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ASSESSING HEAVY METAL POLLUTION IN THE SURFACE SOILS OF CENTRAL ANATOLIA REGION OF TURKEY

Bilgehan Yabgu HORASAN[1] & Fetullah ARIK[2,3]

[1]*Selcuk University Sarayonu Vocational School of Higher Education Department of Environmental Protection and Technologies Sarayonu / Konya*

[2]*Selcuk University Advanced Technology Research & Applıcatıon Center Selçuklu /Konya*

bilgehanyabgu@gmail.com

[3]*Selçuk University Engineering Faculty Geological Engineering Department Selçuklu / Konya,*

fetullah42@hotmail.com

Abstract: Konya is the largest city of Turkey and has been the capital of many civilizations. The current study intends to determine the geochemical characteristics and the distribution of trace elements of soils in an area of approximately 600 km^2 around Konya. Many different types of rocks and younger detricious units are exposed in Konya, formed from the Paleozoic period to the present day. Abandoned Sızma (Konya) mercury deposits and small-sized Pb-Zn-Au enrichments, as well as magnesite, Cr, Fe and Ni enrichments and associated ophiolitic rocks are found in the area. In addition, sites of household wastes, industrial sites, agricultural areas and major highways are in the area. Major components of soils include Al, Fe, Mg, Ca and S, which are 4.43%, 2.43%, 2.44%, 15.56% and 0.20%, respectively. Trace elements include As, Ba, Cr, Cu, Hg, Ni, Pb, Sb, Sr, U, V and Zn, and are 22.31, 400.78, 0.21, 109.97, 20.79, 0.08, 130.68, 21.22, 1.96, 595.41, 2.20, 62.93 and 56.60 ppm respectively. The amounts of As, Cr and Ni in the soils exceed the maximum permissible levels with respect to Turkey, and a majority of other countries. Co, Mo, Pb, Sb and Sr are a health risk in some areas, and essential measures have to be taken to reduce pollution.

Keywords: Konya, soil pollution, toxic element, heavy element, medical geology, environmental geochemistry

1. INTRODUCTION

The study area covers significant areas of Selçuklu, Meram and Karatay counties: approximately 600km^2 in the Konya residential area (Fig. 1). The Konya residential area has hosted many civilizations since 7000 BC, and is determined by the social and cultural characteristics of a strategic location. In the determination of residential areas' not only cultural and political reasons, capable of responding to the needs of contemporary geological, geotechnical properties as well as mineralogical and geochemical characteristics of theirs must also be considered.

Within Konya and its vicinity, many studies have been carried out for geological purposes (Özcan et al., 1988, Hakyemez et al., 1992, Eren 1993). Konya's residential area is made up of a number of very different grain sizes (clay, silt, sand, gravel) and loose/less attached terrestrial detrital material (alluvium). Despite an overall framework to address the pedogenic features of the land, detailed soil geochemistry, geological, petrographical and geochemical studies could not be performed in the area under investigation.

Soils relating different aged igneous, metamorphic and sedimentary rocks, having different origins and chemical properties are exposed, in the Konya residential area. According to soil classification, soils in the region are; Alluvial soils (A), Brown soils (B), Reddish chestnut soils (D), Reddish-brown soils (F), Hydromorphic alluvial soils (H), Colluvial soils (K), Regosols (L) and lithosols (CK). Soils have different thickness depending on the morphology, climatic conditions and altitude.

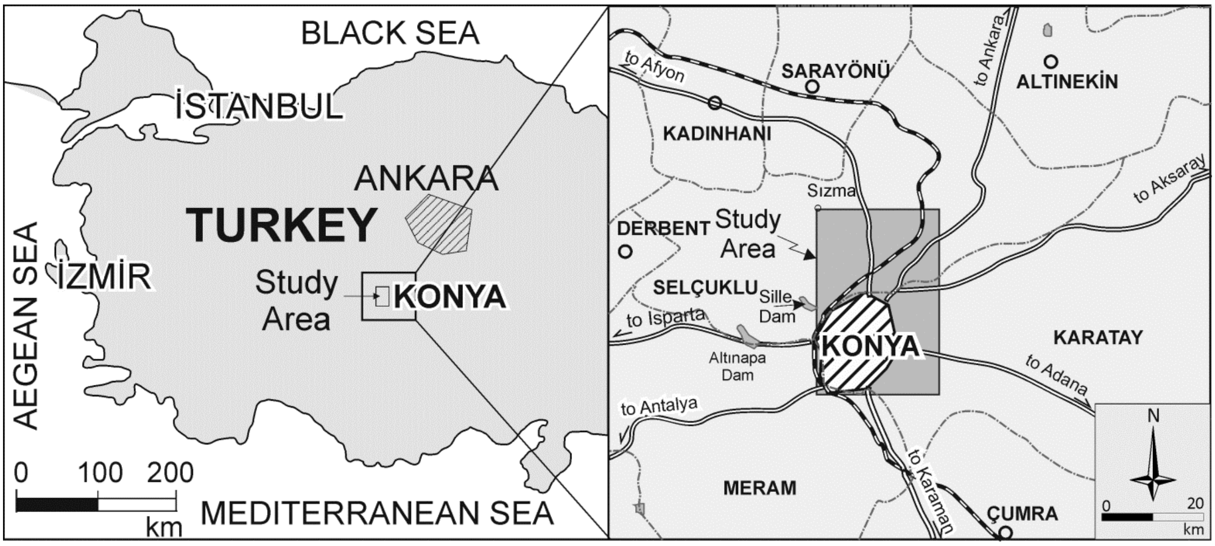

Figure 1. Location map of the study area

Many small metallic mineralizations depend on the young volcanism in the western part of the study area. The Sızma-Ladik Hg deposit, and its waste-bearing mercury production facilities, continued its activities until 1990 on the north-western border of the study area. In addition, a large number of local clays, crushed stone, marble and building stone is still produced. Mineral deposits, and especially rocks, soil, water and plants, in the close environs of metallic ore deposits, are known to be the source of metal impurities affecting the local ecosystem. During the production of ore deposits and the exploitation of metals, large-scale environmental pollution has been identified in many countries depending on mineralogical and geochemical characteristics, and the chemicals used in the metallurgical processes (Lottermoser et al., 1998, Krüger & Gröngröft 2003, Yokel & Delistraty 2003, Camm et al., 2004, Komatina 2004, Selinus et al., 2004, Romero et al., 2007). When dispersed into the environment heavy metals, including mercury, usually cause many years of irreversible pollution (Clark et al., 2001, Chang et al., 2005, Diawara et al., 2006). In Turkey, many metallic mineral deposits have negative effects on the immediate area and further afield and many of them have been the subject of research into heavy metal pollution and acid-mine drainage (Arık & Nalbantçılar 2005, Arık et al., 2009, Arık & Yaldız, 2010).

Despite the many studies done about the abandoned Sızma-Ladik mercury deposits, and its near environs on the north-western border of the study area, both related to mercury and other heavy metals, (Motorcu 1987, Akçay 1998, Horasan 2005) no study has at looked at these issues affecting the Konya residential area. Only limited research has been made around the ore deposits said to be a major problem for Sızma (Güzel et al., 1998).

In addition, household waste in residential areas, together with small and organized industrial sites, agricultural areas and major highways are evident in Konya. Across the world, pollution caused by urbanization is just in its research phase, and a number of analyses and interpretations are made and governments of the countries operate arrangements for pollution sources (Komatina 2004, Selinus et al., 2004, Kabata Pendias & Pendias 2001, Mirsal 2008). Fe, Mn, Co, Zn and Cd are attributed to a main origin in soils, and in the case of Zn, there is also a slight anthropic input due to agricultural chemicals. The impact of car traffic is reflected in the values of Ni and Pb contents (Apostoae, 2016).

