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Investigation of Metal Pollution in Soil Samples Between Akoluk, Mehmetbeyli and Temrezli Villages (Yozgat – Sorgun), Turkey

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Abstract

The study area is located in Kirsehir Turkey's blog from the tectonic units and Tertiary has been observed that epigenetic occur in the sedimentary units. Uranium mineralization is located between Akoluk, Mehmetbeyli and Temrezli Villages of Sorgun district of Yozgat. The unit consisting of conglomerate, sandstone and mudstone alternations (Paleson aged) is located on granites and the youngest unit in the region is Quaternary alluvium. 20 soil samples were taken to investigate the pollution dimensions, possible sources and spatial distribution of the elements, in the soil samples in the study area. In this study, the relationship between element values obtained by geochemical analysis (As, Cr, Cu, K, Mn, Ni, Pb, Th, U, V, Zn and Zr) was investigated statistically. A positive correlation was observed between Cr-Zn, Cu-Ni, K-Mn, Mn-Pb, Mn-Th, Mn-V, Mn-Zr, Pb-Th, Pb-V, Pb-Zn, Pb-Zr, Th-U, Th-V and U-V elements in soil samples ($p < 0.01$; $p < 0.05$). The average shale values were considered as background values in determining the metal pollution dimensions in soil samples. Enrichment factors (EF), geoaccumulation index (Igeo), Contamination factors (CF) and pollutant load index (PLI) were calculated to determine the pollution dimensions of the elements. According to the results of the analysis, the average values of Cr, Fe, U, V and Zr were below the average shale values of the world. For each element examined, the mean EF values K, Mn (in all samples), Ni (in samples 9, 16 and 17), and Zn (in samples 5, 8, 10, 14, 16 and 17) were extremely enrichement. Contamination factor values As (in all samples) elements in terms of considerably contamination and contamination were detected. Since the PLI values (except example 17) were > 1, all elements were found to contaminate the study area. According to the results obtained, the average values of the elements in the study area are K > Mn > Zn > Ni > Pb > V> Cu > As > Th > Zr > Cr > U.

Keywords: Enrichment factor; Geoaccumulation index; Pollution; Soil.

Introduction

Since uranium (U) is widely used in the nuclear industry, global demand has increased. Uranium has become an important energy mineral in the world in the last sixty years.[1] However, harmful metals in uranium mining and mining wastes caused environmental pollution.[2] Plants from polluted soils pick up these metals and can pass through the food chain to humans and animals. This metal is toxic and can cause cancer in living things because it generates radiation.[3,4]

The uranium content of the soil has values ranging from 1 to 8 ppm and an average of about 1 ppm. It can be seen in uranium-rich areas over 100 ppm. In normal soils, the A horizon is the richest zone of uranium because it differs from humic materials, clay-humic complexes, humic-iron and humic-silicate complexes. In uranium-

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containing soils, however, the B horizon may be slightly enriched relative to the A horizon as it contains and/or separates, for example, hydroxides and aqueous oxides of iron, manganese, aluminum. The C horizon above the uranium deposits is the richest in mineral content.[5]

Soil pollution has been an important environmental issue in both developed and developing countries, particularly on land use.[6] Heavy metals are particularly important because they are toxic, carcinogenic and persistent in the environment. According to researches, heavy metals have high atomic weight and have a density of at least five times higher than water and are naturally occurring.[7] In the environment, heavy metals are distributed spatially in the form of mineralization.[8] Numerous domestic, industrial, medical, agricultural and technological applications have led to the spread of heavy metals into the environment, resulting in increased potential impacts on human health and the environment. Heavy metal accumulation in soil consists of both anthropogenic activities and lithogenic sources.[9] Two major sources of heavy metal pollution have been identified: natural resources such as erosion of rocks and thermal waters, or anthropogenic sources involving mining and related industries.[10,11]

Heavy metal deposits and accumulation studies have gained importance as heavy metals in soils can have negative effects on human health and environment.[12–15] While environmental pollution caused by heavy metals is caused by many activities, pollution caused by heavy metals in the soil system is mainly caused by natural processes such as decomposition of minerals, as well as anthropogenic activities related to industry, agriculture, combustion of fossil fuels, vehicle emissions and mining. In the environmental pollution study, some parameters are used to estimate how much soil is affected by heavy metals (either natural or anthropogenic).[16, 17]

Heavy metal pollution is a global problem that concerns all societies.[4] Methods such as enrichment factor (EF), geoaccumulation index (Igeo), contamination factor (Cf) and pollution load index (PLI) are widely used to assess the level of heavy metal pollution.[4,18–22,]

The aim of this study is to define the sources of pollution in the study area, and to determine the natural and anthropogenic pollution geochemically.

