



Transfer factors of ^{226}Ra , ^{232}Th and ^{40}K from soil to pasture-grass in the northeastern of Turkey

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Abstract

The uptake of natural radioactivity by pasture-grass collected from seven different grasslands of Digor was calculated. The activities of ^{226}Ra , ^{232}Th and ^{40}K in pasture-grass were in the range of 21.8 ± 6.3 – 49.6 ± 13.4 , 51.9 ± 13.2 – 127.7 ± 23.8 and 309.5 ± 33.5 – 807.3 ± 64.4 Bq kg⁻¹, respectively. The soil to pasture-grass transfer factors were evaluated and determined to be in the range from 0.26 ± 0.13 to 0.69 ± 0.34 , 0.64 ± 0.27 to 1.99 ± 0.40 and 0.64 ± 0.014 to 1.40 ± 0.032 for ^{226}Ra , ^{232}Th and ^{40}K , respectively. The distribution of ^{226}Ra and ^{232}Th in different parts of pasture-grass indicated a decreasing tendency in order of root > stem > leaf. ^{40}K mainly accumulated in stem of pasture-grass and is followed by declining trend stem > leaf > root.

Keywords Natural radionuclides · Activity concentration · Soil-to-plant transfer factor · Pasture-grass

Introduction

Radioactive elements in the atmosphere, in water and in the soil, pass directly or indirectly to humans, animals and plants. The transition of radioactive elements from the soil to the plants takes place in such processes as the accumulation of the radionuclides coming from the atmosphere on the plant surface and also the transport of the radioactive elements to plant's body by the roots of the plant [1, 2]. Potassium, uranium, radium and other elements may be present in the plant body, depending on factors such as soil properties, climatic situations, sort of plants, part of the plant related and physical-chemistry condition of the radionuclides [3–5]. These radioactive elements in the soil are generally passed to humans and animals through respiration and food. Consumption of plants containing radioactive elements as food can be dangerous for human and animal health [6–9].

Many studies have been extensively carried out in different countries in recent years for determining soil-to-plant transfer factors (TF's) for natural radionuclides and artificial radionuclides [3, 10, 11]. Kritsanuwat et al. [12] studied to find activity concentrations of natural radionuclides

in *Alpinia galangal* growing in northern Thailand. They reported the mean activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in *Alpinia galangal* were 0.9 ± 0.7 Bq kg⁻¹, 0.9 ± 0.9 Bq kg⁻¹ and 785 ± 576 Bq kg⁻¹, respectively. They also found that the TF varied from <0.002 to 0.073 for ^{232}Ra , from <0.001 to 0.061 for ^{232}Th and from 0.26 to 7.9 for ^{40}K [12]. Chakraborty et al. [8] reported results of their investigations for calculating the transfer factors from soil to grass in Bangladesh. In their study, ^{226}Ra , ^{232}Th , ^{228}Th , ^{40}K and ^{137}Cs average activity concentrations were found 22.13 ± 2.30 , 38.47 ± 2.72 , 50.47 ± 4.75 , 451.90 ± 24.89 and 2.41 ± 0.18 Bq kg⁻¹, respectively while in grass, their values were determined 1.26 ± 0.11 , 3.66 ± 0.31 , 7.02 ± 0.49 , 134.95 ± 3.68 and 0.17 ± 0.02 Bq kg⁻¹ respectively. They have also reported the transfer factor values from soil to grass as 0.056, 0.089, 0.137, 0.275 and 0.054, respectively for ^{226}Ra , ^{232}Th , ^{228}Th , ^{40}K and ^{137}Cs [8]. Shayeb et al. [13] examined the transfer factors of ^{226}Ra , ^{232}Th and ^{40}K from soil to date palm pits. The mean activity concentrations of ^{226}Ra , ^{232}Th , ^{137}Cs and ^{40}K in soil samples were ascertained to be 12.8 ± 2.2 , 10.2 ± 2.1 , 0.28 ± 0.1 and 329 ± 87 Bq kg⁻¹, respectively by using the high purity germanium (HPGe) gamma-ray spectrometer. Likewise the mean activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in date palm pits were found as 5.6 ± 1.2 , 2.8 ± 0.4 and 181 ± 17 Bq kg⁻¹, respectively. They reported the geometric mean of TF values of

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^{226}Ra , ^{232}Th and ^{40}K were found 0.33, 0.22 and 0.51, respectively [13].

