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Radioactivity Concentrations in Dust and Soil of Enhanced Naturally Occurring Radionuclides and their Transfer Factors to Urban Trees in Phosphate Polluted Areas

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A survey was carried out to determine the activity concentration levels from the naturally occurring radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) in four different areas affected at various degrees by TE-NORM activity (Al-Nasr quarry for phosphate) using The High Purity Germanium Detector (HPGD) taking into account the background level. The average activity concentration levels due to radionuclides were measured for soil, dust and urban trees leaves (*Eucalyptus globulus*) samples collected from these areas. The transfer factors of radionuclides (^{226}Ra, ^{232}Th and ^{40}K) from soil and dust to plant (*Eucalyptus globulus*) for these areas were measured. It was found that the activity concentration of ^{40}K, ^{232}Th, and ^{226}Ra radionuclides varies according to the variations of the areas. Samples of area (4) showed lower ^{226}Ra and ^{232}Th concentrations than other areas. Area (1) which is close to the source of pollution showed the highest values for ^{226}Ra activity concentration. Leaves of *E. globulus* exhibited different accumulation coefficients according to the distance from the quarry. The transfer factors of radionuclides (^{226}Ra, ^{232}Th and ^{40}K) are given to make rough estimates of the two main mechanisms of radionuclide accumulation; atmospheric deposition and root uptake of the urban trees (*Eucalyptus globulus)*. The relationship between radionuclides concentrations in leaf, deposited dust and soil samples was estimated using Pearson coefficients..

Keywords: *Transfer factor / Radionuclide / Urban trees /Atmospheric deposition*

Introduction

A number of non-nuclear industries are sources of technologically enhanced natural radiation (TE-NORM) as they contribute to the re-distribution of radioactive nuclei in the environment [1, 2 and 3]. The phrase "Technologically enhanced" was added to the term to distinguish clearly between radionuclides as they occur naturally and radionuclides that human activity has concentrated or exposed [4]. Phosphate ores are typically enriched in uranium and they are one of technologically enhanced natural radiation. Occupational exposures mainly occur during mining, processing and transportation of phosphate rocks [5 and 6]. There is no radiological control on the operation of these industries or restrictions on how waste is discharged to the ecosystem (soil, atmosphere, plant, water and living organisms) in relation to its radionuclide content [7 and 8]. 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 [9]. There are two mechanisms for the contamination of plants namely, root uptake or directly by aerial deposition of radionuclides on plants [10]. In order to quantify the transport

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process of radionuclides from soil to plants the term plant / soil concentration ratio has been introduced often to be referred to as transfer factor (TF) [11]. The soil-to-plant transfer factor TF is defined as the ratio of the activity concentration in (Bq/Kg) in the dry weight of the plant to the activity concentration in (Bq/Kg) in dry weight of the soil [12]. The soil-to-plant TF can be used as an index for the accumulation of trace elements by plants or the transfer of elements from soil to plant [13]. For this purpose, four areas of different distances from Al-Nasr quarry for phosphate were selected and the transfer of (^{226}Ra, ^{232}Th and ^{40}K) from the soil and deposited dust in leaves of camphor trees (*Eucalyptus globulus Labill*) growing in these areas has been monitored as it is the common tree species at the study area due to its use as green fence around the quarry and decorative plant in the streets and public parks. *Eucalyptus globulus* Labill is one of the world's most widespread hardwood trees due to its social, economic, environmental impacts and being an object for several genetic, ecological and physiological studies.