Geology of the Study Area

The study area is located within the boundaries of Sorgun district of Yozgat province in the Central Anatolia Region and is bordered by Mehmetbeyli in the north, Şahmuratlı in the west, Temrezli in the south and Akoluk villages in the east (Fig. 1). When the work is discussed in terms of a wider regional scale geological, tectonic units of Turkey[23] shows that take place in Kirsehir Blog. It was identified as Yozgat Batolite and/or Yozgat Intrusive Complex in the previous studies and is located on the northern edge of the Crystalline Complex of Central Anatolia.[24–26]

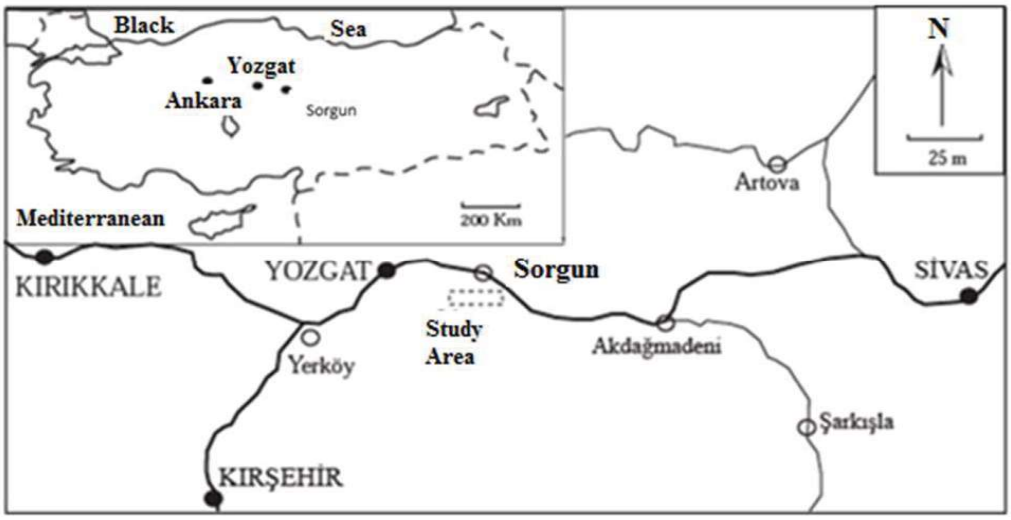

Fig. 1: Location map of the study area.

The uranium mineralization in the region occurred epigenetically in the Tertiary aged sedimentary units in the Sivas Basin. On the granite foundation, Paleocene aged conglomerate, sandstone, mudstone alternation is located. Eocene aged coarse and fine grained sandstone, siltstone and claystone are unconformably overlain by this unit. Andesitic and basaltic volcanics formed by the volcanism formed at the end of Eocene cover all these units in places. Pliocene aged limestones overlie the volcanics. Quaternary aged alluvial cover overlies all of these units (Fig. 2).[27]

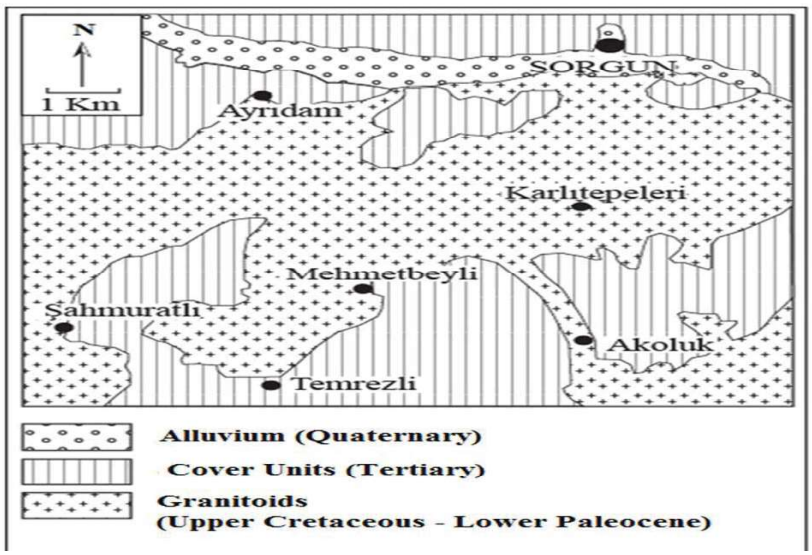

Fig. 2: Geological map of the study area.

