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U and Th Transport and Uptake in *Triticum Sativum* Cultivated Farmland in the Temrezli (Sorgun, Yozgat, Turkey) U and Th Mining Area

Güllü-KIRAT[1*], Nasuh-AYDIN[2]
[1] Department of Geological Engineering, Faculty of Architecture and Eng. Yozgat Bozok University, Yozgat, Turkey
[2] Department of Geological Engineering, Faculty of Architecture and Eng. Balikesir University, Balikesir, Turkey
[*1] gullu.kirat@bozok.edu.tr, [2] nasuhaydin@hotmail.com.tr

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Abstract: In this study, 20 samples *Triticum sativum L. (T. sativum)* plants grown in Temrezli agriculture areas were collected and the distribution and accumulation of uranium and thorium (U and Th) in stems, shells and grains of this plant were identified. In addition, plant ashes and nearby soil samples were analyzed by ICP-MS to determine the concentrations of U and Th. The mean U and Th values in the soils, stems, shells and grains of *T. sativum* plant, were calculated as 2.73 mg/kg, 0.16 mg/kg, 0.17 mg/kg, 0.16 mg/kg and 34.01 mg/kg, 1.02 mg/kg, 0.65 mg/kg, 1.09 mg/kg (in respectively). The mean U and Th enrichment coefficients of this plant were less than 1. The decrease in EC may be due to the saturation of metal uptake and/or transport. Therefore, *T. sativum* plant may be useful in phytoremediation and in remediation areas contaminated by U and Th.

Key words: Enrichment coefficient; phytoremediation; uranium; thorium; *Triticum sativum* plant.

Temrezli'de (Sorgun, Yozgat) Yetiştirilen *Triticum Sativum* Bitkisinde U ve Th Birikimi ve Taşınması

Özet: Bu çalışmada, Temrezli tarım alanlarında yetiştirilen *Triticum sativum L. (T. sativum)* bitkisinden 20 adet örnek alınarak, bu bitkinin dal, kabuk ve tohumlarındaki uranyum ve toryumun (U ve Th) dağılımı ve akümülasyonu (birikimi) tanımlanmıştır. Bitki külü ve ilişkili toprak örneklerinde U ve Th'u belirlemek için ICP-MS ile analiz edilmiştir. *T. sativum* bitkisinin topraklarında, saplarında, kabuklarında ve tohumlarında ortalama U ve Th değerleri (sırasıyla), 2.73 mg/kg, 0.16 mg/kg, 0.17 mg/kg, 0.16 mg/kg ve 34.01 mg/kg, 1.02 mg/kg, 0,65 mg/kg, 1,09 mg/kg olarak bulunmuştur. Bu bitkinin ortalama U ve Th zenginleştirme katsayıları 1'den düşüktür. EC değerlerinin düşük olması, bitki organlarının metalin doygunluğundan kaynaklanabilir. Bu nedenle, *T. sativum* bitkisi, U ve Th tarafından kirlenen alanların iyileştirilmesinde ve fitoremeditasyonunda kullanılabilir.

Anahtar kelimeler: Zenginleştirme katsayısı; fitoremeditasyon; uranyum; toryum; *Triticum sativum* bitkisi.

1. Introduction

Uranium is the naturally occurring heaviest radioactive element and consists of ^{234}U, ^{235}U and ^{238}U isotopes. The main isotopes formed during radioactive decay are $^{235}U$and ^{238}U. Th has two naturally occurring isotopes which are ^{232}Th and ^{230}Th. ^{232}Th is the main radionuclide of the ^{208}Pb decay product. ^{230}Th is found in minerals which contains U. Th coexists with sulphur, nitrogen, carbon, boron, silicon, halogens and intermetallic compounds containing many metallic elements. At high temperatures, the chemical properties of U and Th are similar, which reveals co-formation in hydrothermal beds. However, under normal surface conditions U is chemically more mobile since it is bivalent (unlike strong monovalent behaviour of Th) [1].