Study Area

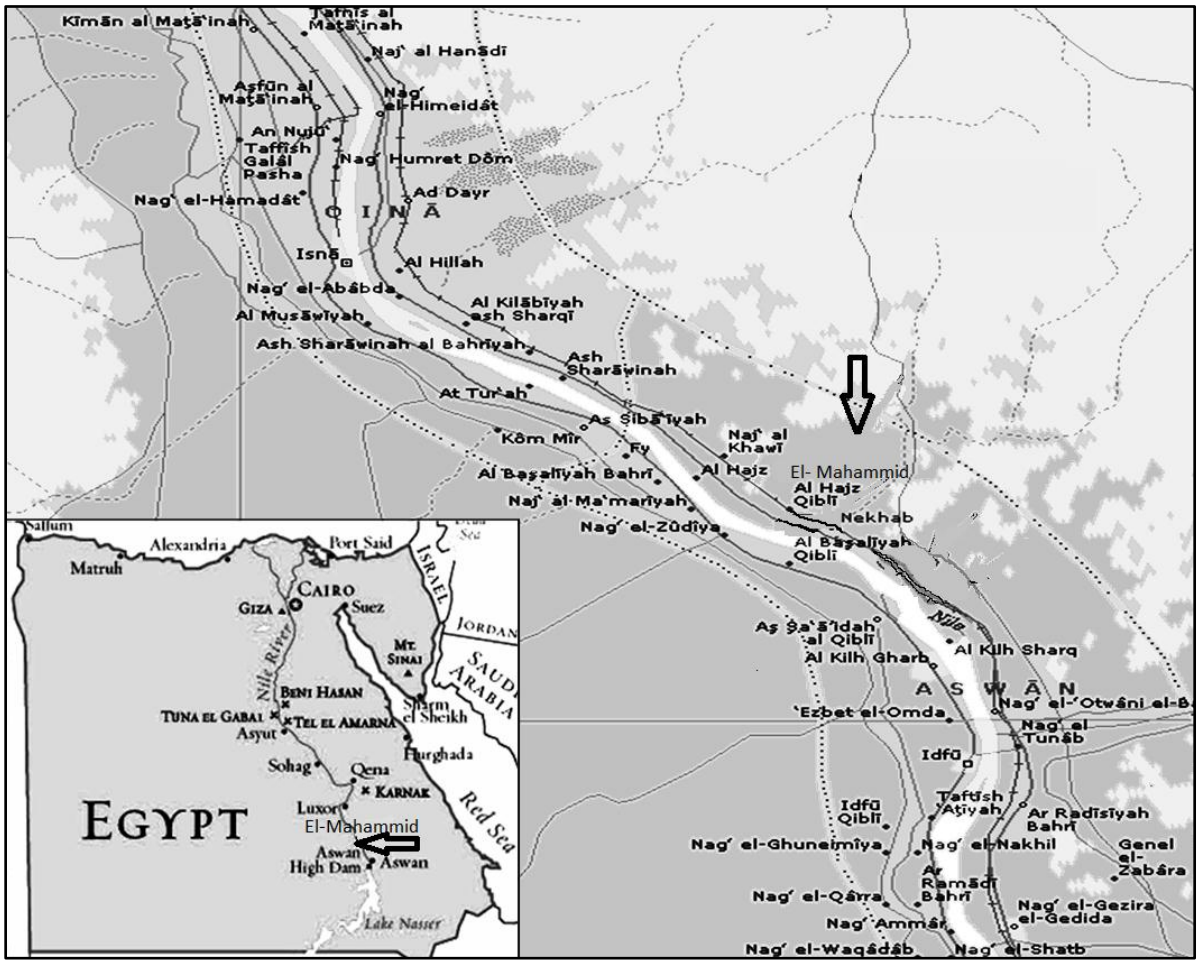
The study areas are adjacent to the quarry for phosphate production of Upper Egypt (25° 6'18.81"N, 32°49'15.53"E 25° 6'4.11"N and 32°49'31.91"E). The rocks containing the phosphate ore are collected, milled and processed for phosphate production. During these operations, the dust spreads with different degrees to cover the neighboring areas, including agricultural and other populated areas [14]. For the purposes of this study, four geographically defined locations (12 sampling points) that covers a distance of 10 km in radius to the North (N), North-East (NE) and North- West (NW) were selected. A control area was selected to be located 40 Km distant from the affected area.