The objective of this study is to find the transfer factors of ^{226}Ra , ^{232}Th , and ^{40}K from the soil to in different parts of pasture-grass, because animals are fed using pasture grasses in this area. Since the dairy products and meat of the animals growing in the region are consumed by people living in both the local and other cities of the country, the activity levels of the natural radionuclides must be known in terms of environmental health.

Materials and methods

Sample collection and processing

Digor, the county of Kars, has Armenia on the eastern border, Kars central district on the western and northern border, and Kağızman district on the southern border. The study area is located between $40^{\circ}22'32''$ North latitude and $43^{\circ}24'45''$ East longitude. The areas have an average altitude of 1450 meters above sea level. Its surface area is 1136 km² and the total population is 24,863 people. The Digor River is irrigating the district lands located at the eastern end of the Erzurum–Kars Plateau. The county's economy is based on agriculture and animal husbandry.

Activity concentrations and distributions of natural radionuclides of root, stem and leaf parts of a total of 36 pasture grass samples taken from 7 different stations in the district of Digor in Kars province were determined. Sampling stations where both soil samples and pasture grass samples are collected are given in Fig. 1. Approximately 1.5 kg of surface soil from each station was taken from a depth of about 7 cm

and kept up in plastic bags. Soil specimens were dried in an oven at 100 °C after removal of irrelevant substances such as roots, stone fragments and inorganic waste. Samples were pulverized, sieved with 2 mm mesh sieve and then sealed in air tight plastic containers.

About 2.5 kg of pasture grass plants were collected from the same places where soil samples were collected. After removing any trace of soil, the plants were divided into subsections such as root, stem and leaf. Each subsection of plant samples were dried for 12 h at 105 °C in an oven and powdered. The powdered plant samples were ashed to a white ash at 400 °C in an oven at which temperature was gradually increased. The ash was weighed and hermetically sealed in a plastic container for the determination of natural radionuclide radioactivity. The activity distribution in the diverse parts of the plant was computed based on the dry weights of the samples. Both 0.1 kg of soil samples and 0.05–0.09 kg plant samples were prepared, depending on sample availability and were stored in plastic containers for 35 days to attain secular equilibrium between ^{226}Ra (daughter of ^{238}U) and ^{232}Th with their daughter nuclei.

Activity determination

A NaI(Tl) scintillation detector based on a gamma-ray spectrometer system was employed for the evaluation of natural radioactivity in the soil samples and plant samples. The detector is protected with employing 5 cm thick lead layers on all sides to reduce minimize the contribution of building materials and the surrounding radiation. The spectrum was analyzed using a PC (Personal Computer) based an MCA (Multi Channel Analyzer) system and Maestro software. The energy calibration and the relative efficiency calibration of the