Inhalation of air containing U powders and the U-containing foods can cause chemical and radiological toxicity. The U compounds entering the bloodstream are filtered by the kidneys. High doses of U intake can result in acute renal failure and death [2-3].

Th existing in the blood is taken from food, water and air. After a few minutes of Th breathing comes sneezing and coughing. Th can be found in the lungs and blood. Th in the lung is thrown into stools and urine a few days later. But the Th in the blood can remain for many years [1].

The global mean of the Th content of soils varies from 3.4 to 10.5 mg/kg and varies from 0.79 to 11 mg/kg for U [4].

Plants and soil which include natural radioactive elements such as U, Th; (e.g., U, Th), although these elements in plants present could be little. The distribution of U and Th around the area is causing great damage.

[*] Corresponding author: gullu.kirat@bozok.edu.tr. ORCID Number of authors: [1] 0000-0002-1167-0574, [2] 0000-0001-8428-9750

Although radioactive elements such as U an Th may be found wihtin plant bodies and surrounding soils, their concentrations are mostly very low. The distribution of U and Th around the area is causing great damage [5-7].

The soils derived from mineralization zones are very rich in terms of the metal within ore minerals. The plants that grow in such soils more being effected than the other plants that grow in different soils and these plants adapt to environment or die. Based on this, the chemical analysis values of the various organs (stems, shells and grains, etc.) of the plant species which were systematically collected from study are effectively used in the determining of indicator plants (ore researches), stating of environmental pollution (phytoremeditation). Therefore, in and around of the Temrezli U deposit, organs of plants will be sampled according to the ore and plant distribution. As a result of this study, the relationship between soil-plant and mineralization brought out by analyses of the plants and the soil samples that feed the plants.

2. Study Area

The study area is located in the vicinity of Sorgun where 35 km east of Yozgat (Fig. 1). The study area is mostly composed of plain fields *T. sativum* plants. Towards the north, the altitude at the Uç Hills is over 1200 m. In Temrezli, summer is hot and arid, winter is cold and hard, and there is a terrestrial climate. This is a defining feature of the arid and steppe vegetation cover. July and August are hottest and driest months. A large part of the annual rainfall falls in the spring and autumn seasons. The mean annual rainfall is 450-500 kg per square meter. It snows in the winter. January is the coldest month of the year.

