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Transfer of natural radionuclides from soil to plants and grass in the western north of West Bank environment- Palestine

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Abstract: The transfer factors of radionuclides (^{226}Ra, ^{238}U, ^{232}Th, ^{40}K and fallout radionuclides ^{137}Cs) from soil to plant and grass collected from the north-west of West Bank environment – Palestine were measured. For soil to plant, the average transfer factor (TF) values were found to be 0.60, 0.50, 0.31, and 1.70 for ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K respectively. For soil to grass the TF values were found to be 1.26, 1.12, 1.15 and 1.20 for ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K respectively. For soil to plant, the average transfer factor values were found to be 0.27 for fallout radionuclides ^{137}Cs. The TF showed wide variation in different species, while a few species of plants indicated preferential uptake of these radionuclides. TF average values from soil to grass were found to be higher than from soil to plant. Results showed that part of the total ^{226}Ra in agricultural soils were from phosphate fertilizers. Because the species of plants were directly involved in the human food chain, information on the concentration level and transfer of radionuclides from soil to plants will provide important data for the environmental risk assessment in such zones. These results have been compared with those of different countries of the world.

Keywords: Activity Concentration, Transfer Factor, Plant, Grass, Caesium-137, Primordial Radionuclides

1. Introduction

There are many sources of radiation and radioactivity in the environment. Gamma radiation emitted from naturally occurring radionuclides, also called as terrestrial background radiation, represent the main external source of irradiation of the human body [1, 2, 3]. Once present in the environment, these radionuclides, whether natural or artificial from fallout i.e. ^{137}Cs, are available for uptake by plants and animals, and also make their way into the food chain [3, 4]. Naturally occurring radioisotopes are the main sources of both external and internal radiation exposure in human beings.

There are two mechanisms for the contamination of vegetation, i.e., by root uptake or directly by aerial deposition of fallout radionuclides on plants. It is necessary to carry out an accurate assessment of these radionuclides in the daily used food materials in order to ascertain the degree of risk and deleterious effects to the public health [5]. Also, the amount of radioactivity in soil is transferred in minute quantities into plants. Plants absorb radionuclides from soil and enter the human body with food.

In recent years, examination of radioactive isotopes in the environment and their role for living things of our planet has attracted growing attention, increasing radionuclide concentration in the environment and threatening living organisms by entering the food chain from plants to animals and, finally, to man [6]. The uptake of radionuclides by plants from the soil is normally described by the transfer factor (TF) [7]. The plants take in deposited radionuclides from soil commonly expressed as soil-to-plant transfer factor (TF); TF is widely used for calculating radiological human dose via the ingestion pathway. The soil-to-plant TF is regarded as one of the most important parameters in the environmental safety assessment for nuclear facilities. The soil-to-plant transfer of radionuclide depends on soil type, electrical conductivity (EC), pH, solid/liquid distribution coefficient, exchangeable K^+, organic matter contents and bicarbonate contents of soil. [8].

Many projects were run by the International Atomic Energy Agency (IAEA) to determine TF mainly for ^{137}Cs [9, 10]. This data has been used extensively in radiological assessment models. Natural environmental radioactivity arises mainly from primordial radionuclides, such as ^{40}K, and the radionuclides from the ^{232}Th and ^{238}U series, and their decay products are considered to be the main contributor to internal radiation dose. Several studies on the transfer of natural radionuclide's from soil to plant have been carried out in different regions in the world [5, 7-8, 11-13]. However, there seems to be no data on the transfer of natural radionuclide's from soil to plant in the environment of Palestine.

In recent studies [3, 14], the concentration of natural radioactivity and associated effective dose levels for ^{226}Ra, ^{238}U, ^{232Th}, ^{40}K and ^{137}Cs radioisotopes were measured for soil and plant samples from Tulkarem district of West Bank Palestine. Moreover, these studies [14] showed that the Excess lifetime cancer risk *ELCR* values of the plant samples were slightly higher than the world average, which may have future health implication on population.