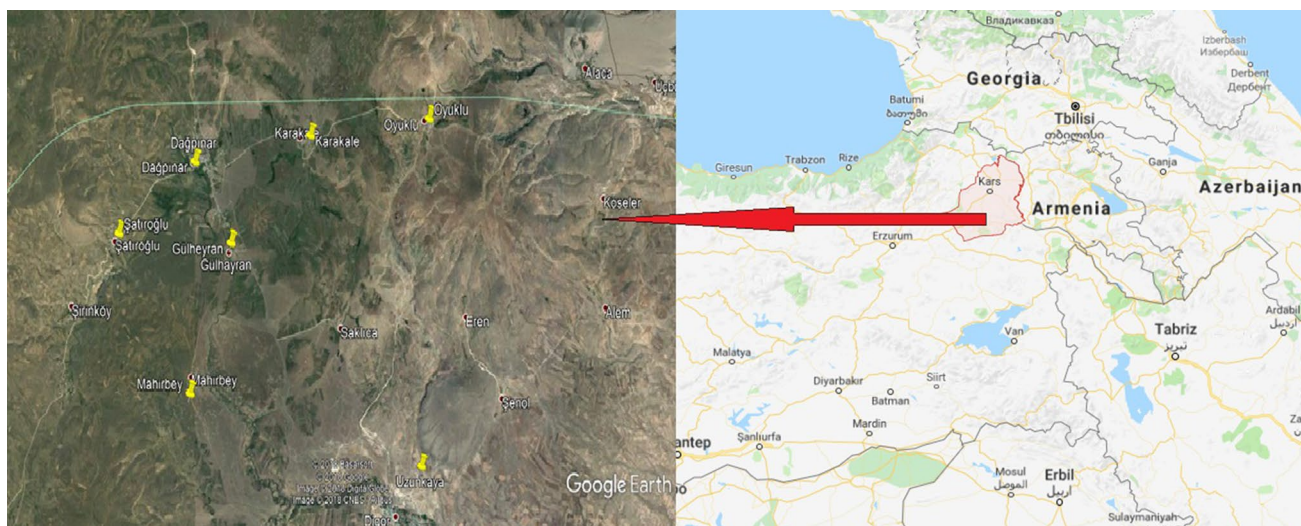


Fig. 1 Satellite map of sampling stations where soil samples and pasture samples are collected

gamma spectrometer were performed with standard calibration material (IAEA-375). For determining the activity concentrations in the soil samples and pasture-grass samples, suitable photopeaks at several energies were taken into account and the appropriate area (ROI) regions were selected for each peak. The activity concentrations of ^{40}K was evaluated from the 1460.8 keV gamma line. ^{226}Ra concentration was found out by measuring the 1764.5 keV gamma-rays from ^{214}Bi . Similarly, 2614.5 keV gamma-rays from ^{208}Tl were used to indicate the activity concentration of ^{232}Th . The samples were counted for a period of 86,400 s. The net peak area under the most significant photo peaks of all radionuclides daughter peaks were determined by taking out the background spectrum corresponding to the same counting time without changing the system was also carried out [14].

Self-absorption corrections

After obtaining the general full energy peak efficiency function for the calibration sample, the full energy peak efficiency should be determined for a sample with different apparent density and composition than the calibration one using some correction factors. One of the correction factors that should be applied for the calculation of efficiency is the self-absorption correction factor (F). F is self-attenuation correction factor for given energy E , that, can be written as described by San Miguel et al. [15].

$$F = \frac{(1 - e^{-\mu_s \rho_s h_s})}{\mu_s \rho_s h_s} \times \frac{\mu \rho h}{(1 - e^{-\mu \rho h})} \quad (1)$$

where μ and μ_s are their corresponding mass attenuation coefficients of reference and sample ($\text{cm}^2 \text{g}^{-1}$) at the selected energy, respectively; ρ and ρ_s are densities of reference and sample (g cm^{-3}), respectively; and h and h_s are heights of reference and sample (cm), respectively.

The mass attenuation coefficients of the reference, soil and pasture grass samples were determined at the energies of interest by using XCOM software package which depended on their main chemical components [16]. The densities of the reference, soil and pasture grass samples were 1.05, 1.50 and 0.60 g cm^{-3} , respectively the heights of the soil and pasture grass samples were 5 and 2.6 cm, respectively. In this study, the self-attenuation correction factor (F) values of pasture grass samples were determined by using Eq. 1 for 1460, 1764 and 2614 keV gamma ray energies and these values are given in Table 1.

Transfer factor calculation

The uptake of radionuclides from soil to plant is usually given as the ratio of radionuclide activity concentration in

Table 1 Radionuclide energies, linear attenuation coefficient values (μ_L) and self-attenuation correction factor (F) of pasture grass sample

Radionuclide	Energy (keV)	μ_L (cm^{-1})	F
^{40}K	1460	0.046	1.15
^{214}Bi	1764	0.042	1.13
^{208}Tl	2614	0.035	1.10

plant (A_{plant}) in dry weight (Bq kg^{-1}) to radionuclide activity concentration in soil (A_{soil}) also which is in dry weight (Bq kg^{-1}). The ratio is called the transfer factor, $TF_{\text{soil-plant}}$, is calculated using Eq. 2 [17, 18].