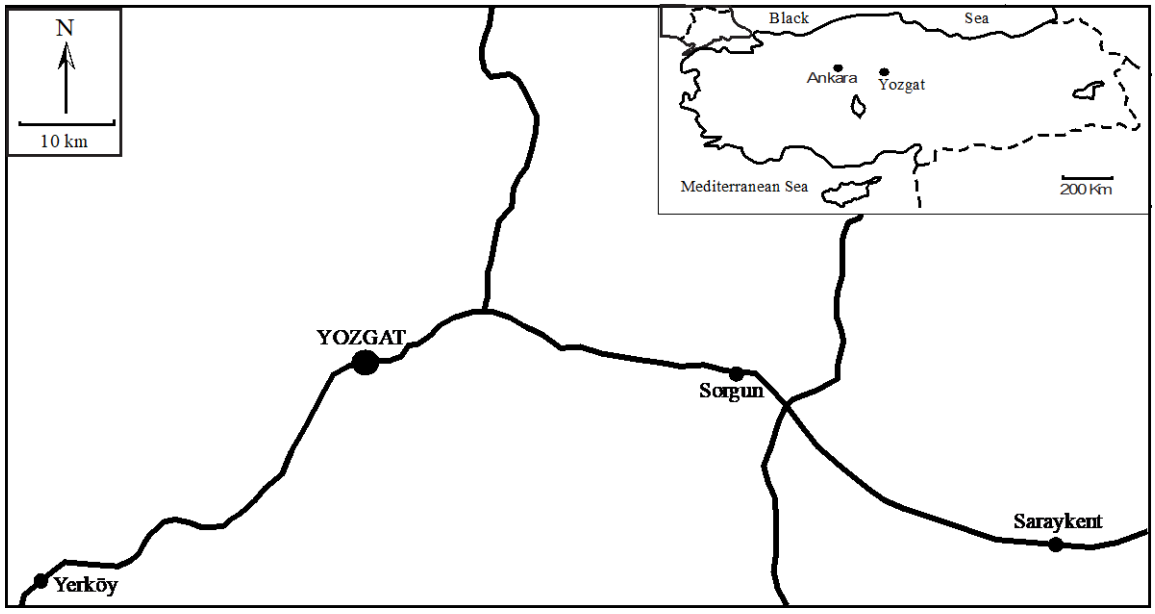


Figure 1. Location map of the study area

Temrezli U deposit is the largest known U deposit of Turkey. Geological units are observed from bottom to top Upper Cretaceous-Lower Paleocene Granitoids, Tertiary Cover Units and Quaternary alluvium (Fig. 2). This bed was discovered in the 1980s by the General Directorate of Mineral Research and Exploration (MTA). Intensive mining activities are underway in this area by a private company. 'In – situ recovery' will be used as a production method, which is known as one of the environmental friendly mining solution [8].

3. Plant and Soil Samples

T. sativum samples consisting of stems, shells, grains and related soils were taken from 20 locations in the Temrezli region. This plant has been selected because it has been cultivated too much in agricultural fields in the study area. Samples were collected about 20 cm deep around the *T. sativum* plant. After the soil samples have been dried at room temperature, the rocks and plant parts were removed using a sieve. The *T. sativum* samples were divided into sections and washed first with the ordinary water and then with distilled water. It was left to

dry at room temperature, after plant samples were dried for 4 hours in an oven at 60 °C, 0.10 g of the ash and soil samples were added 2 ml of concentrated HNO_3 and dried by heating at microwave at 95 °C for 1 hour.

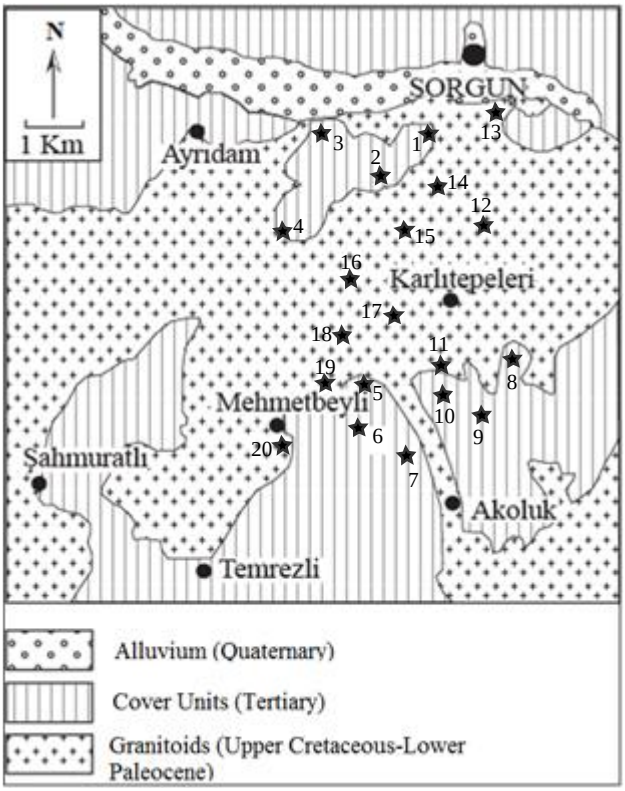


Figure 2. Geological map of the study area [9 from modified].