The objective of this investigation is to study the soil-to-plant transfer factor of natural radioactive nuclides to selected plant samples from the Western North of West Bank Environment - Palestine (Tulkarem district), in order to assess the radiation doses to human beings.

2. Materials and Method

2.1. Study Area

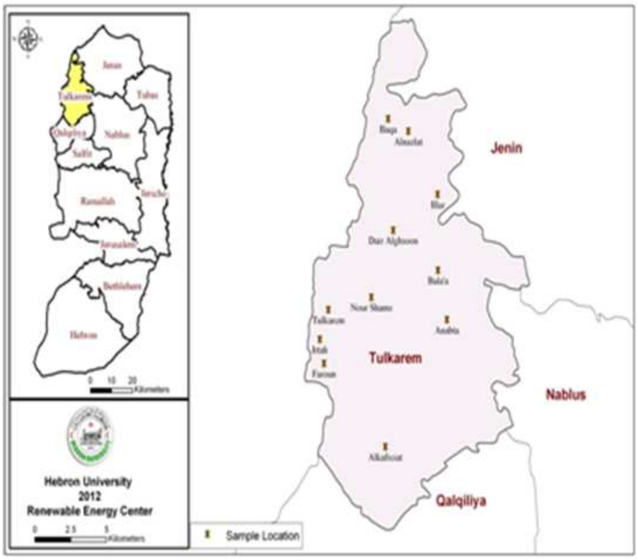

Fig 1. West Bank geographical map and sample location of Tulkarem district, Palestine. (towns of the district can be visible on enlargement)

The study area (Tulkarem governorate) is located in the north-west of West Bank – Palestine. The Tulkarem governorate (Latitude: 21° 32' 48", Longitude: 39° 11' 29") is an administrative district and one of the 16 governorates of the Palestinian National Authority. The governorate's land area is 268 square kilometers, with a population of 173,000 inhabitants www.pcbs.gov.ps. The governorate is situated on the western edge of northern West Bank, in the foothills of the Samarian Mountains about 15 kilometers North West of Nablus and 15 kilometers east of the coastal town of Netanya (Fig. 1). It is bordered by the 1948 cease-fire line, with the Centre and Haifa Districts in the west, and Qalqiliya and Ramallah Districts to the south. Tulkarem arable land allows the city inhabitants to produce citrus fruits, melons, olives, nut, thyme, fig, grapes, almond, tomatoes, potatoes, green beans, guava, and other products. Tulkarem district was among the first districts targeted by the Israeli Segregation Wall plan that started in 2002. So far, about 42×10^6 m^2 of fertile agricultural lands have been destroyed, confiscated or segregated by the construction of the Wall in this district. The targeted land is considered amongst the most fertile in the West Bank where, it has served as the food basket for Palestinians in Tulkarem and elsewhere. http://en.wikipedia.org/wiki/Tulkarm.

2.2. Soil and Plant Species Preparation

Almond, Olive, Fig, Grapes, Nut, Citrus, Thyme leaves samples and Grass of 1kg weight were collected from different zones within Tulkarem Governorate and the surface soil samples were also collected (10 cm deep) from different places under the host plants and grass, and about 2kg of each sample was packed in polythene bag. Twelve different locations (Tulkarem city, Nurshams, Deir-al- Ghsoon, Illar, Irtah, Bal'a, Chemical Factory, Baqa, Anabta, Kafreiat, Far'un and Al-Nazlat) in the area under investigation and the area nearby (about 100 square kilometers) were selected randomly for collection of 48 soil,28 plant leaves and 20 grass samples. The location zones and the code number of these samples are shown in Table 1 and Figure 1 for soils, plants and grasses respectively. The soil samples were ground, crushed to a fine grain of about 100 meshes and sieved and mixed for homogenization, and the large pieces were removed. Samples were then dried at 110˚C for 24 h to ensure that moisture is completely removed. Plant samples were dried for 10 - 15 h at 100˚C in an electric oven to obtain a constant dry weight. Samples were powdered, charred for homogenization. The samples were packed in 1ℓ Marenilli beaker and sealed for 4 weeks to reach secular equilibrium between ^{226}Ra (daughter of ^{238}U) and ^{232}Th with their daughter nuclei. This was done in order to allow for radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy [3].