Sampling and Analysis Methods

In this study, soil samples taken from a depth of 25–30 cm were collected by sieving a 2 mm sieve first and cleared from coarse-grained rock fragments and plant remains. It was then brought to the laboratory and dried at room temperature (Fig. 3).

Fig. 3: A photograph of the soil samples drying in the laboratory.

For homogeneous sampling, all samples were milled to 10 micron size. 0.1 g of soil samples were taken and 2 ml of concentrated HNO_3 were added and dried on the heater. The solvent was prepared from a mixture of HCl + HNO_3 + H_2O (1 : 1 : 1 from each acid). This solvent was diluted by adding distilled water to 500 ml until complete. 20 ml of this diluted mixture was added to each sample to dissolve the samples. These dissolved samples were filtered using filter paper and made ready for analysis.

Elemental analysis of soil samples were performed by Inductively Coupled Plasma—Mass Spectrophotometer (ICP-MS) and BILTEM (Yozgat Bozok University, Science and Technology Research and Application Center).

LOD values (ppb); As: 0.0414, Cr: 0.0426, Cu: 0.0149, K: 8.5567, Mn: 0.2822, Ni: 0.0106, Pb: 0.0136, Th: 0.0038, U: 0.0008, V: 0.1107, Zn: 0.6098 and Zr: 0.0158.

Statistical and Computational Analysis

Various methods and factors are used to assess heavy metal pollution around the mineral deposits.[28] In this study, selected environmental pollution parameters are enrichment factor (EF), contamination factor (CF), geo-accumulation index (Igeo) and pollution load index (PLI).

Enrichment Factor

Enrichment factor (EF) is an index commonly used to determine anthropogenic and natural effects on soils.[28–31] This factor is calculated based on a normalized element (Fe).[32,33] Since Fe is of lithogenic origin in this index, it has been used as a normalizing element and will not affect the importance of the metals to be investigated.[34–36] This factor compares with the concentration of one element in the samples to the concentration of the same element that is not contaminated.[28,37] The enrichment factor is calculated as follows to determine the anthropogenic and natural effects in the samples

$$EF = (Cn/Bn)\ sample/(Cref/Bref)$$

Cn: metal concentration in the sample

Cref: metal concentration in the reference sample

Bn: metal concentration of the Fe in the sample

Bref: metal concentration of the reference Fe in the reference sample

Five contamination categories are assigned on the basis of the enrichment factor;

EF < 2 minimal enrichment

EF = 2 – 5 Moderate enrichment

EF = 5 – 20 Significant enrichment

EF = 20 – 40 Very high enrichment

EF > 40 Extremely high enrichment.[36,38,39]

Geoaccumulation Index

Since the geoaccumulation index (Igeo) is first calculated by Muller (1979), it is also called Muller index.[40] The Muller index is used to determine the amount of contamination caused by heavy metals in the soil. This index is divided into six classes using the following equation between polluted and non-polluted soils.[28,30]

$$Igeo = \log_2 (Cn/1.5\ Bn)$$

Cn: is the measured metal concentration,

Bn: is the background level (average shale)

1.5: a value used to minimize the impact of possible changes.

The degree of pollution is divided into seven different pollution classes.[41]

Igeo < 0 unpolluted

0 < Igeo < 1 unpolluted to moderately polluted

1 < Igeo < 2 moderately polluted

2 > Igeo < 3 moderately to strongly polluted

3 > Igeo < 4 strongly polluted

4> Igeo< 5 strongly to very strongly polluted

5 > Igeo very strongly polluted.[42]

Contamination Factor

The contamination factor (CF) indicates the contamination rate of heavy metals in the soil.[28,43] This factor was calculated using the metal concentration studied with the world shale mean of the metal.[36,44]

This factor is calculated using the following equation.