This study was conducted to identify the relationship of soils to the geochemical features of source rocks, and to model and interpret the distribution and contamination of heavy metals, depending on geogenesis, mining activities and anthropogenic properties, in the Konya residential area.

2. MATERIALS AND METHODS

The study area is located Konya residential area and near environs in Central Turkey (between 41°82’-42°16’N, 44°80’-46°52’E). Geological and geochemical studies of the Konya residential area its surrounding area was compiled (Hakyemez et al., 1992, Özcan et al., 1988, Eren 1993, Roberts 1982, Wiesner 1968, Göğer & Kıral 1969, Besang et al., 1977, Görmüş 1984, Arık & Öztürk 2011, Öztürk & Baykal 2012) and updated onto a geological map. Different characteristics such as pedogenic soil formation was determined and compared with the geological map. Soil maps prepared by KHGM

(1987) were used during the soil mapping studies.

Soil samples were collected from 76 different locations in summer seasons of year 2012 and 2013. Each soil type was represented by approximately 15-20 samples. During the sampling process plant residues, garbage leaves and a grass-covered portion of the first 1cm in the upper levels of soil were cleaned and 5 kg soil samples were collected from the bottom of the cleaned zone. Soil samples were dried in an oven at a temperature of 40ºC for 24 hours, then sieved using a – 80 mesh. A sample of approximately 200g was taken for analysis and the remainder was stored as blank. Samples were chemically analyzed at ACME Analytical Laboratories Ltd. (Vancouver-Canada), by Inductively Coupled Plasma–Emission Spectrometry (ICP-ES) for major elements and by Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) for the trace element contents. The samples were chemically analysed by a Group 1T analysis package, which is most suitable for soil and sediment because of having the same characteristics after interviews with the ACME Analytical Laboratories Ltd. (Vancouver-Canada). Major (Al, Fe, Ca, Mg, K, Na, Mn, Ti, Cr, P and S) and trace (Ag, As, Au, Ba, Be, Bi, Cd, Co, Cs, Cu, Ga, In, La, Lu, Mo, Nb, Ni, Pb, Rb, Re, Sb, Sc, Se, Sn, Sr, Te, Ta, Th, Tl, U, V, W, Y, Zn and Zr) elements of the soils were analyzed to element concentrations. Hg was analyzed by the group 1DX package thought to be important.

The results of chemical analysis were subjected to parametric statistical analysis and correlation analyses. Hierarchical cluster analysis was performed to determine the interrelation of the elements using correlation coefficients. In addition, elemental distribution maps were prepared and interpretations were run to explain the geographic location and heavy metal pollution.

Heavy elements pollution for the evaluation in this study as Turkey territory and purified mud with certain limit values when was exceeded as dangerous adopted (ÇOB 2001) and the world's different regions determined for the elements on the limit values are taken into account. Accordingly, the As, Ba, Cd, Co, Cr, Cu, Hg , Mo, Na, Ni, Pb, S, Se, Sn, Tl, and Zn were analysed in terms of ÇOB standards. In addition, Al, Ca, Fe, K, Mg, Mn, P, Sb, Sr, Ta, Ti and V analyses in other studies were used for a total of 29 elements (Table 1).

3. RESULTS AND DISCUSSION

Owing to its strategic location, Konya has been very important to many civilizations throughout history; its first settlement was established during the Neolithic epoch (8000-5500 BC). Konya had grown rapidly and developed during the domination of Republic of Turkey and today is a modern city in view of the open-air museum.

The region has a continental climate specific to west-central Anatolia. The mean annual precipitation is 324.5 mm and the temperature varies between 23.6 (July) and -0.2 (January) °C. The Konya residential area is a depression basin bounded by the dip-slip normally faults. The Konya fault zone is in the west, the Karaömerler fault is in the north and the Göçü fault is in the east of the city. This Miocene-Pliocene basin was formed by block faulting during the formation of Old Konya Lake (Roberst 1982) and was covered by clastic and carbonate rocks formed from coastal areas, and by pyroclastic rocks and lava flows formed due to Erenler-Alacadag volcanism. In the near term and is still found in the ruins of Konya Lake in the coastal area and river basins representing the Pleistocene-Holocene period, which have been dominated by terrestrial-lacustrine clastics. A volcano-sedimentary sequence having approximately 1.5 km in thickness has been formed by the collapses in the basin. In the near term and is still found in the ruins of Konya Lake in the coastal area and the river basins representing the Pleistocene-Holocene period has been dominated by terrestrial-lacustrine clastics. Shortage of average annual rainfall and severe drought in the basin caused quite weak vegetation. Agricultural activities in the large lowland areas commonly are carried out using groundwater.

3.1. General Geology

Study area is located in Anatolides according to (Ketin 1966), Bolkardağı Unit in Taurides according to (Özgül 1976), Afyon-Bolkardağı Zone determined by (Okay 1986) and Kütahya - Bolkardağı belt according to (Özcan et al., 1988). Paleozoic to present-day metamorphic, igneous and sedimentary rocks are exposed in the study area (Fig 2). There is no consensus in the research regarding the local stratigraphical development of the study area (Özcan et al., 1988, Hakyemez et al., 1992, Roberts 1982, Wiesner 1968, Göğer & Kıral, 1969, Eren 1993). The units cropping out in the study area can be divided into two main groups: basic units and cover units.

The basic units are low grade Ladik metamorphics (Eren 1993) and ophiolitic rocks. Ladik metamorphics were divided into two main subgroups such as Sızma and unconformably overlying Ardıçlı groups.

The Sızma group consists of carbonaceous rocks of Silurian-Lower Carboniferous Bozdağ formation and Devonian-Lower Permian Bağrıkurt formation, consisting of alternating green-grey phyllite, schists, turbidites metasandstone, and metaconglomerate, recrystallized limestone and different sizes of exotic metacarbonate blocks. Ardıçlı Group covered Sızma Group unconformably.

The Ardıçlı group is represented by four units with lateral and vertical transitions. These units are Upper Permian (?) - Lower Triassic Bahçecik formation, composed of phyllite, metaclastic alternation with metacarbonates, and show transition with Upper Permian (?) - Triassic Ertuğrul formation, composed of chalcschist, phyllite and metasandstones (Göğer and Kıral 1969). Upper Permian - Lower Jurassic dolomite and dolomitic limestones of Kızılören formation and Upper Triassic - Lower Cretaceous Lorasdağı formation consist of thick recrystallized limestone, dolomitic limestone and dolomites (Görmüş 1984, Özcan et al., 1988, Hakyemez et al., 1992, Eren 1993).

Upper Cretaceous ophiolitic rocks tectonically overly all other units. Hatip ophiolitic melange is represented by mudstone, radiolarite, sandstone, volcanic, metamorphic and ultramafic rocks containing different sizes and ages of limestone blocks (Özcan et al., 1988, Eren 1993, Öztürk & Baykal 2012, Göğer & Kıral 1969). Çayırbağı ophiolites consist of serpentinized peridotites. Abundant stockwork magnesites, listwaenites chromite and magnetite beside rare sulphidic formations, in places beside iron crust formations, are at the top of the ophiolites (Öztürk & Baykal 2012, Zedef 1994).

Cover units are represented by Dilekçi and Konya Group's terrestrial-lacustrine clastics, contemporaneous volcanic products and young clastics.