2.3. Transfer Factors (TF)

In soil, each radioactive element follows complex dynamics in which a part of its concentration is transported into the soil solution, while another part gradually becomes strongly bound to the particles of the soil. The portion of these radionuclides, which is in the soil solution, can be incorporated via the root into the plants. In some cases this is facilitated by their chemical similarity with other elements that the plant normally uses for its growth [12].

The soil-to-plant TF, which are the ratios of specific activities in plant parts and soil, can be used as an index for the accumulation of trace elements by plants or the transfer of elements from soil to plant through the roots [11]. All the results of the activity concentrations of different radionuclides in the plant and soil samples were taken from previous published articles [3, 14].

From observed activity concentrations of the radionuclide (^{226}Ra, ^{238}U,^{232}Th, ^{40}K and ^{137}Cs) in the plant and in the corresponding soil, the TF values were calculated according to the equation [7, 15]:

$$\mathrm{TF} = A_P/A_S \tag{1}$$

Where A_P is the activity of radionuclides in plant (Bqkg^{-1}dryweight) and A_S is the activity of radionuclides in soil (Bqkg^{-1}dry weight). The dry weight was preferred because the amount of radioactivity per kilogram dry weight is much less variable than the amount per unit fresh weight [5].

3. Results and Discussion

3.1. Transfer Factors from Soil to Plant Leave

Activity concentration of radionuclides in soil and plant leaves and their TF are presented in the Table 1. TF values for ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K were found to have the ranges of 0.19 - 1.12, 0.09 - 1.12, 0.10 - 0.49 and 0.13 - 16.3 with average values of 0.60, 0.50, 0.31 and 1.7, respectively. TF average values for ^{40}K are considerably higher than other radionuclides, which suggest higher levels of uptake of ^{40}K. It is interesting to note that although all the plant species are grown in soils of similar physical -chemical characteristic and similar concentration of these radionuclides, the TF value are different for different species. This indicated that, some plant species concentrate higher ^{40}K radionuclides than others, and plants may uptake potassium from soil as an essential element of metabolism and other radionuclides may be taken as a homologue of an essential element [12]. The data compiled by IAEA for soil to plant transfer factor of ^{40}K in leaves was in the range of 0.49 to 5.6 with average value of 1.4. In the present study the average value of TF for ^{40}K in plant species was found to be higher than IAEA value [16]. The higher transfer factor of potassium at that time was not at risk streak because that value was not at staid position to harm the body. For ^{226}Ra, IAEA has compiled soil-to-plant TF of ^{226}Ra for leaves with the average value of 0.11 with a range of 0.01 - 1.0 [16]. The observed range values of soil-to-plant TF in the present study are within the range of reported values, and the average value is higher than the reported values. In general, the values of ^{232}Th TF were lower than those values reported in other studies and the default values suggested by IAEA [16].

Table 1. *The activity concentrations (AC, in Bqkg^{-1})of radionuclides and their transfer factors(TF) from soil to plant leaf samples collected from some area in western north of West Bank, Palestine.*