$$CF\ metal = C\ metal/C\ background$$

C metal: Metal value in the sample

C background: Background value of the metal

Four grades of CF have been classified;

1 ≤ CF low contamination,

1 ≥ CF < 3 moderate contamination,

3 ≥ CF < 6 considerably contaminated,

6 ≥ CF highly contaminated.[36]

Pollution Load Index

The pollution load index (PLI) is often used to evaluate and estimate the degree of pollution in soils.[45] PLI can be calculated as the geometric mean of all metal concentrations. If the PLI concentration is close to 1, it indicates that these concentrations are close to the background concentration, while PLI concentrations above 1 indicate soil pollution.[46,47] Total heavy metal pollution is obtained using this index and from the following equation.[28,48]

$$PLI = (CF1 \times CF2 \times CF3 \times ... CFn)^{1/n}$$

$0 \leq PLI < 1$ unpolluted

$1 \leq PLI < 2$ lightly polluted,

$2 \leq PLI < 3$ moderately polluted

$(3 \leq PLI < 4)$ moderately to highly polluted

$(4 \leq PLI < 5)$, highly polluted

$(PLI \geq 5)$ very highly polluted.[49]

Results and Discussion

Table 1 shows the minimum, maximum, mean ± standard deviation (SD), median, mod, skewness and kurtosis of the statistical analysis results calculated for the element contents in soil samples in the study area. The concentration of uranium in uncontaminated soils ranges from 1.90–4.40 mg/kg.[49,50] Uranium concentrations found in this study were found in the range of 1.3 to 8.2.

Table 1: The statistical analysis results calculated for the element contents in soil samples in the study area

	Minimum	Maximum	Mean ± St. Dev	Median	Mode	Skewness	Kurtosis
As	33.6	56.1	43.89 ± 5.3	42.6	46.0	0.4	0.8
Cr	–5.1	35.9	9.685 ± 8.8	8.2	4.9	1.4	3.3
Cu	30.5	57.0	46.81 ± 6.9	49.3	49.3	–1.3	1.4
K	1588.7	8283.5	4279.7 ± 1461.7	4118.7	4247.8	0.9	2.0
Mn	217.0	1578.3	1064.9 ± 344.4	1054.6	983.4	–0.7	0.3
Ni	58.0	279.2	116.2 ± 50.8	109.1	120.5	1.9	4.9
Pb	22.5	104.6	63.9 ± 21.9	62.1	62.0	0.2	–0.2
Th	13.0	139.0	33.2 ± 27.7	26.7	15.1	3.3	12.1
U	1.3	8.2	2.7 ± 1.7	2.1	1.4	2.1	5.0
V	39.6	86.0	55.5 ± 12.3	53.5	45.1	1.1	0.8
Zn	70.9	236.0	143.1 ± 33.2	145.4	134.6	0.4	3.1
Zr	6.4	17.1	12.9 ± 2.9	13.6	13.5	-1.1	0.8

It was observed that K and Mn elements had the highest concentrations in the soil samples taken. Th,[51,52] As, Mn, Ni, Pb and Zn element values were found to be higher than average earth crust values and As, Cu, Mn, Ni, Pb, Th, U[53] and K[54] element values were higher than average shale values (Table 2).

Table 2: Average earth crust and shale values of As, Cr, Cu, Fe, Mn, Ni, Pb, V, Zn and Zr.[51–57]

Elements	As	Cr	Cu	Fe (%)	K	Mn	Ni	Pb	Th	U	V	Zn	Zr
Earth crust	1.8	100	55	5	18400[a]	950	75	13	2–20[c]	0.5–5[c]	135	70	165
Shale	13	90	45	4.7	2500[b]	850	70	20	10[d]	3[d]	130	95	180

The correlation coefficient between elements in soil samples was calculated using Sperman correlation matrix to quantitatively analyze and confirm the relationship between metals. Significant positive correlations between Mn-Pb, Mn-V, Th-V and Th-U metal pairs indicate a common origin, while weak positive correlations (such as As-V, Cu-Zn, U-Pb, Th-Zn, Th-Zr and U-Zn) indicate different origins (Table 3).

Table 3: Correlations between metals in soil samples in the study area.