The Dilekçi group consists of lateral and vertical transitions with each other, from bottom to top, Sille, Ulumuhsine, Küçükmuhsine formations, Sulutas volcanics and Yürükler formations. The Sille formation is represented by conglomerate, sandstone and mudstones. The Ulumuhsine formation consists of limestone, marl, mud, conglomerate and sandstones. The Küçükmuhsine formation consists of andesite and dacitic tuffs, tuffites, agglomerates and volcanogenic sandstones. These units were cut by the Sulutas Volcanics and consist of andesite and dacites, beside rhyolitic, rhyodacitic and basaltic neck, dike and lava flows. The age of the volcanism was identified as 11.95-3.35 Ma (Upper Miocene - Lower Pliocene) using the K/Ar method by (Jung & Keller 1974, Besang et al. 1977, Keller et al., 1977). The Dilekçi Group was covered by younger clastic and carbonaceous sediments of Yürükler and Topraklı formations (Eren 1993).

The Topraklı formation commonly consists of old alluvial deposits, slope debris, lake shore sediments and actual alluvial deposits. Investigated soils were more defined, and were named and compared by the many researchers who have studied the local characteristics around Konya (Hakyemez et al., 1992, Nalbantçılar 2002). These deposits were named by the Konya Group representing the Pliocene-Pleistocene transition and numerous braided fluvial facies; some of them have significant distribution size. These units are from west to east: Beşyüzevler, Konya, Aslımyayla, Sakyatan, Göçü and Karahüyük formations. The Konya group starts with usually small and semi-circular gravel, moderately sorted medium-thick cross-bedded conglomerates, medium-thick bedded coarse sandstones and pebbly mudstone alternation. The topmost sequence are soils composed of slightly consolidated and unconsolidated material, with very little pinned clay, silt, gravel and terrestrial carbonates in places.

3.2. Classification of Soils

Due to differences in climate, topography and geological features, the source material that has formed soils in the study area, belonging to Zonal, Azonal and Intrazonal Ordos, having variable thickness.

Zonal soils are represented by brown (B), reddish chestnut (D), reddish-brown (F), non-calcareous brown (U) and non-calcareous brown forest soils (N). Brown soils (B-Group) are found in the north of the study area. Usually inclined, stony and calcium rich areas, covering a significant portion of B-type soil, are evaluated with activities such as pasture, irrigated vineyards and orchards. Reddish chestnut soils (D-Group) are located just south of Sızma County (Tunçez & Candan 2008). Generally this is common in the morphology of mountainous and hilly areas. Reddish brown soils (F-Group) are common in mountainous areas. The natural vegetation includes herbs, shrubs and various forest trees. Non-calcareous brown soils (U-Group), usually developed on volcanic rocks, were located in the vicinity of creeks in the Sille neighbourhood. Common agricultural products are wheat, sunflower and other regional plant species. Non-calcareous brown forest soils (N-Group) are spread on the ophiolitic units in the southwest of the area. These soils are usually inclined, while wheat, vineyards and orchards are cultivated in the flat areas.

Intrazonal soils are only Hydromorphic alluvial soils (H). These soils (H) are seen in the Aslım Swamp in the centre of Konya. Water-loving and salt-tolerant reed, thatch, moss, herbs and buckets (Tunçez & Candan 2008) develop on H-type soils.

Azonal soils are alluvial (A) and colluvial soils (K), regosols (L) and bare rocks (CK, lithosol) (Fig. 3). Alluvial soils (A-Group) cover a very wide area and consist of fluvial and lacustrine sedimentary rocks with A and C horizons. Alluvial soils came into the environment due to river and wave action in different periods. Most are rich in lime washed from uplands (Tunçez & Candan 2008). Vegetation varies depending on climate and arable lands. Colluvial soils (K-Group) are observed along the Konya Fault Zone where there are sudden changes in the slope. These soils show similar features usually found near to the alluvial soils, while open and stony soils are prone to erosion. Regosols (L) was observed in the Yazır and Bosna-Hersek neighbourhood and is composed of unconsolidated sediments. L-Group soils are coarse-grained, permeable, have a low water holding capacity and are shallow soils. Bare rocky areas and lithosols (CK) are spread around the foothills of Doğudag. The vegetation of these groups is very weak.

3.3. Soil Geochemistry and heavy metal distribution

According to environmental studies and soil geochemistry, while some of the elements analysed are regarded as elements necessary for organisms (Sparks 2005, Wilson 2012), some indicate a lack of evidence of any negative effect. Today, the harmful effects of heavy elements vary from country to country and region to region. Therefore, the acceptable limits of these elements in a number of countries are listed (Lottermoser et al., 1998, Krüger & Gröngröft 2003, Komatina 2004, Selinus et al., 2004, De Vivo et al., 2008, Essington 2005, Iskandar & Birkham 2001).

In Turkey, regulations controlling soil pollution were published by the Ministry of the Environment and Forests (ÇOB, 2001) and came into force in year 2001. Only trace elements were considered in some studies while some major and minor elements are combined together. When all these studies were taken together more than 50 different elements were reported. Some elements were not taken into consideration because they were below their limit of detection. As, Ba, Cd, Co, Cr, Cu, Hg, Mo, Na, Ni, Pb, S, Se, Sn, Tl, and Zn have acceptable limits in the soils of Turkey (ÇOB 2001). In addition, Al, Ca, Fe, K, Mg, Mn, P, Sb, Sr, Ta, Ti and V, frequently analysed in other studies, were evaluated together in this study. Consequently, major oxides such as Al, Fe, Mg, Ca, Na, K, Ti, P and S were given in percentage (%) concentration. Mn and other trace elements, such as As, Ba, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sn, Sr, Te, Tl, U, V and Zn, were analysed in ppm (Table 1). Student t test results indicate that performed calculations and statistical analyses were acceptable and consistent with a significance level of 95%.

The average amount of Al in the soils is 4.43%. Maximum Al values are observed in the intersection areas along the channels from Sille Dam, and traversing Konya and its industrial zones. The main value of Fe within the soils is 2.43%, though higher values of Fe were observed in the agricultural areas of Meram County (Fig. 2).

Widely observed in the basic and cover units, carbonaceous rocks naturally influence the soils. The values of Ca in the soils ranged from 1.45% to 32.25%. Mg is usually high in the southwest of the area. Na, K, Mn, Ti and P values are 2.44%, 15.56%, 0.31%, 1.31%, 524.41 ppm, 0.21% and 0.06%, respectively (Fig. 2).

The average As value in the soil samples is 22.3 ppm, and measured As values ranged from 4-68 ppm. West of the city, levels of As exceeded the permissible levels. Maximum levels of As were observed in Sızma Town, which shows the relationship between this element and mercury deposits. Cd has an average of 0.21 ppm and ranges from 0.08-0.46 ppm (Fig. 2). The average level of Hg is 0.08 ppm (0.01-2.21 ppm), while the highest Hg value is seen around Sarıcalar village.

The mean Sr value is 595 ppm and the highest Sr value (4320 ppm) is observed close to the cement factory in the industrial region. Higher levels of Ba, S and Sr in this region indicate contamination resulting from industrial activities (Fig. 2). Other significant elements in the study area are Cr 110 ppm (10-1426), Ni 131 ppm (8-2010), Pb 21.2 ppm (3.11-170), V 63 ppm (13-105), Zn 57 ppm (16-100), where higher values exceed acceptable levels. Mean values of other elements such as Co, Cu, Mo, Sb, Se, Sn, Te, Tl are: 15.56, 20.79, 1.96, 0.35, 1.74, 0.63, 0.44, and 2.20 ppm, respectively (Fig. 3).

Cluster analyses were performed to determine relationships with each of the elements in the samples. Simple correlation analyses were performed in order to determine the relationships between the elements. Al has very strong correlation coefficients with K, Ti, Ta and Tl. Similar to Al, very strong positive correlations exist between the Ti-Ta and Ti-V, Co-Cr, Co-Ni, Co-Pb and Co-Sb and Ni-S element pairs.