Zone symbol	**Sample code**	**Type of sample**	**^{226}Ra**	**AC ^{238}U**	**^{232}Th**	**^{40}K**	**^{226}Ra**	**TF ^{238}U**	**^{232}Th**	**^{40}K**
Z_1	SS.1	Soil	127.8	83.5	44.8	404.0	0.49	0.30	0.10	0.35
	LS.2	Leaves	62.8	24.8	3.6	140.0				
	SS.2	Soil	95.7	60.4	43.5	309.0	0.63	0.45	0.23	0.50
	LS.2	Leaves	60.1	27.0	9.8	153.0				
Z_2	SS.3	Soil	41.2	24.6	21.4	124.4	0.39	0.33	0.16	0.84
	LS.3	Leaves	15.6	8.1	3.5	104.0				
	SS.4	Soil	73.0	34.1	19.7	112.9	1.12	1.12	0.34	0.13
	LS.4	Leaves	81.4	38.1	6.6	15.0				
Z_3	SS.5	Soil	43.2	25.6	5.3	34.3	0.65	0.57	0.75	0.79
	LS.5	Leaves	28.1	14.7	4.0	61.0				
	SS.6	Soil	79.1	36.1	23.3	87.4	0.37	0.36	0.23	1.60
	LS.6	Leaves	29.2	13.0	5.3	139.0				
Z_4	SS.7	Soil	8.8	12.2	14.8	89.0	0.85	0.64	0.49	0.70
	LS.7	Leaves	7.5	7.8	7.2	61.4				
	SS.8	Soil	91.5	47.4	31.8	75.6	0.96	0.72	0.11	0.67
	LS.8	Leaves	87.7	34.3	3.6	51.0				
	SS.9	Soil	95.9	47.7	29.3	92.6	0.31	0.32	0.21	0.15
	LS.9	Leaves	30.1	15.1	6.2	14.3				
Z_5	SS.10	Soil	70.2	37.3	28.9	117.1	0.80	0.65	0.31	13.8
	LS.10	Leaves	55.6	24.2	9.0	1622				
Z_6	SS.11	Soil	90.6	49.7	23.8	141.0	0.20	0.23	0.32	0.55
	LS.11	Leaves	18.2	11.3	7.7	77.6				
	SS.12	Soil	59.1	30.1	9.6	53.0	0.21	0.25	o.44	0.28
	LS.12	Leaves	12.6	7.5	4.2	15.0				
Z_7	SS.13	Soil	88.3	42.3	26.6	86.8	0.96	0.98	0.35	16.3
	LS.13	Leaves	85.2	41.4	9.3	1413				
Z_8	SS.14	Soil	106.6	54.7	20.2	90.6	0.19	0.09	0.30	0.34
	LS.14	Leaves	21.0	4.7	5.9	31.0				
	SS.15	Soil	92.8	47.8	4.4	111.7	0.68	0.55	0.41	12.31
	LS.15	Leaves	63.5	26.3	1.8	1376				
	Total	Av.	-------	------	------	------	0.60	0.50	0.31	1.70

Differences between radionuclides TF values for various plant species are due to the different characteristics of the plants. By comparing TF values corresponding to uranium, and radium, we concluded that the uranium ^{238}U was statistically indistinguishable, whereas the uptake for radium was higher than for the other elements. Because uranium is an actinide element, this may explain its more analogous chemical behavior, whereas, this argument cannot be extended to radium which is an alkaline-earth.

To evaluate the dependence of TF values on the age of the leaves, samples of olives and citrus (evergreen) were collected in several zones, and analyzed for the radionuclides concentrations. These results suggested that TF values of ^{232}Th and ^{40}K for leaves depend on the age of the leaves. It is concluded that, if the age increases the TF values are decrease.

In general, the comparative uptake of ^{226}Ra, ^{238}U, and ^{232}Th by different plants is affected by numerous physical, chemical and biological conditions of the soil. The combined effects of these conditions, as well as the individual chemical properties of the nuclides, tend to affect its uptake by plants. For example, retention of radionuclides onto the soil particles will affect their availability for plant uptake. Martinez et al., reported that ^{232}Th exhibited a much lower mobility than ^{238}U, which is consistent with our observations that ^{232}Th has smaller TF values [17]. The magnitude and range of TFs of^{226}Ra, ^{238}U and ^{232}Th found in this study appeared to be generally similar to values obtained in other studies, where root uptake was the primary mechanism of accumulation.