	As	Cr	Cu	K	Mn	Ni	Pb	Th	U	V	Zn	Zr
As	1											
Cr	–0.097	1										
Cu	–0.063	0.438	1									
K	–.462(*)	0.14	0.266	1								
Mn	–0.286	0.006	0.19	.538(*)	1							
Ni	0.075	0.286	.501(*)	0.001	-0.059	1						

	As	Cr	Cu	K	Mn	Ni	Pb	Th	U	V	Zn	Zr
As	1											
Cr	–0.097	1										
Cu	–0.063	0.438	1									
K	–.462(*)	0.14	0.266	1								
Pb	–0.299	0.083	0.061	0.429	.878(**)	-0.196	1					
Th	–0.165	–0.152	–0.115	-0.038	.558(*)	-0.116	.591(**)	1				
U	0.111	–0.265	–0.313	–0.291	0.291	-0.083	0.298	.670(**)	1			
V	0.351	–0.106	0.043	0.006	.643(**)	0.117	.517(*)	.618(**)	.545(*)	1		
Zn	-0.337	.524(*)	0.353	0.307	0.425	–0.125	.536(*)	0.397	0.138	0.071	1	
Zr	0.196	0.22	0.384	0.378	.540(*)	0.243	.575(**)	0.239	–0.022	0.436	0.256	1

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

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

EF values for heavy metals in the investigated soils are given in Table 4. EF is an instrument used for the assessment of anthropogenic metal pollution. Potassium was the extremely high enrichment. The highest EF value for K was 1051.6 and ranged from 573.4 to 2216.9. The highest EF value of K was observed in Example 11. On the other hand, the mean EF values of Mn was 253.5, with K and Mn indicating the extremely high enrichment. The mean EF values for Ni and Zn were 29.8 (in the range 11.0–83.2) and 34.5 (in the range 25.5–47.1), indicating very high enrichment. The mean EF values of As, Cu, Pb, Th and V show significant enrichment ranging from 5 to 20. Average EF values of Cr and Zr range between 2 and 5 and moderate enrichment is observed. Uranium has the lowest average Ef value (0.6), varies between 0.3 and 1.5 and this value indicates that there is non-enrichment. The mean EF values increased in the order of K > Mn > Zn > Ni > V > Pb > Cu > As > Th > Zr > Cr > U (Table 4).[39]

Table 4: Enrichment factor (EF) of metals in the study area

S. No.	As	Cr	Cu	K	Mn	Ni	Pb	Th	U	V	Zn	Zr
1	8.5	1.4	7.4	668.7	226.1	14.6	18.3	11.8	0.9	12.0	28.0	2.7
2	7.0	1.2	7.6	573.4	234.1	11.0	14.1	5.2	0.7	11.6	25.5	2.0
3	7.7	0.6	9.1	624.1	255.4	25.0	15.0	8.7	0.8	15.5	26.4	3.1
4	7.5	3.7	7.6	847.1	271.6	20.3	19.9	6.6	0.6	13.7	29.5	2.6
5	7.1	1.7	10.6	1336.3	273.4	16.8	18.6	5.9	0.4	10.0	32.2	3.0
6	6.9	2.3	9.8	769.5	209.1	16.4	12.7	5.1	0.3	8.4	45.5	2.6
7	7.6	2.0	8.4	579.0	174.4	18.0	10.1	25.9	1.5	8.9	30.0	2.0
8	10.0	2.4	12.3	1374.1	205.6	23.9	13.2	5.3	0.3	9.9	40.6	3.0
9	9.7	4.3	12.1	760.3	187.8	46.1	11.0	3.0	0.3	10.3	27.6	2.9
10	14.8	0.9	15.8	1530.1	476.9	23.9	24.5	10.8	0.5	20.8	47.1	4.8
11	11.1	1.3	13.2	2216.9	371.9	32.2	16.6	7.2	0.6	15.3	36.7	3.6
12	17.0	0.6	11.3	845.8	251.5	21.5	14.4	5.6	0.7	16.7	26.3	2.7
13	11.1	4.4	10.8	882.5	204.3	26.5	11.1	4.5	0.3	11.7	30.9	3.5
14	11.5	2.1	14.4	1299.4	258.5	33.3	15.7	4.4	0.4	12.6	40.2	3.5
15	10.3	1.2	12.3	1404.1	323.5	27.8	16.3	7.2	0.6	12.1	33.4	3.8
16	12.5	3.5	15.8	1481.5	401.0	83.2	19.2	7.9	0.7	18.1	43.2	4.1
17	21.8	–2.4	22.8	742.7	101.4	67.8	10.5	14.6	1.4	25.7	45.3	3.0
18	14.2	1.7	12.5	1008.8	164.1	21.9	8.9	5.1	0.9	15.6	29.5	2.3
19	14.1	9.0	12.4	951.7	215.3	33.2	13.9	5.4	0.4	13.6	35.8	4.0
20	12.3	1.3	8.2	1136.9	263.2	32.2	16.6	4.1	0.5	12.1	36.0	3.6