$$TF_{\text{soil-plant}} = \frac{A_{\text{plant}} (\text{Bq kg}^{-1}, \text{ dry weight})}{A_{\text{soil}} (\text{Bq kg}^{-1}, \text{ dry weight})} \quad (2)$$

According to the concentration ratio, the concentration of radionuclides in plants should express the concentration in the associated soil. However, this is not always true, as the characteristic features of the soil may reduce the uptake of radionuclides by the plants. Studies show that the accumulation of radionuclides in the soil of agricultural areas differs according to the different soil samples studied. Soil properties such as mineral structure, organic matter content, pH, hydrological conditions can be cited as the reason for differences in transfer factor (TF) from soil-to-plants measured in different parts of the world [4]. The nutrients ions that plants receive from soil in accordance with their requirements are transported to specific tissues of the plant metabolism, depending on the function of the element. Since radionuclides can be taken together with nutrients, they may have alike chemical attitude to the basic nutrient. To examine the translocation and the preferential location of a radionuclide accumulation within a plant, the total content of a radionuclide in entire plant has been normalized for dry weight part of every one plant part [9, 12].

Results and discussion

The ^{226}Ra , ^{232}Th and ^{40}K radioactivity concentrations in Bq kg^{-1} (dry weight) for studied soil samples and in different parts of pasture-grass samples are presented in Tables 2, 3 and 4. The range of measured activity of ^{226}Ra in the surface soil of Digor district was $60.2 \pm 12.5 \text{ Bq kg}^{-1}$ to $98.1 \pm 13.3 \text{ Bq kg}^{-1}$ with an average of $80.1 \pm 13.8 \text{ Bq kg}^{-1}$. The range of measured activity of ^{232}Th for the soil samples was $54.7 \pm 11.6 \text{ Bq kg}^{-1}$ to $81.1 \pm 13.3 \text{ Bq kg}^{-1}$ with an average of $65.7 \pm 12.6 \text{ Bq kg}^{-1}$. The activity concentration of ^{40}K was ranged from $450.0 \pm 38.5 \text{ Bq kg}^{-1}$ to $736.6 \pm 50.2 \text{ Bq kg}^{-1}$

Table 2 The average value of specific activity of ^{226}Ra (in Bq kg^{-1} , dry weight) in different parts of pasture-grass samples and their corresponding soil in Digor district. The transfer factors of ^{226}Ra radionuclide from soil to each part of pasture-grass at each station

Sample stations Id and locations	$^{226}\text{Ra}_{\text{soil}}$	$^{226}\text{Ra}_{\text{root}}$	TF_{root}	$^{226}\text{Ra}_{\text{stem}}$	TF_{stem}	$^{226}\text{Ra}_{\text{leaf}}$	TF_{leaf}
S.1. Gülheyran	60.2 ± 12.5	38.3 ± 8.4	0.64 ± 0.32	36.9 ± 9.6	0.61 ± 0.31	32.0 ± 8.6	0.53 ± 0.26
S.2. Oyuklu	88.6 ± 16.4	34.2 ± 8.5	0.39 ± 0.19	35.6 ± 8.2	0.40 ± 0.20	32.8 ± 9.2	0.37 ± 0.18
S.3. Dağpınar	74.0 ± 14.5	26.0 ± 6.0	0.35 ± 0.17	40.3 ± 11.7	0.55 ± 0.27	26.2 ± 6.0	0.35 ± 0.17
S.4. Uzunkaya	88.1 ± 11.5	23.5 ± 6.6	0.27 ± 0.13	27.0 ± 8.4	0.31 ± 0.15	23.3 ± 6.8	0.26 ± 0.13
S.5. Mahirbey	72.4 ± 14.0	49.6 ± 13.4	0.69 ± 0.34	26.5 ± 8.7	0.37 ± 0.18	21.8 ± 6.3	0.30 ± 0.15
S.6. Şatroğlu	98.1 ± 13.3	28.3 ± 7.4	0.29 ± 0.14	25.4 ± 8.4	0.26 ± 0.13	33.3 ± 11.0	0.34 ± 0.17
S.7. Karakale	79.7 ± 14.2	33.8 ± 8.4	0.42 ± 0.21	26.5 ± 8.5	0.33 ± 0.16	38.5 ± 10.4	0.48 ± 0.24
Mean			0.43 ± 0.22		0.40 ± 0.20		0.38 ± 0.18