3.2. Transfer Factors from Soil to Grass

Values of TF have been calculated from activity concentration of radionuclides in soil and grass; values of TF are presented in Table 2. Results have been obtained for ^{226}Ra in grass with a TF average value of 1.26, and a range between 0.27- 2.12. Results showed that, the TF average values in grass corresponding to the ^{238}U were 1.12, with a range of 0.36- 1.62, the TF average values for ^{232}Th were 1.15 and a range of 0.1- 4.97, and the TF average values for ^{40}K were 1.20 and a range of 0.36- 2.90 . The TF values show a very wide variability for ^{232}Th and the average TFs of ^{226}Ra had the highest values compared to other radionuclides, which must be explained by the higher absorption of radium. It was be observed that radionuclides TF values from soil to grass were higher than from soil to plant leafs. The high average values of TF (TF >1) for all radionuclides is attributed to the abundance of the organic matter in the zone soils.

The variation observed in TFs for the grass samples is due to various factors such as age of the grass, and the environment in which the grass is grown. In the present study the average values of TF for all radionuclides except ^{40}K were found to be higher than IAEA values [16]. This was possibly due to low concentrations of radioactive elements in the soil that the grass grown on it.

It is worthy to note that if TF >1, this will lead to a transfer of radionuclides from plants to livestock and finally to humans through the food chain, this may lead to many radiation hazards to the human population.

Table 2. *The activity concentrations (AC, in Bqkg^{-1}) of radionuclides and their transfer factors (TF) from soil to grass samples collected from some area in western north of West Bank, Palestine.*

Zone symbol	Sample code	Type of sample	^{226}Ra	AC ^{238}U	^{232}Th	^{40}K	^{226}Ra	TF ^{238}U	^{232}Th	^{40}K
Z_9	SS.16	Soil	33.4	17.0	9.4	104.8	0.54	1.17	2.22	1.34
	GS.16	Grass	18.0	19.8	20.9	140.3				
	SS.17	Soil	66.7	30.0	3.3	99.9	0.29	0.63	4.97	0.61
	GS.17	Grass	19.2	18.8	16.4	60.6				
Z_{10}	SS.18	Soil	72.3	36.9	34.8	171.6	2.15	1.62	0.10	0.36
	GS.18	Grass	155.4	59.6	3.5	61.0				
	SS.19	Soil	92.1	47.1	34.2	147.2	0.27	0.36	0.35	0.59
	GS.19	Grass	25.0	17.1	12.0	87.0				
Z_{11}	SS.20	Soil	83.7	39.4	27.7	112.0	0.66	0.65	0.21	0.96
	GS.20	Grass	55.6	25.5	5.9	111.5				
	SS.21	Soil	71.2	41.6	33.9	126.4	2.12	1.59	0.93	1.93
	GS.21	Grass	157.6	66.1	31.6	244.0				
Z_{12}	SS.22	Soil	69.0	35.4	27.9	109.5	1.87	1.33	0.14	0.77
	GS.22	Grass	129.0	47.3	3.8	84.0				
	SS.23	Soil	73.5	36.2	24.8	124.9	1.81	1.39	0.17	0.66
	GS.23	Grass	133.0	50.2	4.2	82.2				
Z_5	SS.24	Soil	59.4	27.9	28.4	106.7	0.82	1.39	1.71	2.90
	GS.24	Grass	48.6	38.8	48.5	309.0				
Z7	SS.25	Soil	6.2	13.8	12.6	49.9	2.10	1.03	0.67	1.88
	GS.25	Grass	13.0	14.2	8.4	93.6				
	Total	Avg.	------	------	--------	-------	1.26	1.12	1.15	1.20

3.3. TF of ^{137}Cs for Different Plant Species

Table 3. *Average activity concentrations of* ^{137}*Cs and their transfer factors (TF) from soil to plant samples collected from some area in western north of West Bank, Palestine.*

Zone symbol	^{137}Cs (soil)(Bqkg^{-1})	^{137}Cs (plant)(Bqkg^{-1})	TF
Z_1	12.6	0.1	0.01
Z_2	7.3	1.2	0.16
Z_3	4.9	2.0	0.41
Z_4	10.2	1.2	0.12
Z_5	4.3	3.3	0.77
Z_6	8.9	1.0	0.11
Z_7	9.4	3.1	0.33
Z_8	5.9	0.4	0.07
Z_9	1.6	0.9	0.56
Z_{10}	15.3	4.3	0.28
Z_{11}	7.0	2.5	0.36
Z_{12}	16.5	1.3	0.08
Total Av.	8.7	1.8	0.27