The calculated Igeo values are shown in Table 5. Regarding the Igeo values, As was found to be the highest pollutions among the selected metals. The Igeo values of As, Cr, Cu, K, Mn, Ni, Pb, Th, U, V, Zn and Zr were found to be less than 1. Igeo values indicate that the study area is not polluted by these metals. The average Igeo values of the metals were As > Th > Pb > K > Ni > Zn > Mn > Cu > U > V > Cr > Cr (Table 5).

Table 5: Geoaccumulation index (Igeo) of metals in the study area

S. No.	As	Cr	Cu	K	Mn	Ni	Pb	Th	U	V	Zn	Zr
1	0.7	0.02	0.2	0.3	0.3	0.2	1.0	1.3	0.35	0.10	0.3	0.02
2	0.7	0.02	0.2	0.3	0.4	0.2	1.0	0.7	0.29	0.12	0.4	0.02
3	0.7	0.01	0.2	0.3	0.3	0.4	0.8	1.0	0.29	0.13	0.3	0.02
4	0.6	0.04	0.2	0.4	0.3	0.3	1.0	0.7	0.22	0.11	0.3	0.02
5	0.5	0.02	0.2	0.5	0.3	0.2	0.9	0.6	0.12	0.07	0.3	0.02
6	0.6	0.03	0.2	0.3	0.3	0.2	0.7	0.5	0.12	0.07	0.5	0.02
7	0.6	0.02	0.2	0.2	0.2	0.3	0.5	2.8	0.55	0.07	0.3	0.01
8	0.6	0.02	0.2	0.4	0.2	0.3	0.5	0.4	0.09	0.06	0.3	0.01
9	0.6	0.04	0.2	0.3	0.2	0.6	0.5	0.3	0.09	0.07	0.3	0.01
10	0.7	0.01	0.2	0.4	0.3	0.2	0.7	0.6	0.09	0.09	0.3	0.02
11	0.6	0.01	0.2	0.7	0.3	0.3	0.6	0.5	0.14	0.09	0.3	0.02
12	0.7	0.00	0.1	0.2	0.2	0.2	0.4	0.3	0.13	0.07	0.1	0.01
13	0.8	0.05	0.2	0.3	0.2	0.4	0.5	0.4	0.11	0.09	0.3	0.02
14	0.7	0.02	0.3	0.4	0.2	0.4	0.6	0.4	0.12	0.08	0.3	0.02
15	0.6	0.01	0.2	0.5	0.3	0.3	0.7	0.6	0.15	0.07	0.3	0.02
16	0.6	0.03	0.2	0.4	0.3	0.8	0.6	0.5	0.15	0.09	0.3	0.02
17	0.7	–0.01	0.2	0.1	0.1	0.4	0.2	0.6	0.19	0.08	0.2	0.01
18	0.7	0.01	0.2	0.3	0.1	0.2	0.3	0.3	0.20	0.08	0.2	0.01
19	0.9	0.08	0.2	0.3	0.2	0.4	0.6	0.4	0.10	0.08	0.3	0.02
20	0.7	0.01	0.1	0.3	0.2	0.3	0.6	0.3	0.13	0.07	0.3	0.02

CF and PLI values for the metals examined are given in Table 6. As is the considerably contamination among the metals examined. The CF values of this metal varied between an average of 3.4 mg/kg and 2.6–4.3. The second largest values in the soil are Pb and Th and mean CF values are 3.2 and 3.3. Pb and Th were found to cause significant contamination in the study area. Similarly, the CF values of Cu, K, Mn, Ni and Zn indicate moderate contamination in the studied soils. U (0.91) has low pollution in the range of 1 ≤ CF. CF values are as follows: As > Th > Pb > K > Ni > Zn > Mn < C > U > V < Cr > Zr (Table 6). The calculated PLI values range from –1.1 to 2.1 (Table 6). A PLI value greater than 1 indicates pollution. The PLI values calculated in the study area were above 1 (except for example 17) and showed that there was metal pollution. Pollution ranking by location, 1 > 4 > 7 > 2 > = 16 > 3 > 19 > 13 > 11 > 5 > 6 > 14 > 15 > 8 > 9 > 10 > 20 > 18 > 12 > 17.