MDA for $^{226}\text{Ra} = 5.48 \text{ Bq kg}^{-1}$ **Table 3** The average activity concentration of ^{232}Th (in Bq kg^{-1} , dry weight) in each part of pasture-grass and their corresponding soil. The transfer factors of ^{232}Th radionuclide from soil to each part of pasture-grass at each station

Sample stations Id and locations	$^{232}\text{Th}_{\text{soil}}$	$^{232}\text{Th}_{\text{root}}$	TF_{root}	$^{232}\text{Th}_{\text{stem}}$	TF_{stem}	$^{232}\text{Th}_{\text{leaf}}$	TF_{leaf}
S.1. Gülheyran	54.7 ± 11.6	63.5 ± 11.6	1.16 ± 0.23	108.7 ± 19.2	1.99 ± 0.40	104.5 ± 17.9	1.91 ± 0.39
S.2. Oyuklu	80.4 ± 15.2	82.2 ± 17.7	1.02 ± 0.20	127.7 ± 23.8	1.59 ± 0.32	90.7 ± 20.7	1.13 ± 0.23
S.3. Dağpınar	81.1 ± 13.3	51.9 ± 13.2	0.64 ± 0.13	107.9 ± 19.2	1.33 ± 0.27	101.9 ± 17.8	1.26 ± 0.25
S.4. Uzunkaya	55.3 ± 10.5	58.9 ± 12.8	1.07 ± 0.21	108.8 ± 20.4	1.97 ± 0.40	85.4 ± 15.3	1.54 ± 0.31
S.5. Mahirbey	65.4 ± 12.7	78.6 ± 15.1	1.20 ± 0.24	97.5 ± 18.6	1.49 ± 0.30	115.4 ± 23.0	1.76 ± 0.35
S.6. Şatroğlu	61.8 ± 11.6	87.1 ± 17.3	1.41 ± 0.28	109.9 ± 20.3	1.78 ± 0.36	104.9 ± 18.5	1.70 ± 0.34
S.7. Karakale	61.2 ± 12.9	92.0 ± 18.8	1.50 ± 0.30	105.1 ± 21.8	1.72 ± 0.35	67.3 ± 9.7	1.10 ± 0.22
Mean			1.14 ± 0.23		1.69 ± 0.34		1.49 ± 0.30

MDA for $^{232}\text{Th} = 2.83 \text{ Bq kg}^{-1}$ **Table 4** The mean activity concentration of ^{40}K (in Bq kg^{-1} , dry weight) in every part of pasture-grass and their corresponding soil. The transfer factors for ^{40}K radionuclide from soil to different part of pasture-grass in each station

Sample stations Id and locations	$^{40}\text{K}_{\text{soil}}$	$^{40}\text{K}_{\text{root}}$	TF_{root}	$^{40}\text{K}_{\text{stem}}$	TF_{stem}	$^{40}\text{K}_{\text{leaf}}$	TF_{leaf}
S.1. Gülheyran	616.6 ± 43.0	570.0 ± 53.6	0.92 ± 0.021	774.3 ± 78.7	1.26 ± 0.028	807.3 ± 64.4	1.31 ± 0.030
S.2. Oyuklu	626.7 ± 56.2	400.38 ± 50.1	0.64 ± 0.014	794.9 ± 84.4	1.27 ± 0.029	723.8 ± 63.8	1.15 ± 0.026
S.3. Dağpınar	736.6 ± 50.2	611.3 ± 62.4	0.83 ± 0.019	722.8 ± 62.1	0.98 ± 0.023	688.5 ± 48.5	0.93 ± 0.021
S.4. Uzunkaya	558.5 ± 39.3	558.8 ± 54.1	1.00 ± 0.022	784.1 ± 72.6	1.40 ± 0.032	769.5 ± 59.5	1.38 ± 0.031
S.5. Mahirbey	450.0 ± 38.5	502.6 ± 54.6	1.12 ± 0.025	424.8 ± 56.9	0.94 ± 0.022	309.5 ± 33.5	0.69 ± 0.012
S.6. Şatroğlu	719.0 ± 43.9	522.9 ± 56.3	0.73 ± 0.016	568.7 ± 70.7	0.79 ± 0.018	505.7 ± 52.3	0.70 ± 0.016
S.7. Karakale	611.8 ± 47.6	394.2 ± 33.8	0.64 ± 0.015	761.0 ± 76.5	1.25 ± 0.028	519.2 ± 58.1	0.85 ± 0.019
Mean			0.84 ± 0.019		1.13 ± 0.025		1.00 ± 0.023