Table 1. Chemical and statistical analysis results and of the major elements and some trace elements of the soils in the study area (DL: detection limit, Avg: Arithmetic Mean, KC: Kurtosis coefficient, SC: Skewness coefficient, SD: Standard Deviation, SE: Standard error of the mean, Tc: Calculated t value, LL: Lower limit of main mass, UL: Upper limit of main mass, Table t value is taken 1.99 at 95% significance level for 76 samples).

Element	Unit	D.L.	Avg.	Median	K.C.	S.C.	S.D.	S.E.	t_c	Min.	Max	L.L	U.L
Al	%	0.020	4.43	4.54	-0.77	-0.31	1.67	0.19	23.07	0.43	7.17	4.05	4.81
Fe	%	0.020	2.43	2.34	1.73	0.78	0.99	0.11	21.43	0.25	5.71	2.20	2.66
Mg	%	0.020	2.44	1.82	10.56	3.10	2.45	0.28	8.67	0.56	14.49	1.88	3.00
Ca	%	0.020	15.56	14.03	-0.24	0.35	7.01	0.80	19.33	1.40	32.25	13.95	17.16
Na	%	0.002	0.31	0.29	2.25	1.36	0.19	0.02	13.91	0.03	0.92	0.26	0.35
K	%	0.020	1.31	1.38	-0.90	-0.12	0.58	0.07	19.61	0.13	2.49	1.18	1.44
Mn	ppm	2.000	524.41	501.50	1.56	1.00	222.14	25.48	20.58	76.00	1223.00	473.65	575.17
Ti	%	0.001	0.21	0.22	-0.40	-0.50	0.07	0.01	25.04	0.02	0.33	0.20	0.23
P	%	0.001	0.06	0.06	3.85	1.53	0.03	0.00	17.80	0.02	0.19	0.06	0.07
S	%	0.040	0.20	0.04	68.51	8.11	0.82	0.09	2.12	0.04	7.08	0.01	0.39
As	ppm	0.200	22.31	20.95	3.57	1.49	10.95	1.26	17.77	4.00	66.80	19.81	24.81
Ba	ppm	1.000	400.78	358.00	-0.11	0.52	187.52	21.51	18.63	41.00	880.00	357.93	443.63
Cd	ppm	0.020	0.21	0.19	0.53	0.62	0.07	0.01	24.72	0.08	0.46	0.19	0.22
Co	ppm	0.200	15.56	12.45	22.05	4.51	15.83	1.82	8.57	1.00	102.70	11.94	19.18
Cr	ppm	1.000	109.97	68.00	26.03	5.07	220.79	25.33	4.34	10.00	1426.00	59.52	160.43
Cu	ppm	0.020	20.79	20.87	0.52	0.59	7.21	0.83	25.13	6.08	42.91	19.14	22.44
Hg	ppm	0.010	0.08	0.02	56.35	7.19	0.27	0.03	2.62	0.01	2.21	0.02	0.14
Mo	ppm	0.050	1.18	0.89	34.98	5.32	1.33	0.15	7.77	0.19	10.62	0.88	1.48
Ni	ppm	0.100	130.68	56.70	27.95	5.22	308.66	35.41	3.69	7.80	2010.20	60.15	201.21
Pb	ppm	0.020	21.22	19.56	43.01	6.12	19.97	2.29	9.26	3.11	169.71	16.65	25.78
Sb	ppm	0.020	1.96	1.45	57.07	7.15	2.49	0.29	6.85	0.41	21.93	1.39	2.52
Se	ppm	0.300	0.35	0.30	12.30	3.35	0.14	0.02	21.53	0.30	1.10	0.32	0.39
Sn	ppm	0.100	1.74	1.80	0.29	0.22	0.74	0.09	20.49	0.20	4.10	1.57	1.91
Sr	ppm	1.000	595.41	379.50	14.99	3.51	670.16	76.87	7.75	73.00	4320.00	442.27	748.54
Ta	ppm	0.100	0.63	0.70	-0.65	-0.32	0.24	0.03	23.22	0.10	1.10	0.58	0.68
Tl	ppm	0.050	0.44	0.46	0.53	0.46	0.18	0.02	21.71	0.11	1.02	0.40	0.48
U	ppm	0.100	2.20	2.10	34.67	4.99	1.12	0.13	17.15	0.80	10.20	1.95	2.46
V	ppm	1.000	62.93	62.00	-0.16	-0.16	20.86	2.39	26.30	13.00	105.00	58.17	67.70
Zn	ppm	0.200	56.60	57.25	-0.17	0.14	18.25	2.09	27.04	16.60	100.00	52.43	60.77

In addition, strong positive correlations exist between many element pairs. According to their strong positive correlations, Al, Ti, Ta and Tl may be referred to act together. Likewise, a significant association among Cr, Ni, Mg and Co may be mentioned. On the other hand Ca, with almost all other elements, is negatively correlated, and Ca acted independently from the other main components.

A cluster analysis dendrogram was prepared to determine the association of elements and this showed a strong and very strong correlation (Fig. 4). At first view, four groups can be distinguished in the dendrogram. The first of these groups is the Mg-Cr-Ni-Co group. For these components to occur in the same group shows that they may be associated with ophiolitic rocks outcropped in the southwest of the study area.

The second group is the toxic metals group, represented by Hg-Pb-Sb-As (Fig. 4). These elements generally have higher values in the north of the study area. Mercury, produced in the past in the Sızma area, and Sb, As and Pb enrichments, thought to be associated with this, are also present. Therefore, these elements had been emerged from the Sızma area and dispersed to near environs.

The third group, which is defined as the main component and the heavy element group, is divided into several different sub-groups. In the main component subgroups, the most prominent group is the Ti-V-Al-Ta-K-Sn (-Tl (-Ba)) subgroup (Fig. 4). The Cu-Zn (-P) subgroup was added to this group, and Fe-Mn and Mo-U (-Cd) subgroups were added with lower coefficients. When looking at the overall distribution of these sub-groups, which elements among found strong positive correlations located in the same group have been seen. The last group in the dendrogram is represented by Ca-Sr; S and Se were subsequently added to this group. Ca does not have a positive correlation with any elements except Sr. This behaviour of Ca and Sr shows the effect of industrial activity, as well as natural factors, on the distribution of elements.