After the samples were cooled, 2 ml HNO_3 and HCl-HNO_3-H_2O mixture was added (HCl-HNO_3-H_2O (1:1:1, v/v; 6ml per 0.10 g of ash and soil). The resulting mixture was diluted with distilled water to a final volume of 50 ml and calculations were made according to final volume. The digests were analyzed using ICP-MS techniques for U, Th and other elements at the BILTEM (Yozgat Bozok University, Science and Technology Application and Research Center) Yozgat, Turkey.

3.1. Enrichment coefficients of stems (ECst), shells (ECsh) and grains (ECg)

Enrichment coefficientsfor plant stems (ECst), shells (ECsh) and grains (ECg) were calculated using the ratios of the element concentration ratios in plant stems, shells and grains and soils (value of the plant stems, shells and grains divided by the value of soils). (ECst), shells (ECsh) and grains (ECg) values are used as an symbol for the transfer of elements from soil to plants [10-14]. Besides, this values indicates the capacity of a given plant species for phytoremediation [15].

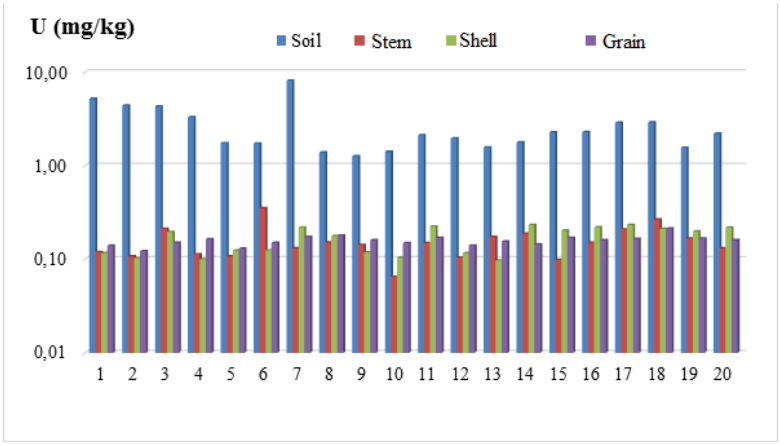
4. Results and Discussion

4.1. U and Th concentrations in the soils

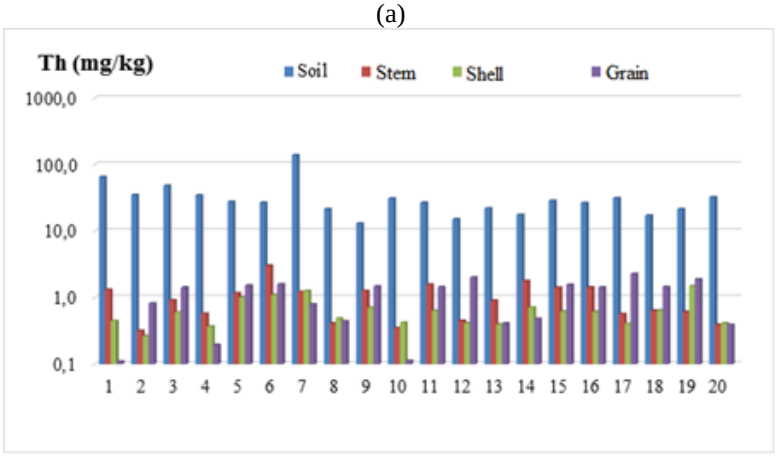
The soil samples were collected from the Temrezli area and its around. U concentrations in the soil are between 1.27 - 8.17 mg/kg (mean: 2.73 mg/kg) (Fig. 3). The maximum limit for U concentrations in soils are 1 mg/kg recommended by WHO [16]. U concentrations in soils of Siwaqa region range between 1.83-56.8 mg/kg (mean: 12.64 mg/kg).U concentrations of surface soil range from 1.5-8 mg/kg (mean:3.17 mg/kg) in the Italy; 0.10-2.33 mg/kg (mean:0.79 mg/kg) in the Poland; 0.3-10.7 mg/kg (mean: 3.7 mg/kg) in the US.; <0.22-45 mg/kg (mean:2.3 mg/kg) in the U.S. (Alaska) and 0.72-2.05 mg/kg (mean: 1.22 mg/kg) in the Canada [4]. Soil

samples have exceeded the values of U concentration in soils as recommended by WHO [16]. and the mean values of U concentration in the U.S. (Alaska), Poland and Canada soils as recommended by Kabata-Pendias and Pendias [4].