MDA for $^{40}\text{K} = 57.8 \text{ Bq kg}^{-1}$

with an average value of $617.0 \pm 45.5 \text{ Bq kg}^{-1}$. The average activity concentration of ^{226}Ra , ^{232}Th and ^{40}K estimated to be about two times higher than the world average value of 35, 30 and 400 Bq kg^{-1} , respectively [14].

The activity concentration of ^{226}Ra for pasture-grass vary from 23.5 ± 6.6 to $49.6 \pm 13.4 \text{ Bq kg}^{-1}$ for roots, 25.4 ± 8.4 to $40.3 \pm 11.7 \text{ Bq kg}^{-1}$ for stem and 21.8 ± 6.3 to $38.5 \pm 10.4 \text{ Bq kg}^{-1}$ for leaf. The distribution of ^{226}Ra in individual parts

of pasture-grass indicate decreasing tendency as root, stem and leaf, respectively. When the mean value of ^{226}Ra radioactivity levels in whole part of pasture-grass obtained as $31.3 \pm 8.6 \text{ Bq kg}^{-1}$ was compared to those reported values for whole pasture by others. The mean activity concentration of ^{226}Ra in grass was found to be higher than $1.26 \pm 0.11 \text{ Bq kg}^{-1}$ found by Chakraborty et al. [8] and lower than $67.16 \pm 3.2 \text{ Bq kg}^{-1}$ found by Strok and Smodiš [19].

The levels of ^{232}Th concentration for pasture-grass varied from 51.9 ± 13.2 to $92.0 \pm 18.8 \text{ Bq kg}^{-1}$ for root, 97.5 ± 18.6 to $127.7 \pm 23.8 \text{ Bq kg}^{-1}$ for stem and 67.3 ± 9.7 to $115.4 \pm 23.0 \text{ Bq kg}^{-1}$ for leaf, respectively. The distribution of ^{232}Th in individual parts of pasture-grass shows decreasing propensity as stem, leaf and root, respectively. When the grass as a whole is examined, the average value of ^{232}Th radioactivity, $92.8 \pm 17.9 \text{ Bq kg}^{-1}$, was higher than the average values of ^{232}Th radioactivity in plants such as vegetables, fruit and grass in other reported studies [8, 12, 13, 20, 21].

The measured activity of ^{40}K for the pasture-grass samples varied from 394.2 ± 33.8 to $611.3 \pm 62.4 \text{ Bq kg}^{-1}$ for root, 424.8 ± 56.9 to $794.9 \pm 84.4 \text{ Bq kg}^{-1}$ for stem and 309.5 ± 33.5 to $807.3 \pm 64.4 \text{ Bq kg}^{-1}$ for leaf, respectively. According to our study results ^{40}K is mainly present in all plant parts. High concentration of ^{40}K is monitored in stem and it follows a decreasing trend stem ($690.1 \pm 71.7 \text{ Bq kg}^{-1}$), leaf ($617.6 \pm 54.3 \text{ Bq kg}^{-1}$), and root ($508.6 \pm 52.2 \text{ Bq kg}^{-1}$) are observed in pasture-grass. Because radionuclides may have similar chemical behavior as the nutrient ions, they can be taken with nutrients and transported to specific tissues of plant metabolisms [21]. The percentage of radionuclides in different parts of the pasture-grass did not indicate any remarkable variation in the studied areas, and

the extensive distribution model acquired is demonstrated in Fig. 2.