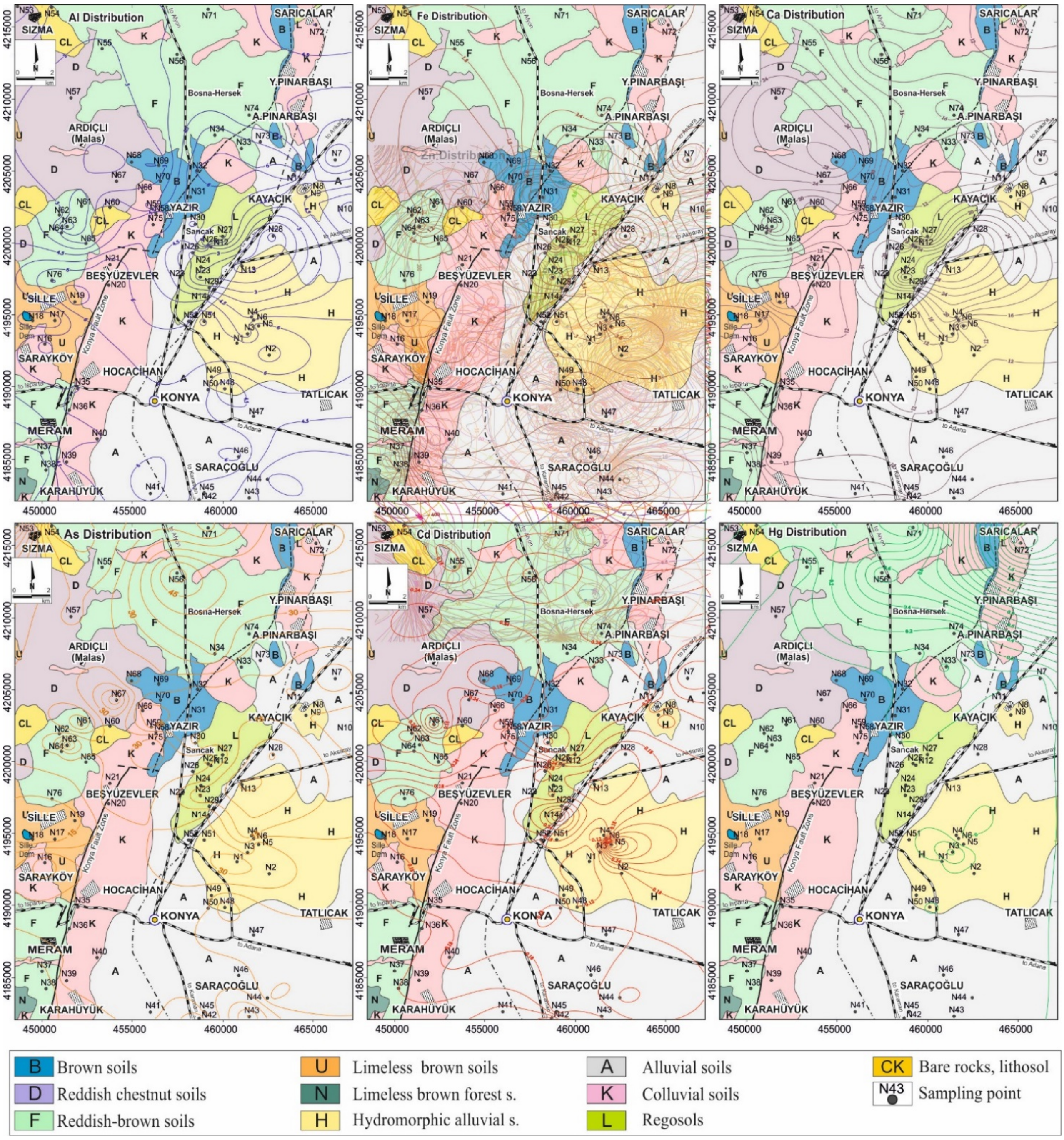

Figure 2. Al, Fe, Ca, As, Cd and Hg distributions of the soils around the Konya

To sustain their lives, humans have carried out many activities that have caused undesirable pollution in the environment and soil. In particular, pollution caused by mining and agriculture is well known (Lottermoser et al., 1998, Krüger & Gröngröft 2003, Komatina 2004, Selinus et al., 2004, Kabata Pendias & Pendias 2001, Essington 2005).

According to Selinus et al., (2004) major human activities that cause environmental and soil pollution include mining (production, drilling, smelting and refining processes), power generation (fossil, nuclear, geothermal etc.), other industrial and production activities (metallurgy, chemicals, cement, ceramic, glass, plastic, paint etc.), household waste (garbage, ash, sewage), agricultural activities (fertilizer, insecticides, consumption of fossil fuels), transport (use of motor vehicle), and the supply of water for drinking and using (purification and distribution). Heavy metals are discriminating factors for identifying a specific flora of polluted soil. A bioindicative value has been identified for some species that grow in soils polluted by heavy metals northeast-Algeria. The presence of one of these five species or the presence of all of them (*Calicotome spinosa*, *Cistus monspeliensis*, *Lamarckia aurea*, *Verbascum sinuatum*, *Rumex bucephalophorus and*

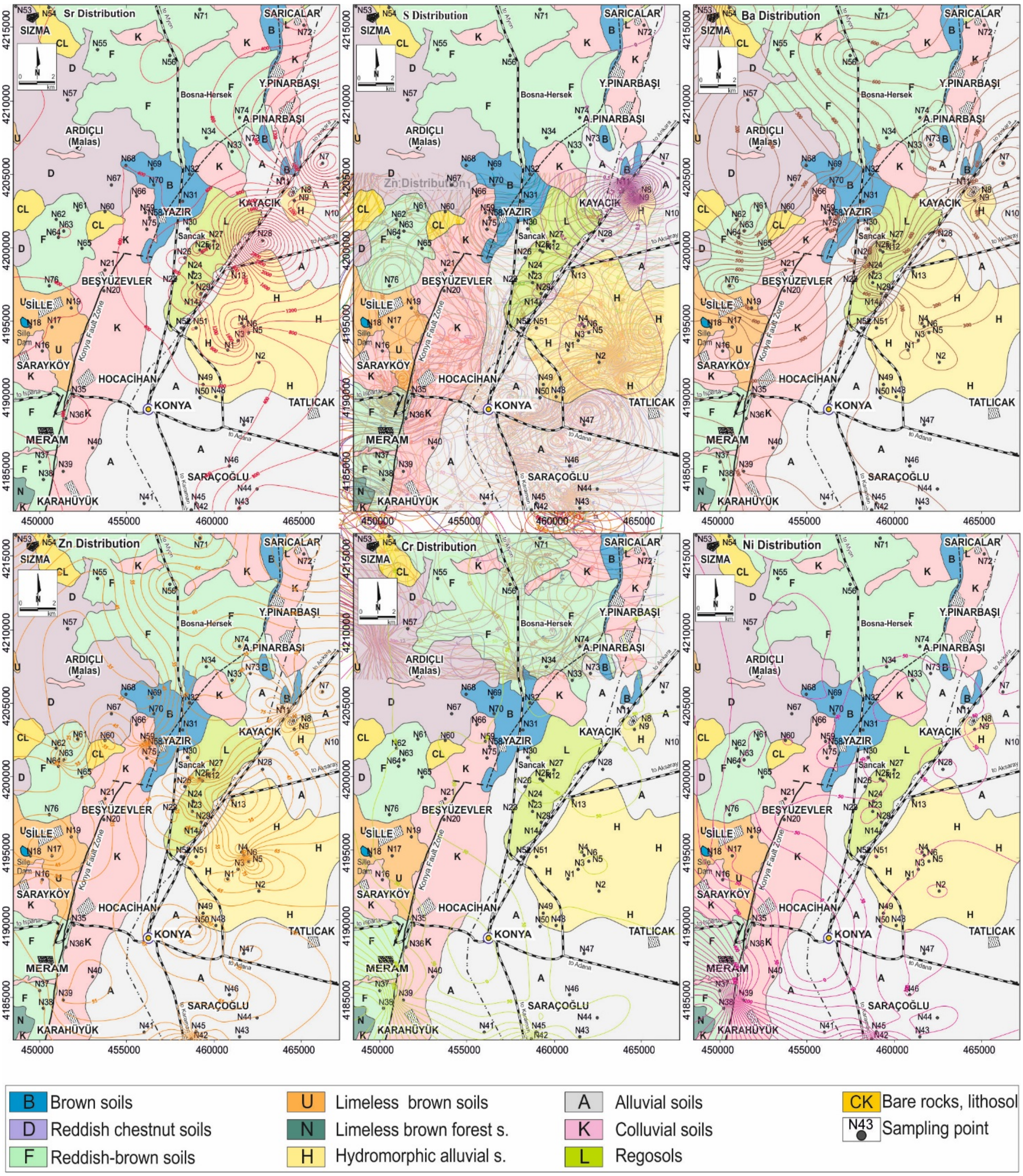

Figure 3. Sr, S, Ba, Zn, Cr and Ni distributions of the soils around the Konya

Trifolium compestre) may indicate metal pollution in the minefields (Lehout et al., 2018).