Table 6: Contamination factor (CF) and pollution load index (PLI) of metals in the study area

S. No.	As	Cr	Cu	K	Mn	Ni	Pb	Th	U	V	Zn	Zr	PLI
1	3.6	0.1	0.9	1.5	1.5	1.2	5.0	6.5	1.7	0.5	1.6	0.1	2.1
2	3.6	0.1	1.1	1.5	1.9	1.1	4.7	3.5	1.5	0.6	1.8	0.1	1.9
3	3.3	0.0	1.1	1.4	1.7	2.0	4.2	4.8	1.4	0.7	1.5	0.1	1.8
4	3.1	0.2	0.9	1.8	1.7	1.5	5.2	3.5	1.1	0.6	1.6	0.1	2.0
5	2.6	0.1	1.1	2.5	1.5	1.1	4.4	2.8	0.6	0.4	1.6	0.1	1.7
6	2.8	0.1	1.1	1.6	1.3	1.2	3.3	2.7	0.6	0.3	2.5	0.1	1.6
7	3.1	0.1	1.0	1.2	1.1	1.4	2.7	13.9	2.7	0.4	1.7	0.1	2.0
8	3.1	0.1	1.1	2.2	1.0	1.4	2.7	2.1	0.5	0.3	1.7	0.1	1.5
9	3.2	0.2	1.2	1.3	0.9	2.8	2.4	1.3	0.4	0.3	1.2	0.1	1.5
10	3.3	0.0	1.0	1.7	1.6	1.0	3.5	3.1	0.5	0.5	1.4	0.1	1.5
11	3.2	0.1	1.1	3.3	1.6	1.7	3.1	2.7	0.7	0.4	1.4	0.1	1.7
12	3.5	0.0	0.7	0.9	0.8	0.8	1.9	1.5	0.7	0.3	0.7	0.0	1.0
13	4.1	0.2	1.2	1.7	1.2	1.8	2.7	2.2	0.5	0.4	1.6	0.1	1.8
14	3.5	0.1	1.3	2.1	1.2	1.9	3.1	1.8	0.6	0.4	1.7	0.1	1.6
15	3.2	0.1	1.1	2.2	1.5	1.6	3.3	2.9	0.8	0.4	1.4	0.1	1.6
16	3.2	0.1	1.2	2.0	1.6	4.0	3.2	2.6	0.8	0.5	1.5	0.1	1.9
17	3.6	-0.1	1.1	0.6	0.3	2.1	1.1	3.1	1.0	0.4	1.0	0.0	–1.1
18	3.7	0.1	0.9	1.4	0.7	1.1	1.5	1.7	1.0	0.4	1.1	0.0	1.3
19	4.3	0.4	1.1	1.5	1.0	1.9	2.8	2.1	0.5	0.4	1.5	0.1	1.8
20	3.5	0.1	0.7	1.7	1.2	1.7	3.1	1.5	0.7	0.3	1.4	0.1	1.4

Conclusion

In this research, metal concentrations and pollution sources in soil samples in the area of Sorgun and surrounding uranium mineralization were interpreted using statistical techniques. In soil samples in the study area, the highest element concentrations were observed in K and Mn. In addition, Mn, Ni, Cu, Zn, Pb, As, Th values were higher than average shale values. For the accurate evaluation of heavy metal pollution results, enrichment factor, geoaccumulation index, contamination factor and pollution load index methods were applied. According to the classification, the extremely high enrichment in EF values is related to K and Mn elements. Among the studied elements, As with the highest Igeo value showed the unpolluted to moderately polluted. Igeo values of other elements were found to be less than 0.68. Among the calculated CF values, the considerably contamination was As, while the other studied elements showed moderate to low contamination. Igeo and CF values respectively; As > Th > Pb > K > Ni > Zn > Mn > Cu > U > V > Cr > Zr. Except for Example 17, all samples have PLI values above 1 and it can be said that these samples contain metal contamination.

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