The values of transfer factors (TF) of ^{226}Ra , ^{232}Th and ^{40}K from soil to pasture-grass were calculated by using the ratio of the radionuclide concentration in plant (Bq kg^{-1} , dry weight) to its concentration in soil (Bq kg^{-1} , dry weight). The obtained TF values for ^{226}Ra , ^{232}Th and ^{40}K in the root, stem and leaf parts of the pasture-grass from soil in Digor District are shown in Tables 2, 3 and 4. The TFs of ^{226}Ra values range from 0.27 ± 0.13 to 0.69 ± 0.34 for root, from 0.26 ± 0.13 to 0.61 ± 0.31 for stem and 0.26 ± 0.13 to 0.53 ± 0.26 for leaf. As can be seen from Table 2, the mean value of TFs of ^{226}Ra radionuclide in roots, stems and leaf parts of 36 pasture-grass samples were 0.43 ± 0.22 , 0.40 ± 0.20 and 0.38 ± 0.18 , respectively. The TFs of ^{226}Ra in root is higher than stem and leaf in pasture-grass samples.

Also shown in Table 3 is that the TFs for ^{232}Th are 0.64 ± 0.13 to 1.50 ± 0.30 for the root, 1.33 ± 0.27 to 1.99 ± 0.40 for the stem and 1.10 ± 0.22 to 1.91 ± 0.39 for the leaf in the grass-grass samples studied. The average value of TFs of ^{232}Th radionuclide in roots, stems and leaf parts of all pasture-grass samples were estimated 1.14 ± 0.23 , 1.69 ± 0.34 and 1.49 ± 0.30 respectively. The TFs of ^{232}Th at the stem part of plant samples is higher than the TFs of ^{232}Th at the root and leaf parts of pasture-grass samples. When the plant samples taken from the studying stations are examined, the TF values for ^{40}K were found to be 0.64 ± 0.014 to 1.12 ± 0.025 for the root, 0.79 ± 0.018 to 1.40 ± 0.032 for the stem and 0.69 ± 0.012 to 1.38 ± 0.031 for the leaf (see Table 4). The mean value of TFs for ^{40}K in different parts of pasture-grass samples was found to be 0.84 ± 0.019 , 1.13 ± 0.025 and 1.0 ± 0.023 for stem, leaf and root, respectively.

Fig. 2 Weight normalized distribution of ^{40}K , ^{226}Ra and ^{232}Th radionuclides in individual parts of the pasture-grass

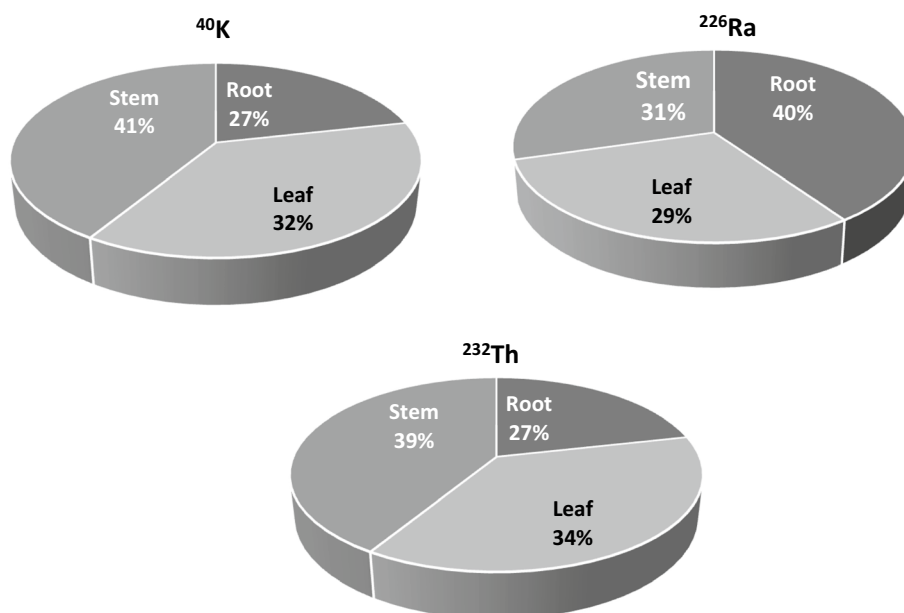


Table 5 Comparison of the average level of natural radioactivity obtained in pasture-grass and the transfer factor of soil-to-plant in this study with those in other countries