All of these activities are performed extensively in Konya. Accordingly, in Konya city centre the concentration of some elements is caused not only by geological structure and mineral deposits, but also by human activity.

According to Kurt (2018), in Mersin province east of the work he has taken samples taken 15 cm and 100 cm. The analysis found that the concentrations of heavy metals such as V, Cr, Mn, Fe, Co and Ni were similar at the top and bottom. These elements originate from ophiolitic rocks located northern Mersin Province. The fact that concentrations of heavy metals such as V, Cr, Mn, Fe, Co and Ni are similar in the upper and lower soil indicates that these elements are of lithological origin. He stated that these elements originate from ophiolitic rocks in northern Mersin Province.

The soils in the study area were compared with Soil Pollution and Control Regulations (ÇOB 2001) and acceptable levels in different regions of the world (Table 3).

The soils in Konya exceed the highest permissible levels of As, Cr and Ni in Austria, Poland, Germany, the European Union, Russia, England and the USA, (Kabata Pendias & Pendias 2001) together with Turkey (ÇOB 2001). In addition, high values of Co, Mo, Pb and Sb created a risk factor for human health in some areas of the city. Especially Sr has quite high values in the city centre, did not focus on in other studies.

The average values for elements examined in a number of studies (Komatina 2004, Selinus et al., 2004,

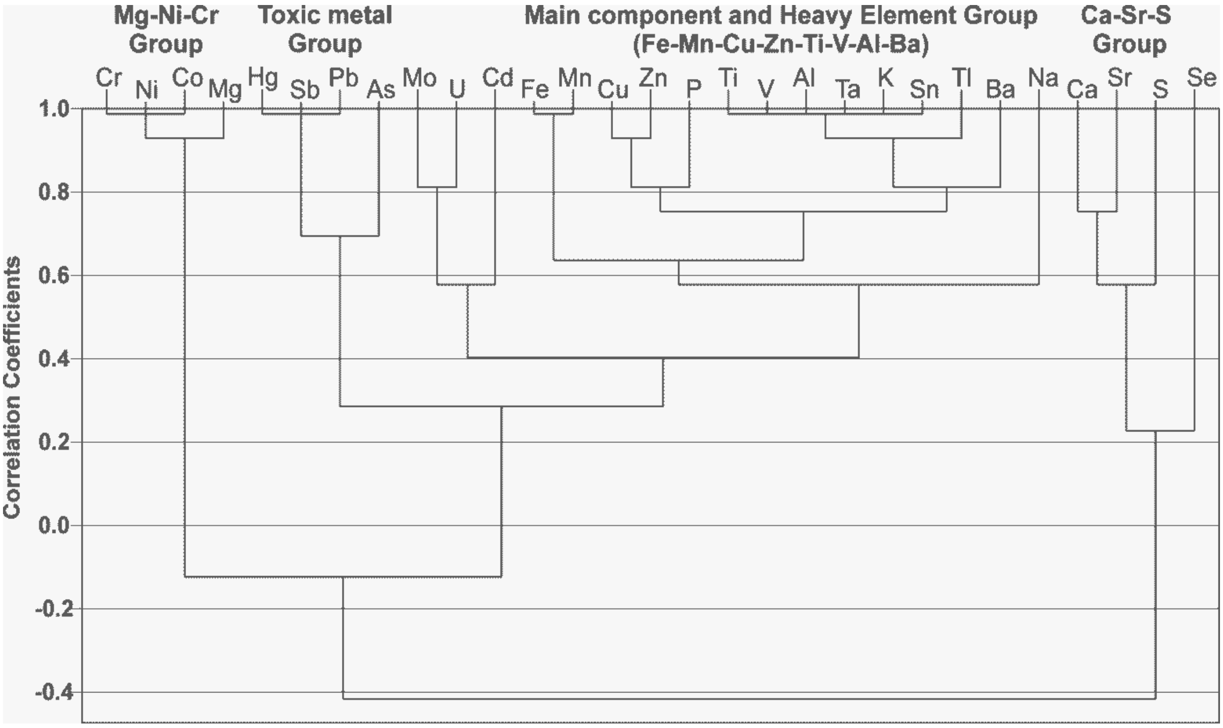

Figure 4. Cluster analysis dendrogram prepared according to the simple correlation coefficient in soil samples

Table 3. Comparing with maximum limit values given for some elements in soils in our country (ÇOB 2001) and in different countries (Kabata Pendias & Pendias 2001) and the resulting values of this study (in italics: given values for Turkey; bold: higher values).

Country/ Year	*Maximum allowable element values of soils in different countries and Turkey*										Present study	
	Austria	**Poland**	**Germany**		**European Union**	**Russia**	**England**	**USA**		***Turkey***		
Element	**1977**	**1977-1993**	**1984**	**1992**	**1986**	**1986**	**1987**	**1988**	**1993**	***2001***	**Average**	**Maximum**
As	50	30	20	-	-	2	10	14	-	*20*	**22.3**	**67**
B	100	-	25	-	-	-	-	-	-			
Be	10	10	-	-	-	-	-	-	-		1.7	3
Cd	5	1–3	3	1.5	1–3	-	3–15	1.6	20	*1*	0.2	0.5
Co	50	50	-			-	-	20		*20*	16	**103**
Cr	100	50–80	100	100	50–150	0.05	-	120	1500	*100*	**110**	**1426**
Cu	100	30–70	100	60	50–140	23	50	100	750	*50*	21	43
F	500	-	200	-	-	-	-	-	-			
H		5	2	1	1–1.5	2.1	-	0.5	8			
Mo	10	10	-	-	-	-	-	4	-	*10*	1.2	**10.6**
Ni	100	30–75	50	50	30–75	35	20	32	210	*30*	**131**	**2010**
Pb	100	70–150	100	100	50–300	20	500–2000	60	150	*50*	21	**170**
Sb	-	10	-	-	-	-	-	-	-		2	**22**
Se	10	10	10	-	-	-	-	1.6	-	*5*	0.4	1.1
V	-	150	-	-	-	150	-	-	-		63	105
Zn	300	100–300	300	200	150–300	110	130	220	1400	*150*	57	100
Ba										*200*	**401**	**880**
Hg										*1*	0.1	**2.2**
Sn										*20*	1.7	4.1
Tl										*1*	0.4	1.0

Table 4. Comparing with the analyzed elements in soils in around of Konya and the results of the studies in different regions of the world (*Italics*: average values of the world; **bolds**: higher values).