The main indicator of the contamination of the environment is the presence of ^{137}Cs isotope. ^{137}Cs, which has appeared because of power plant failures and nuclear detonations, is a very important and dangerous isotope. The contamination of samples by this isotope is relatively low, with higher values observed for soils than for plants for all examined sites. This proves the durability of cesium adsorption in the soil particles [6]. Analyzing obtained data concerning the transfer of ^{137}Cs from the soil to green parts of plants, it should be noticed that all samples reveal the transportation of this isotope. The high availability of ^{137}Cs in some samples is probably due to its sandy texture containing little clay to fix ^{137}Cs in the soil.

Soil-to- plant TF of ^{137}Cs for different plant species was calculated by using ^{137}Cs activity concentration in plant samples, and the average value of ^{137}Cs activity in soil. As shown in Table 3, TF value for ^{137}Cs is in the range of 0.01–0.77 with an average value of 0.27. TF factor for ^{137}Cs is found to be less than that of all other radionuclides in all plant species. This indicates that ^{137}Cs is less efficiently transported from soil to plants than ^{226}Ra,^{238}U, ^{232}Th and ^{40}K. It was reported that soil-to-plant TF depends on soil properties such as nutrient standard, exchangeable K content, pH and moisture content [15]. In the present study, the average values of TF of ^{137}Cs in plant parts were found to be in close agreement with IAEA range value for plants which was in the range of 0.02-3.2 [16].

Also the higher concentration of fallout radionuclides in some plant samples and soil particles must be due to the accumulation of atmospheric fallout over a long period of time through dry weight deposition and due to strong adsorption of those nuclides to soil particles. The deposition fallout radionuclides on the upper layer of the earth crust may get washed out by heavy rains. This leads to the movement of fallout nuclides along with surface soil, whereas root dust keeps on accumulating without any movement [18].

3.4. Estimated ^{226}Ra from the Fertilizers

The results implied that the activity concentrations of ^{226}Ra are greater than for ^{238}U in the soil samples; however, we must consider the effect of excess ^{226}Ra which could come from phosphate fertilizers. Uchida and Tagami, estimated that about 50% of total ^{238}U in upland field soils came from the fertilizers [19]. It is known that ^{226}Ra is included in the fertilizers [20] and their use in agricultural fields must have a small contribution as external radiation to the population. Thus, using the previously data approach [13], we estimated ^{226}Ra from the fertilizers contents in soil (Ra_{Fz}) as follows:

$$\mathrm{Ra_{Fz}}\ (\mathrm{Bqkg^{-1}}) = \mathrm{Ra_s} - \mathrm{Th_s} \times [\mathrm{U/Th_N}] \times \mathrm{A} \tag{2}$$

where Ra_S is the total ^{226}Ra radioactivity concentration in a soil samples, Th_S is ^{232}Th concentration in the soil, [U/Th$_N$] is the average value of naturally observed [U]/[Th] concentration ratio (0.23), and A is a conversion factor from ^{238}U concentration to ^{226}Ra radioactivity since 1 mg kg^{-1} ^{238}U is equal to 12.3 Bqkg^{-1} of ^{226}Ra when two isotopes will reach equilibrium.

As shown in Table 4, the Ra_{Fz} values were 2.4 to 50.0 Bqkg^{-1} with an average value of 22.6 Bqkg^{-1} in the area under investigation. Concerning the contributing percentages of Ra_{Fz} to total ^{226}Ra in soil samples, we obtained 2 to 65.7 % with an average value of 26.7%. The results implied that quarter of the total ^{226}Ra in agricultural soils was from phosphate fertilizers.