References	Location of sample	Type of sample	Activity concentration (Bq kg ⁻¹)			Transfer factors		
			²²⁶ Ra	²³² Th	⁴⁰ K	TF _{Ra}	TF _{Th}	TF _K
Kritsanuwat et al. [12]	Thailand	Alpina Galangal	0.9±0.7	0.9±0.9	785±576	0.023±0.03	0.015±0.02	2.2±2.1
Abdou et al. [2]	Egypt	Jew's Mallow	0.501±0.03	0.136±0.02	11.436±0.42	0.032	0.0041	0.018
Shayeb et al. [13]	Saudi Arabia	Date Palm Pits	5.6	2.8	181	0.33	0.22	0.51
Pulhani et al. [21]	India	Wheat Grains	0.7±0.1	1.1±0.02	102.9±9.8	0.015	0.019	0.23
Jazzar and Thabayneh [3]	Palestine	Grass				1.26	1.15	1.20
Chakraborty et al. [8]	Bangladesh	Grass	1.26±0.11	3.66±0.31	134.95±3.68	0.056	0.089	0.275
Strok and Smodis [19]	Slovenia	Grass	67.16±3.2			0.42±0.12		
Tome et al. [4]	Spain	Grass-Pasture				0.17	0.058	
Karunakara et al. [22]	India	Plant	35.4±2.2		142.1±12.4	BDL-0.37		0.09–5.61
Keser et al. [20]	Turkey	Cabbage		5.9±1.7	489.0±11.2		0.08	2.08
IAEA [23]		Plant				0.04	0.05	1.4
This study	Digor Turkey	Pasture-Grass	31.4±8.6	92.8±17.9	605.5±59.4	0.40±0.20	1.44±0.30	0.99±0.023

Table 5 compares the activity concentrations of ²²⁶Ra, ²³²Th and ⁴⁰K in pasture grass samples examined and the transfer factor of soil to plant in the present study with those by other researcher within the world. Tome et al., Chakraborty et al., Al-Masri et al. and Strok and Smodis reported that TF values for ²²⁶Ra from soil to grass were 0.17, 0.056, 0.082 and 0.42±0.12, respectively [4, 8, 9, 19]. The reported values of ²²⁶Ra activity in stem and leaves of Itovu from Kaiga region, India were 5.9±0.9 and 4.6±1.1 Bq kg⁻¹ dry weight, respectively [22]. The ²²⁶Ra transfer factors reported in International Atomic Energy Agency [23] for grass and different type of vegetables vary in the range 0.0011–0.1. The ²²⁶Ra transfer factors from soil to pasture grass observed in the present study are comparable to these reported values.

Tome et al. [4] reported that TF values of between 0.013 and 0.270 for ²³²Th were found in a uranium mine for grass-pasture. For cabbage grown in Turkey, the mean TF value for ²³²Th found by Keser et al. was 0.08 [20]. Furthermore, the published TF mean value for thorium in grass is 0.011, which is lower than the results obtained in the present study [23]. In this study, the mean TF value of ⁴⁰K in pasture-grass is 0.99±0.023, which is similar to the value reported 1.2 in grass samples in Palestine but it is higher than 0.275 in grass in Bangladesh [3, 8]. The ⁴⁰K transfer factors average value observed in present study is higher than the reported values in literature in some plants such as vegetables, fruits and wheat [2, 13, 21]. However, our obtained the mean transfer factor for ⁴⁰K value is lower than the values reported in the studies in India, Thailand and Turkey [12, 20, 22].

Conclusions

The activity concentrations of natural radionuclides were determined in soils and pasture-grass collected from seven villages in Digor district of Turkey. Results have shown that ²²⁶Ra to be rather kept in roots as compared to stems and leaf. ⁴⁰K concentration is primarily transported by stem of the plants hence higher concentration was seen in stem of pasture-grass samples than in the leaf and root. The obtained transfer factors of natural radionuclides in different parts of pasture-grass indicated that the uptake of ²³²Th was slightly higher than ⁴⁰K but about three times higher than ²²⁶Ra in examined pasture-grass samples. Since plants such as pasture-grass can be used for bio monitoring, the data obtained from this study can be used for radiological assessment of the environmental health risk.

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