Th concentrations in the Temrezli soil samples are between 13 mg/kg and 139 mg/kg (mean: 34.01 mg/kg) (Fig. 3). Th concentrations of surface soils range from 4.2-14.1 mg/kg (mean: 8 mg/kg) in the Canada; 0.4-15 mg/kg (mean: 8 mg/kg) in the Germany; 3.6-17.8 mg/kg (mean: 9.3 mg/kg) in the Bulgaria;1.4-7.2 mg/kg (mean: 3.4 mg/kg) in the Poland; 2.2-21.0 mg/kg (mean: 7.6 mg/kg) in the U.S. and 1.6-76 mg/kg (mean: 6.1 mg/kg) in the U.S. (Alaska) [4]. In the study area, Th concentration is appeared to be very high, between 3.8 - 12.4 mg/kg in soils of the U.S. and between 8 - 27 mg/kg in soils of China [16-17]. and in soils as recommended by Kabata-Pendias and Pendias [4].



(a)



(b)

Figure 3. (a) U concentrations of the soil samples, (b) Th concentrations of the soil samples, stem, shell and grain of *T. sativum* plant.

Granites are widespread in the Temrezli area and its around (Fig. 2). Acid rocks (granites, gneisses; U: 2.5-6 mg/kg and Th: 10-23 mg/kg) generally contain more Th and U than do mafic rocks (basalts, gabbros; U: 0.3-1 mg/kg and Th: 1-4 mg/kg), and in the sediments it is thought that these elements are probably concentrated in argillaceous deposits (U: 3-4 mg/kg and Th: 9.6-12 mg/kg) than in sandstones (U: 0.45-0.59 mg/kg and Th: 1.7-3.8 mg/kg) and limestones (U: 2.2-2.5 mg/kg and Th: 1.7-2.9 mg/kg). The carrier of Th is fundamentally monazite mineral. Th is concentrated in some weathered deposits, because this monazite mineral is very robust to weathering [4]. The U and Th concentrations may be related to the Ag, Fe, Mn, Pb and V elements of the Temrezli region, because the presence of U and Th showed a positive linear correlation with the occurrence of these metals. These positive correlations (U, r = 0.574-0.028 and Th, r = 0.712-0.079) were observed between U and the metals Ag and V, and between Th and the heavy metals Ag, Fe, Mn, Pb and V, whereas negative linear

correlations (U-Ca r = -0.61, U-Cd r = -0.51 and Th-Ca r = -0.74, Th-Cd r = -0.71) were observed between U and Th with the metals Ca and Cd (Table 1).

Table 1. Correlations between U and Th in soils of the study area (*Correlation is significant at the 0.05 level; ** Correlation is significant at the 0.01 level)

	B	Na	Mg	Ca	V	Cr	Mn	Fe	Co	Ni
U	0.174	0.03	-0.349	-,614(**)	,556(*)	-0.284	0.305	0.377	-0.177	-0.091
Th	-0.007	-0.002	-0.186	-,740(**)	,579(**)	-0.223	,565(*)	,532(*)	0.082	-0.075

	Cu	Zn	As	Ag	Cd	Sb	Pb	U	Th
U	-0.353	0.149	0.116	,574(*)	-,508(*)	0.028	0.318	1	,695(**)
Th	-0.273	0.354	-0.149	,712(**)	-,706(**)	0.079	,616(**)	,695(**)	1

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

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

The linear correlations between U and Th with Ag, Fe, Mn, Pb and V showed that they have been carried in hydrothermal solutions to Temrezli region. Many studies have assumed that the transfer of U and Th from soil to plants is a positive correlations relationship due to some ecological and agricultural conditions [7].