Table 4. *The estimated activity concentrations of radium in fertilizers (*Ra_{Fz}*, Bqkg*$^{-1}$*) in some soil samples in western north of West Bank, Palestine.*

Zonesymbol	Sample code	^{226}Ra	AC ^{238}U	^{232}Th	Ra$_{Fz}$	%
Z_1	SS.1	127.8	83.5	44.8	2.4	2.0
Z_2	SS.4	73.0	34.1	19.7	17.8	24.4
Z_3	SS.5	43.2	25.6	5.3	28.4	65.7
Z_4	SS.9	95.9	47.7	29.3	13.9	14.5
Z_6	SS.12	59.1	30.1	9.6	32.2	54.5
Z_7	SS.13	88.3	42.3	26.6	13.8	15.6
Z_8	SS.14	106.6	54.7	20.2	50.0	47.0
Total	Average	84.8	45.4	22.2	22.6	26.7

Finally, Table 5, compares the reported values of transfer factors (TF) from soil to plant samples, obtained in other countries, with those determined in the present study. It is found that, the average values of TF for ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K were within or higher than those of the other countries [5, 7, 8, 12, 19, 21-23].

Table 5. *Comparison of transfer factors (TF) from soil to plant samples at different locations in the area under investigation with those in other countries.*

Country	Type of sample	^{226}Ra		TF ^{238}U		Values ^{232}Th		^{40}K		Reference
		Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	
Japan	Crops	0.001-0.06	0.0064	-----		-----		-----		[19]
Romania	Plants	0.07 – 9.34	4.71	0.05 – 0.66	0.36	-----		------		[21]
Egypt	Plants	0.19 – 0.73	0.43	------		0.09 – 0.88	0.31	0.31–2.95	1.06	[7]
Malaysia	Rice	-----		0.04 – 0.20		0.02 – 0.15		0.09 – 4.12		[22]
Saudi Arabia	Plants	0.06 – 0.19	0.12	------		------		0.08–0.23	0.16	[5]
India	Plants	----		BDL – 0.31		0.22 – 0.34		0.13 – 0.95		[12]
Bangladesh	Grass		0.06	------			0.09		0.28	[8]
	Plants		0.06	------			0.10		0.27	
IAEA	Plants	0.01 – 1.00	0.11	------		------		0.49–5.60	1.40	[23]
Palestine	Plant	0.19 – 1.12	0.60	0.09- 1.12	0.50	0.10- 0.49	0.31	0.13- 16.3	1.70	present study
	Grass	0.27- 2.12	1.26	0.36-1.62	1.12	0.10- 4.97	1.15	0.36- 2.90	1.20	

4. Conclusions

A radiological study was performed to obtain transfer factors of ^{226}Ra ,^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in 48 plant leaves and grass samples on soil contaminated in 12 zones from the western north of West bank environment- Palestine. The main conclusions that are derived from the present work can be summarized as follows:

1. Results predicted that for all transformation from soil to plant leafs, potassium has highest average TF. This was due to the fact that potassium is an important element to plant fertility, even though potassium is a radioactive element, but it does not harm the environmental system.
2. From plant fraction analysis, the younger leaves have the highest average TF values.
3. The average values of TF from soil to plant leaves for ^{40}K was found to be higher than IAEA value, while in another radionuclides, the average values of TF are within the IAEA range.
4. In grass, the average TF values varies in the order of ^{226}Ra > ^{40}K > ^{232}Th > ^{238}U and was found to be higher than IAEA value except ^{40}K radionuclide.
5. TF factor for ^{137}Cs in present study was found to be less than that of all other radionuclides in all plant species and was found to be in close agreement with IAEA range value for plants**.**
6. Results showed the quarter of the total ^{226}Ra in agricultural soils was from phosphate fertilizers.
7. The results of this study were compared well with other studies carried out in other countries and with the worldwide average TF.

The information on the concentration level and transfer of radionuclides from soil to plants will provide important data for the environmental risk assessment at such zones.

Authors Contribution

Two authors were involved in the conception, designing, drafting, and approved the final version of the manuscript.

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