Element	**Previous studies**						**Average of**	**Present study**	
	1	**2**	**3**	**4**	**5**	**6**	**Previous studies**	**Average**	**Maximum**
Al (%)					7.10		*7.10*	4.43	**7.17**
Fe (%)		3.80		3.20	4.00		*3.67*	2.43	**5.71**
Mg (%)		0.50			0.50		*0.50*	2.44	**14.49**
Ca (%)		1.37			1.50		*1.44*	**15.56**	**32.25**
Na (%)		0.63			0.50		*0.57*	0.31	**0.92**
K (%)		0.83			1.40		*1.12*	**1.31**	**2.49**
Mn (%)	0.04	0.04	0.04		0.10	0.08	*0.06*	0.05	**0.12**
Ti (%)	0.45	0.35	0.80	0.50	0.50		*0.52*	0.21	0.33
P (%)		0.06			0.08		*0.07*	0.06	**0.19**
S (%)		0.07			0.08		*0.07*	**0.20**	**7.08**
As (ppm)	2.00	5.80	7.65		6.00	30.00	*10.29*	**22.31**	**66.80**
Ba (ppm)		500.00	413.00		500.00		*471.00*	400.78	**880.00**
Cd (ppm)		0.58	0.53	0.60	0.35	0.60	*0.53*	0.21	0.46
Co (ppm)	9.00	7.90	7.90	12.00	8.00	14.30	*9.85*	**15.56**	**102.70**
Cr (ppm)	130.00	54.00	61.00	84.00	70.00	73.00	*78.67*	**109.97**	**1426.00**
Cu (ppm)	27.50	18.00	19.20	26.00	30.00	32.00	*25.45*	20.79	**42.91**
Hg (ppm)		0.03	0.11	0.10	0.06		*0.08*	0.08	**2.21**
Mo (ppm)	1.50	1.80	1.82		1.20		*1.58*	1.18	**10.62**
Ni (ppm)	55.00	20.00	22.00	34.00	50.00	26.30	*34.55*	**130.68**	**2010.20**
Pb (ppm)	18.00	32.00	28.60	29.00	35.00	54.00	*32.77*	21.22	**169.71**
Sb (ppm)								1.96	21.93
Se (ppm)	0.01	0.33	0.33		0.40		*0.27*	0.35	**1.10**
Sn (ppm)				5.80			*5.80*	1.74	4.10
Sr (ppm)			147.40		250.00		*198.70*	**595.41**	**4320.00**
Ta (ppm)								0.63	1.10
Tl (ppm)								0.44	1.02
U (ppm)								2.20	10.20
V (ppm)	100.00	58.00	70.80	108.00	90.00	86.00	*85.47*	62.93	**105.00**
Zn (ppm)	50.00	64.00	64.00	60.00	90.00	131.00	*76.50*	56.60	**100.00**

1. Iskandar & Birkam, 2001; 2. Kabata-Pendias & Pendias, 2001; 3. Komatina, 2004; 4. Selinus et al., 2004; 5. Essington, 2005; 6. Mirsal, 2008

Kabata Pendias & Pendias 2001, Mirsal 2008, Essington 2005, Iskandar & Birkham 2001) was found by handling some of these elements. However, the elements Sb, Te, Tl and U discussed in this study have not been studied in other research (Table 4). The average levels of Ca, K, S, As, Co, Cr, Ni and Sr in the soils surrounding Konya are higher than in other regions of the world (Table 4). Concentrations of Al, Fe, Mg, Na, Mn, P, Ba, Cu, Hg, Mo, Pb, Se, V and Zn exceed the world average in some samples.

In different countries, various elements and the values of their acceptable limits are updated over the years (Table 4). Although acceptable levels of the elements in Turkey are close to the levels of other countries, limit values of the some elements in practice was not given. Therefore, it needs to be updated of scope and ranges of the limit values also in Turkey.

4. CONCLUSIONS

Konya city centre, with a dynamic population of over one million, is a rapidly developing town with intensive agricultural and industrial activities. In large agricultural areas of central Anatolia different types of fertilisers and pesticides are used to produce crops such as grain, corn, sugar beet and sunflower. In addition, intensive industrial activities support agriculture. In a significant area of the plains, industrial sites exist for the motor vehicle industry, and the manufacturing and supply of materials for industrial activities are also carried out. Furthermore, Konya is an important junction for transportation routes across Turkey.

There are active and abandoned sand quarries, crushed stone and curb production facilities to the north of Konya. Also, on the Konya – Ankara way, there is a cement factory and a lot of clayey limestone and limestone aggregate quarries. There are abandoned mercury deposits, local Fe, Pb, Zn and Cu anomalies in volcanic rocks, and many volcanic covering stones, trass and clay quarry are found in the northwest of the area. Local Cr, Fe and Ni enrichments, as well as large magnesite deposits, are located in the ultramafic rocks in the southwest of the area.

In the Konya residential area, depending on mentioned above agricultural, industrial and mining activities, Cr, Ni, Co, Mg, As, Hg and Sr are higher than that of the Turkey Regulations and the values of limit in agricultural soils in different regions of the world and average values of the studies carried out for research in different regions of the world. Some of the elements examined (Al, Fe, Ca, K, Na, S, P, Ba, Cu, Mo, Pb, V and Zn) exceed the above standards in certain areas of the city.

Detailed soil studies are needed for Ag, As, Ba, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, Tl and Zn and their toxicity disclosed In the enrichment regions. In terms of environmental pollution and public health it is important to compare samples of water and plants to determine the effects of these metals on the local ecosystem.

Intensive industrial facilities are located to the east of the Konya-İstanbul highway, which is the most important transport artery towards the north from the city centre. Materials used in industry, and its waste, constitute a risk for residents. Therefore, within a medium-term plan, industrial facilities should be subject to periodic geochemical controls and transported to an appropriate region rather than the city centre. In planning areas of city expansion, comprehensive mineralogical - geochemical surveys should be carried out, and risk areas identified in geological – geotechnical studies based on reconstruction plans, together with the other physical limitations including geological and geochemical characteristics.

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Conflicts of interest

We have no conflicts of interest to disclose. We have been declared and used guidelines for defining authors of the Journal of Environmental Monitoring and Assesment.

REFERENCES

Akçay, M., 1998. *Element distribution profiles and gold-silver and base metal potential of the environments of Ladik-Sızma (Konya) mercury deposits geochemical and statistical approach*. Turkey Bulletin of Geology, 41(1), 37-47.

Apostoae L, 2016, *Heavy Metal Contents in The Soıl Of the Botanıcal Garden In Iaşı, Romanıa*, Carpathian Journal of Earth and Environmental Sciences, Vol. 11, No 2, p. 519 – 528.

Arık, F. & Nalbantçılar, M.T., 2005. *Negative effects of ore deposits West of Kütahya on the surface and groundwater. UCTEA Chamber of Geological Engineers, 58th Geological Congress of Turkey*. Extended Abstracts, 11-17 April 2005, 259-260.

Arık, F. & Öztürk, A., 2011. *Konya's natural resources and potential.* I. Konya City Symposium, UCTEA Konya Chamber of the City Council, Konya 2011, Proceedings, 161-174.

Arık, F. & Yaldız, T. 2010. *Heavy metal determination and pollution of the soil and plants of Southeast Tavşanlı (Kütahya, Turkey).* Clean, Soil, Air, Water, 38 (11), 1017–1030.

Arık, F., Yaldız, T., Nalbantçılar, M. T. & Arslan, Ş. 2009. *Heavy metal pollution depending of metallic ore deposits in the area among Köprüören, Çobanköy and Köreken (Kütahya).* Ist. Medical Geology Workshop, Urgup, Proceedings, 110-126.

Besang, C., Eckhardt, F.J, Harre, W., Kreuzer, H. & Moller, P. 1977. *Radiometricshe altersbestimmungen an Neogenen eruptivgesteinen der Turkei.* Geol. Jb. (B25), 3-36.

Camm, G.S., Glass, H.J., Bryce, D.W. & Butcher, A.R. 2004. *Characterization of a mining-related arsenic-contaminated site*. Cornwall, UK. Journal of Geochemical Exploration, 82, 1 –15.

Chang, P., Kim, J.-Y. & Kim, K.W. 2005. *Concentrations of arsenic and heavy metals in vegetation two abandoned mine tailings in South Korea*. Environmental Geochemistry and Health, 27, 109-119.

Clark, M.W., Walsh, S.R. & Smith, J.V. 2001. *The distribution of heavy metals in an abandoned mining area; a case study of Strauss Pit, the Drake mining area, Australia: implications for the Environmental management of mine sites.* Environmental Geology, 40 (6), 655-662.

ÇOB 2001. *Soil Pollution and Controlling Regulation of Turkey*. Official Newspaper, number 24609 dated 10.12.2001 cevreorman.gov.tr/yasa/y/25831.doc, Accessed 14 November 2013.