Important relationships (r = 0.79) were detected between U and Th content in the soils (r = 0.79) and in the stems (r = 0.48) in Temrezli region. This means that the more U and Th in soil, the more Th accumulates in the stems (1, 5-7, 9, 11, 14-16 number locations), in the shells (6, 7, 19 number locations) and in the grains (3, 5, 6, 9, 11, 12, 15-19 number locations) (Fig. 4).

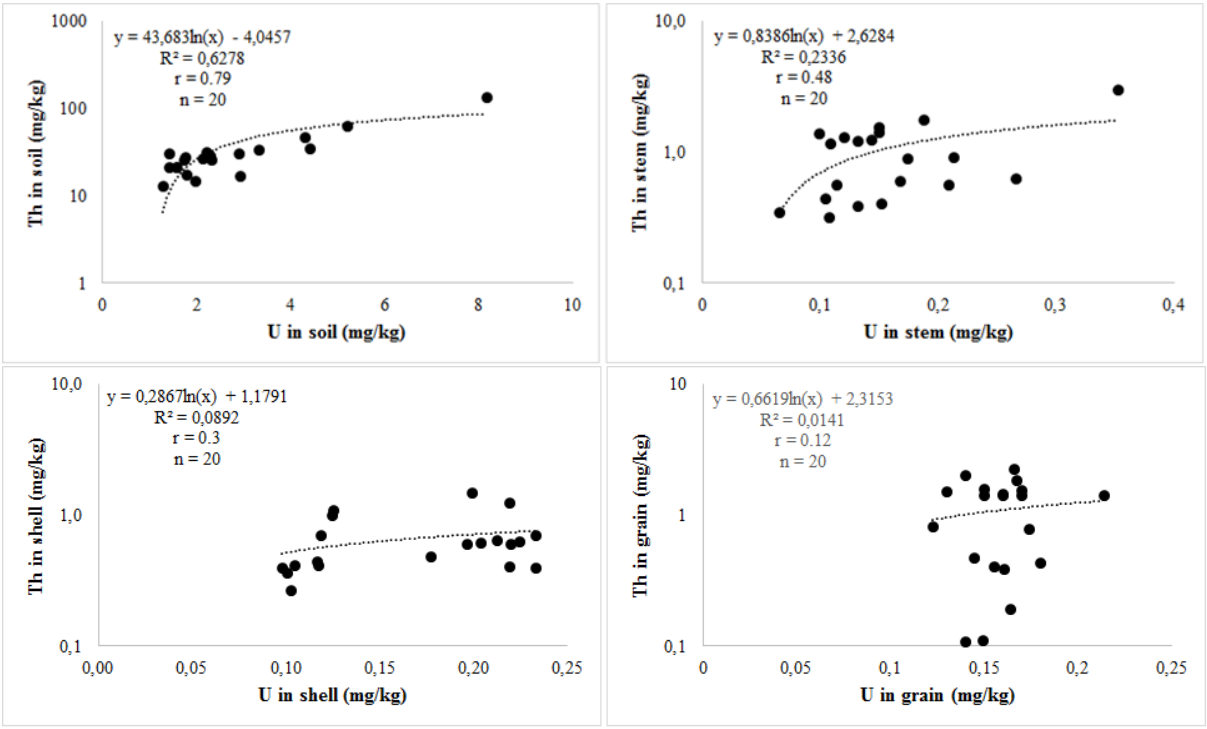


Figure 4. Correlations between U and Th in soil, stem, shell and grain in the study area.

