.2	1.8	-1.3	0.9	-2.5	0.4	3.8	29
	N23	0.4	3.2	0.3	2.9	1.2	5.5	-0.2	2.0	-1.2	1.0	1.1	5.2	-0.4	1.8	-1.2	1.1	-2.4	0.4	3.7	30
	N24	0.1	3.3	0.5	4.3	1.7	9.9	0.1	3.4	-1.6	1.0	1.0	6.4	-1.2	1.3	-1.0	1.5	-2.3	0.6	4.1	52
9.	N25	-19	0.0	-1.4	0.7	-19	0.0	-0.8	1.0	-0.8	1.0	0.7	2.7	-3.2	0.2	-1.1	0.8	-2.1	0.4	0.7	2.7
	N26	-19	0.0	-1.5	0.6	-19	0.0	-1.2	0.8	-0.8	1.0	0.7	2.8	-5.5	0.0	-1.2	0.8	-2.2	0.4	0.8	3.0
	N27	-19	0.0	-1.8	0.5	-19	0.0	-1.0	0.9	-0.7	1.0	0.3	2.1	-8.8	0.0	-1.1	0.8	-2.1	0.4	0.4	2.2

Table 5. Average, Max. and Min. Geoaccumulation index

	Zn_{Igeo}	CuI_{geo}	Cd_{Igeo}	Al_{Igeo}	Cr_{Igeo}	Fe_{Igeo}	Pb_{Igeo}	Mn_{Igeo}	As_{Igeo}	Hg_{Igeo}
Mean	11.3	6.9	-5.6	-2.3	-1.2	-1.1	-1.1	-0.4	0.6	2.1
Sediment Quality	UP	UP	UP	UP	UP	UP	UP	UP	MP	HP
Min	-19.9	-19.4	-8.8	-3.2	-1.5	-1.8	-2.1	-1.4	-0.2	0.4
Max	1.7	0.4	-0.2	-1.8	-0.4	-0.7	0.5	0.2	1.3	4.1

UP; Unpolluted, MP; Unpolluted to Moderate Polluted, HP; Moderate Polluted to Highly Polluted

Table 6. Average, Max. and Min. Enrichment Factor results

	EFAl	EFCd	EFCu	EFCr	EFPb	EFMn	EFZn	EFAs	EFHg
Mean	0.5	0.5	0.7	1.0	1.3	1.7	2.3	3.6	13
Sediment Quality	De	De	De	Ude	De	De	Me	Me	Se
Min	0.3	0.00370	0.00000247	0.7	0.5	0.8	0.00000175	2.1	2.2
Max	0.6	1.9	3.3	1.6	4.3	3.4	9.9	6.9	52

De; Depletion to mineral enrichment, Ude; Unpolluted depletion to mineral enrichment, Me; Moderate enrichment, Se; Significant enrichment

According to EF (Enrichment Factor) pollution evaluation, Cu_{EF}, Pb_{EF} was found as “Moderate Enrichment” in locations 1, 7 and 8, Zn_{EF} was found as “Moderate Enrichment” in location 6, “Significant Enrichment” in locations 1, 2 and 7, Mn_{EF}, was found as “Moderate Enrichment” in locations 1, 2, 3, 4, 6 and 8, **As_{EF}** was found “Significant Enrichment” in locations 1 and 8, and “Moderate Enrichment” in locations 2, 3, 4, 5, 6 and 7. Hg_{EF} was found as “Moderate Enrichment” in locations 5 and 9 locations, “Significant Enrichment” in locations 1, 2, 3, 4 and 6, “ Very High Enrichment” in locations 7 and 8 (Table 2; Table 4). In addition, according to the average EF evaluation, it was identified as Al <Cd <Cu <Cr <Pb <Mn <As <Zn <Hg (Table 6).

The Cf Contamination factor was evaluated according to the Pollution load index and found as “Pollution” in locations 1, 7 and 8. As a result of the evaluations made on the samples taken in the study area, locations 1, 2, 7 and 8 stand out in terms of Ba, As and Hg accumulation. The sources of pollution caused by heavy metal and toxic elements are not only caused by human activities, but also by geological processes (Horasan and Arık, 2019). These points are represented by the Afyonkarahisar main road Ladik junction (locations 1 and 2) and the intersection point of the railway and Sarayonu main road (locations 7 and 8). In the evaluation of the data, it was determined that Hg and As enrichments developed at two different points. Considering the clustering analysis and regression compliance test, it is thought that this situation comes from the same source in the vicinity of mercury bed in Ladik - Sızma region, it is thought to be enriched due to geological processes and climatic factors due to Sb, As, and Pb enrichment, and it is thought to be related to exhaust gas emission from vehicle traffic in samples taken 5 meters from roadsides. It is also thought that As is enriched as anthropogenic by the pesticides used in agricultural activities. Zn concentration was found to be higher than the other locations in the samples taken at 5 and 25 meters near the road. In the Zn cluster analysis, the fact that it is included in the Pb - Sb - Cu subgroup in the Geoanthropogenic group shows the development of zinc after completion of Pb - Sb - Cu hydrothermal mineralization in the region. This can be explained mainly due to the fact that Zn is especially at intersection points (1 and 2 Highway-Highway intersection, 7 and 8 Highway - Railway intersection), vehicle traffic is slow, exhaust gas emissions occur due to long vehicle waiting period, the abundance of mandatory braking at these stops cause Zn contamination. It is also due to the anthropogenic addition of zinc used in agricultural fertilizers (Apostoae, 2016). Leading pollutant heavy metals caused by traffic are lead, nickel, mercury, cadmium, zinc, chromium, and copper. Lead (Pb) is released from Tetra Ethyl Lead, which is added to gasoline in motor vehicles to prevent knockout. Nickel (Ni) is released as a pollutant from diesel fuel and engine oil. It is known that cadmium (Cd) and zinc (Zn) are mostly caused by diesel fuel, vehicle tires, oils, and other vehicle equipment (Li et al., 2001). High accumulation of Zn, Pb, and Cd at the roadside makes it risky to grazing animals as well as agricultural activity (Kıcińska, 2016). It is understood that Mg-P correlation relationships are insignificant according to the regression compliance test and that magnesium may be the result of a geological process originating from the dolomitic limestones and ophiolitic units in the region, but it is also thought to be enriched as anthropogenic with phosphate in the content of agricultural fertilizers. In addition, Ba-Ca and Ti-Sr are enriched in soils as a result of the decomposition, alteration, and transport of carbonated rocks by geological processes and climatic factors.

4. CONCLUSIONS

In the study, the geological, geochemical and anthropogenic events controlling the heavy metal accumulation in the agricultural lands on Sarayonu district link road at the Ladik intersection on Konya - Afyon highway and the railway junction intersecting in the continuation of this road were determined. The pollution factor in the agricultural lands in the region has been determined to be primarily due to the geological and geochemical processes of the mercury deposits formed by hydrothermal processes, and secondly, the anthropogenic processes resulting from the highway and railway vehicle traffic and agricultural activities.

Acknowledgment

The authors would like to thank Selcuk University Scientific Research Projects Coordinator (Project No: 18402019) for supporting this study. In addition, in all stages of this study, researchers performed equal task sharing.

Conflıcts of ınterest

We have no conflicts of interest to disclose. We have been declared and used guidelines for defining authors of Carpathian Journal of Earth and Environmental Sciences.

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Received at: 25. 06. 2019
Revised at: 01. 02. 2020
Accepted for publication at: 09. 01. 2020
Published online at: 12. 02. 2020