De Vivo, B., Belkin, H.A. & Lima, A. 2008. *Environmental Geochemistry, Site Characterization, Data Analysis and Case Histories.* Elsevier, 429 pp.

Diawara, M.M., Litt, J.S., Unis, D., Alfonso, N., Martinez, L.A. Crock, J.G., et al 2006. *Arsenic, cadmium, lead and mercury in surface soil, Puablo, Colorado; implications or pollution healty risk.* Environmental Geochemistry and Health, 28, 297-315.

Eren, Y. 1993**.** *Stratigraphy of autochthonous and cover units of the Bozdağlar massif NW Konya.* Geological Bulletin of Turkey, 36, 7-23

Essington, M.E. 2005. *Soil and water chemistry: an integrative approach,* ISBN: 0-8493-1258-2, CRC ress, Boca Raton London New York Washington, D.C. 534 pp.

Göğer, E. & Kıral, K. 1969. *Geology around the Kızılören (West of Konya),* MTA Report Number, 5204 (unpublished)

Görmüş, M. 1984. *Geological investigations around the Kızılören (Konya).* Selçuk University, Graduate

School of Natural Sciences, Msc thesis, Konya 67 pp. (unpublished).

Güzel, A., Nalbantçılar, M.T., Yıldırım, Ö. S., Murathan, A. & Gökay, M.K. 1998. *Contamination Around Abandoned Sızma (Turkey) Mercury Mine.* 1st International Workshop on Environmental Quality and Environmental Engineering in The Middle East Region, Selcuk Univ. Environmental Engineering Dept. Konya Turkey,601-608

Hakyemez, H.Y., Elibol, E., Umut, M., Bakırhan, B., Dağıstan, H., Metin, T. et al. 1992. *Geology of the Çumra Akören (Konya)*. MTA Report Number: 9449, 63 pp. Ankara.

Horasan, B.Y. 2005. *Hydrothermal alteration related to Sızma (Konya) mercury deposits.* Selçuk University, Graduate School of Natural Sciences, Msc thesis, Konya 61 p.

Iskandar, I.K. and Birkham, M. B. 2001. *Trace elements in soil: bioavailability, flux, and transfer.* SBN 1-56670-507-X, Lewis Publishers, Boca Raton London New York Washington D.C. 286 pp.

Jung, D. & Keller, J. 1972. *Die jungen vulkanite im raumzwischen Konya und Kayseri (Zentral-Anatolien).* Z. Deutsch. Geol. Ges., 123, 503-512.

Kabata-Pendias, A. & Pendias, H. 2001. *Trace Elements in Soils and Plants,* 3.th. edition, CRC press LLC 413 pp.

Keller, J., Jung, D., Burgath, K. & Wolff, F. 1977. *Geologie und petrologie des Neogenen kalkalkali vulkanismus von Konya (Erenlerdağı-Alacadağ Massiv, Zentral Anatolien).* Geol., Jb., B25 37-117.

Ketin. İ. 1966. *Tectonic units of Anatolia.* Journal of MTA, 66, 23-34.

KHGM, 1987. *The land aménagement planning of Turkey, Ministry of Agriculture and Rural Affairs*. General Directorate of Rural Services., Ankara.

Komatina, M.M. 2004. *Medical Geology – Effects of Geological Environments on Human Health. Developments in earth Environmental Sciences*. Elsevier Academic Press, 488 pp.

Krüger, F. & Gröngröft, A. 2003. *The difficult assessment of heavy metal contamination of soils and Plants in Elbe River Floodplains.* Acta Hydrochim. Hydrobiol. 31(4–5), 436–443.

Kurt M.A., 2018. *Comparison of Trace Element and Heavy Metal Concentrations of Top and Bottom Soils In A Complex Land Use Area.* Carpathian Journal of Earth and Environmental Sciences, 13(1),47 – 56.

Lehout, A., Charchar,N., Nourıne,H., & Bouyahmed, H., (2018), *The Effect Of Heavy Metals On Plant Communıtıes Dıstrıbutıon In An Abandonend Mınıng Area (Northeast-Algerıa)* Carpathian Journal of Earth and Environmental Sciences, 13, (1), p. 37 – 45.

Lottermoser, B.G., Ashley, P.M., Muller, M. and Whistler, B.D. 1998. *Metal contamination due to mining activities at the Halls Peak massive sulphide deposits, New South Wales. In: Ashley PM, Flood PG (eds) Tectonics and metallogenesis of the New England Orogen.* Geol Soc Australia Spec Publ 19, 290–299.

Mirsal, I.A. 2008. *Soil Pollution, Origin, Monitoring and Remediation*. 2nd Edition, ISBN: 978-3-540-70775-2, Springer-Verlag Berlin Heidelberg, 311 pp.

Motorcu, A. 1987. *Mercury deposits of Ladik - Sızma (Konya) province. Graduate School of Natural Sciences*. Msc thesis, Konya, Thesis abstracts 237-238.

Nalbantçılar, M.T. 2002. *Groundwater quality and pollution of the Konya residential area, Selcuk University, Graduate of Natural and Applied Sciences*. PhD thesis, Konya, 117pp.

Okay, A.I. 1986. *High-pressure/low temperature metamorphic rocks of Turkey*. In blueschists and eclogites, The Geol.Soc of Amer., Mem. 164, 338-348.

Özcan, A., Göncüoğlu M. C., Turhan, N., Uysal, S., Şentürk, K. and Işık, A. 1988. *Late Paleozoic Evolution of the Kütahya-Bolkardagi Belt.* METU Journal Pure and Appl. Sci. Series A Geosciences, 21(1-3), 211-220.

Özgül, N. 1976. *Some basic geological features of the Taurus Mountains.* Bulletin of Geological Society of Turkey, 19, 5-78.

Öztürk, A. & Baykal, A. 2012. *Heavy and Precious Metal Exploration using with Geophysical Methods in The Ophiolitic Rocks Exposed Hatıp-Çayırbağı (Meram-Konya) Region.* Journal of Fac. Eng.Arch. Selcuk Univ., 27(4) 149-167.

Roberst, N. 1982. *Age, palaoenvironments and climatic significance of late Pleistosen Konya Lake, Turkey*. Quaternary Research, 19, 154-171.

Romero, F.M., Armienta, M.A. Hernandez, G.G. 2007. *Solid-phase control on the mobility of Potentially toxic elements in an abandoned lead/zinc mine tailings impoundment,Taxco, Mexico*. Applied Geochemistry, 22 109–127.

Selinus, O., Alloway, B., Centeno, J.A., Finkelman, R.B., Fuge, R. 2004. *Essentials of Medical Geology, Impacts of the Natural Environment on Public Health,* Elsevier Academic Press, 812 pp.

Sparks, D.L. 2005. *Toxic metals in the environment: The Role of Surfaces*. Elements, 1, 93–97.

Tunçez, S. & Candan, E. 2008. *Konya provincial environmental status report,* Republic of Turkey, Ministry of Environment and Urban Planning EIA Konya Provincial Directorate of Environment and Urban Services Department 381 p.

Wiesner, K. 1968. *Studies on the Konya mercury deposits.* Journal of MTA, 70, 178-213.

Wilson, L.M.D. 2012. *Toxic Metals and Human Health.* http://www.lef.org/protocols/index. htm?fc=2#toxic, Accessed 14 September 2012.

Yokel, J. & Delistraty, D.A. 2003. *Arsenic, lead, and other trace elements in soils contaminated with pesticide residues at the Hanford Site (USA).* Environmental Toxicology, 18, 104–114.

Zedef, V. 1994. *Origin of Magnesite In Turkey, A Stable Isotope Study.* University of Glasgow, PhD thesis, 175pp.

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