Fig. 5 clearly shows that the EC values of U in the plant stems, shells and grains is less than 1 and the Th EC values is greater than 1 in the some location samples. Although the chemical properties of U and Th are

similar, the behavior of these metals in plants and in the soil may change. Therefore, it is thought that there are other factors affecting the U and Th chemistry in the plant - soil system [7].

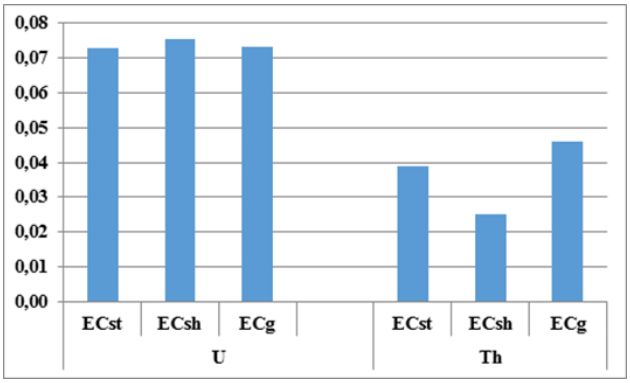


Figure 5. Mean U and Th enrichment coefficients for stems (ECst), shell (ECsh) and grains (ECg) of *T. Sativum* plant in the study area

The highest U and Th concentration in all analyzed soil samples were 8.17 and 139 mg/kg (in respectively) in the location 7, which were collected from Temrezli area. U and Th were found in high concentrations in acidic soils (pH 3.6 - 4.7) near the surface. (0 - 20 cm). In slightly acidic soil (pH = 5.8 - 7.0), U was more soluble at a significant level than Th. The Th resolution is 5 to 14 times higher than the resolution [18].

4.2. U and Th concentrations in the plants

In the Temrezli region, 20 plant species were selected for the determination of U and Th concentrations. The selected *T. Sativum* plants are grown in a wide range in this region and they are an annual plant species. The mean U and Th concentrations of *T. Sativum* plants in study area varies according to plant parts (U in the stems: 0.16 mg/kg¸U in the shell: 0.17 mg/kg, U in the grains: 0.16 mg/kg; Th in the stems: 1.02 mg/kg, Th in the shell: 0.65 mg/kg, Th in the grains:1.09 mg/kg). These concentrations were significantly higher than the U and Th values in *T. Sativum* plant stems, shells and grains. U and Th concentrations of *T. sativum* plant parts and the associated soils are given in Fig. 3.

The U concentrations for *T. Sativum* plant samples ranged between 0.07 and 0.35 mg/kg for the stems, between 0.10 and 0.23 mg/kg for the shells and between 0.12 and 0.21 mg/kg for the grains (Fig. 3). The Th concentrations for *T. Sativum* plant samples ranged between 0.32 and 3.03 mg/kg for the stems, between 0.27 and 1.50 mg/kg for the shells and between 0.11 and 2.27 mg/kg for the grains (Fig. 3). The U and Th enrichment coefficients (ECst, ECsh and ECg) for *T. Sativum* plant stems, shells and grains are shown in Fig. 5; the mean ECst, ECsh and ECg values were 0.07 mg/kg, 0.08 mg/kg and 0.07 mg/kg for U and 0.04 mg/kg, 0.03 mg/kg and 0.05 mg/kg for Th (in respectively) (Fig. 5).

5. Conclusions

The U and Th concentrations in soils from the Temrezli area varied between 1.27-8.17 mg/kg (mean: 2.73 mg/kg), and 12.97-139 mg/kg (mean: 34.01 mg/kg), which are higher than some other soils reported by other researchers. The distribution and accumulation of U and Th was examined in the stems, shells and grains of 20 *T. Sativum* plant samples that has been raised to agricultural land in the Temrezli mining area. The mean concentrations of U and Th in the stems, shells and grains of this plant were found 0.16 mg/kg, 0.17 mg/kg and 0.16 mg/kg and 1.02 mg/kg, 0.65 mg/kg and 1.09 mg/kg (in respectively).

(ECst), (ECsh) and (ECg) were calculated using the ratios of element concentrations in plant organs. The mean concentrations of U and Th in *T. Sativum* plant from the study area varied between 0.07 mg/kg, 0.08 mg/kg and 0.07 mg/kg, and 0.04 mg/kg, 0.03 mg/kg and 0.05 mg/kg (in respectively). According to these values can be used as a symbol in the transfer of elements from soil to plants. Besides, these values can be used for U and Th phytoremediation in contaminated soils.

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References

[1] Jones LD. Uranium And Thorium Occurrences In British Columbia. Ministry of Energy, Mines and Petroleum Resources, 1990; 32: pp.78.
[2] ATSDR. Toxicological profile for Carbon Tetrachloride. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service 2005.
[3] Sheppard MI, Sheppard SC. The plant concentration ratio concept as applied to natural U. Health Phys. 1985; 48: 494-500.
[4] Kabata-Pendias A, Pendias H. Trace elements in soils and Plants. 3rd Edition, CRC Press, Boca Raton, 2001; 403 p.
[5] Buck EC, Brown NR, Dietz NL. Contaminant uranium phases and leaching at the Fernald site in Ohio. Environ. Sci. Technol. 1996; 30: 81–88.
[6] Airey PL, Ivanovich M. Geochemical analogues of highlevel radioactive waste repositories. Chem. Geol. 1986; 55: 203–213.
[7] Shtangeeva I. Uptake of uranium and thorium by native and cultivated plants. Journal of Environmental Radioactivity, 2010; 101: 458–463
[8] Aydin N. Investigation Of Geology, Geochemistry And Operability Of Temrezli (Sorgun – Yozgat) Uranium Deposit. Balikesir University Institute Of Science Geological Engineering Balıkesir, Ph.D Thesis, 2016; 112 p.
[9] MTA (Mineral Research and Exploration General Directorate). The potential, trade and expected developments of the metal and mineral resources in the world and Turkey. XII, 1987; Release number: 197
[10] Brown SL, Chaney RL, Angle JS, Baker AJM. Phytoremediation potential of Thlaspi caerulescens and bladder campion for zinc and cadmium contaminated soil. J. Environ. Qual. 1994; 23: 1151-1157.
[11] Baker AJM, Reeves RD, Hajar ASM. Heavy metal accumulation and tolerance in British populations of the metallophyte Thlaspi caerulescens. New Phytologist 1994; 127: 61-68.
[12] Whicker FW, Hinton TG, Orlandini KA, Clark SB. Uptake of natural and anthropogenic actinides in vegetable crops grown on a contaminated lake bed. J. Environ. Radioact. 1999; 45: 1–12.
[13] Wei CY, Chen TB, Huang ZC. Cretan bake (Pteris cretica L.): an arsenic-accumulating plant. Acta Ecol Sinica 2002; 22: 777-782.
[14] Chen SB, Zhu YG, Hu QH. Soil to plant transfer of 238U, 226Ra and 232Th on U mining-impacted soil from southeastern China. J. Environ. Radioac. 2005; 82: 223-236.
[15] Zhao FJ, Lombi E, Mc Grath SP. Assessing the potential for zinc and cadmium phytoremediation with the hyperaccumulator Thlaspi caerulescens. Plant Soil 2003; 249: 37-43.
[16] WHO. The World health report 2007: a safer future. WHO Library cataloguing – in – Publication data, Geneva, Switzerland 2007.
[17] Govindaraju K. Compilation of working values and sample description for 383 geostandards, Geostand. Newslett 1994; 18, 1.
[18] Ahmad SM, Tansey TR, Busser BW, Nolte MT, Jeffries N, Gisselbrecht SS, Rusan NM, Michelson AM. Two forkhead transcription factors regulate the division of cardiac progenitor cells by a polo-dependent pathway. Dev. Cell, 2012; 23(1): 97-111.