Sampling and Sample Preparation

Samples of soil, fine dust and plant leaves were collected in two seasons throughout year 2016 at different distances from the El-Nasr quarry for phosphate. All samples (soil, dust and leaves) were collected in triplicate. Soil samples were collected from 25 cm depth under the rhizosphere of *E. globulus* trees. Samples with large grain size were crashed to small pieces, dried at 105 ^{0}C, sieved to a fine grain size powder, weighted, sealed and stored for at least 4 weeks before counting. Dust samples were collected from the dust that was produced from phosphate ore milling processes, which carried by the wind and fallen on leaves. After that, these samples were sieved, weighed, sealed in tight plastic containers and stored for at least 4 weeks before counting. At least one-kilogram leaves of *E. globulus* was detached from each tree at a height of 1.5-2.0 m above the ground from the outer and inner parts of the canopies in the four sides of the tree. Then the samples were washed and dried in the sun rays for an enough period. The samples were ground, weighted and stored for one month to reach equilibrium before counting. The natural radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the collected samples were measured using the High Purity Germanium Detector (HPGD) system consists of an N-type coupled to a computer based multi-channel analyzer (MCA), which mounted in a cylindrical lead shield and cooled in liquid nitrogen. For the efficiency calibration, a multi-element standard of known activities was used. Assuming secular equilibrium in the uranium and thorium decay series, the ^{238}U and the ^{232}Th activities were determined indirectly via activities of their daughters. The nuclides chosen were ^{214}Bi (609.3, 1120.3 and 1764 KeV) and ^{214} Pb (351 KeV) for ^{238}U, ^{208}Tl (2614 KeV), ^{212}Pb (238 KeV) and ^{228}Ac (911 KeV) for ^{232}Th [15 and 16]. The specific activity of ^{40}K was determined directly by 1461 KeV photo peak. The background was measured frequently and subtracted from the net count for all measured samples. The activity concentrations of the natural radionuclides in the measured samples were computed using the following relation [17]:

$$A_S = N/\varepsilon P_r M \quad (Bq/Kg) \qquad (1)$$

Where N is the net counting rate of γ-ray (counts per second) corrected for background, ε is the detector efficiency of the specific γ-ray, P_r is the absolute transition probability of γ-decay and M is the mass of the sample (Kg).



Map (1): The areas under investigation

Results and Discussions

Table (1) and Figure (1) present the mean of the measured activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soils and dust for the four areas under investigation. Radium activity concentrations in fine dust samples of area (1) and area (2) are much higher than those found in soil samples of the same two areas. High concentrations of ^{226}Ra in dust and soil of the two first areas near the quarry is due to the influence of the high deposition of the radioactive nuclides produced from milling processes near the quarry. From Table (1) and Figure (2), it can be seen that the average values of ^{40}K in plant samples are considerably higher than those of the other radionuclides, which suggests higher levels of ^{40}K uptake and indicates that plants may uptake potassium from soil as an essential element of metabolism. Other radionuclides may be taken as a homologue of an essential element [9]. Table (2) shows Pearson Correlation Coefficients matrix for radionuclides activities in plant leaves samples with their corresponding activities in both soil and deposited dust samples. Except for ^{226}R, radionuclides in the leaves have large positive correlation coefficients with those of the deposited dust coefficients (r for ^{232}Th = 0.109, r for ^{40}K = 0.60) than that of soil (r for ^{232}Th = -0.056, r for ^{40}K = 0.222), reflecting the role of atmospheric deposition and foliar uptake in the observed accumulation. Meanwhile, ^{226}R in plant leaves showed positive correlation coefficients with their corresponding activities in both soil (r = 0.534) and deposited dust (r = 0.494), indicating the accumulation of this radionuclide in leaves that may be also due to resuspension from soil. However, these results reflect the role of deposited dust in the observed radionuclides plant accumulation. The data compiled by the IAEA for

soil to plant transfer factor of ^{40}K in leaves were in the range of 0.49 to 5.6. From Table (1) and Figs. (3 and 4), it could be seen that the average values of TF for ^{40}K in plant species of different areas are within the range of reported values (IAEA, 2010). For ^{226}Ra, the IAEA has compiled soil-to-plant TF of ^{226}Ra for leaves with a range of 0.01 - 1.0 (IAEA, 2010). The range values of soil-to-plant and dust-to-plant TF in the present study are within the range of reported values except for TF of ^{226}Ra for the dust of area (1) as it has a high concentration of less mobility. Transfer factors of ^{226}Ra, ^{232}Th and ^{40}K from soil to plant were higher compared to dust to plant for the different areas under investigation.

Conclusion

It was observed that the concentrations of ^{226}Ra, ^{232}Th and ^{40}K activity in the plant decreased according to the pattern ^{40}K> ^{226}Ra> ^{232}Th, while the high concentrations of ^{226}Ra were recorded for fine dust collected from areas near El-Nasr quarry. The result shows that radioactivity concentration of ^{226}Ra was found in the plant planted in the soil contains a greater concentration than that of the dust, reflecting the role of the soil in the accumulation of ^{226}Ra in the plant. ^{40}K has the highest average of TF, whereas potassium is an important element to plant metabolism. Moreover, varying seasons seem not to have a decisive influence on TF values.

Table (1): The radioactivity concentrations of (^{226}Ra, ^{232}Th and ^{40}K) in Bq/Kg in soil and dust samples and their transfer factors (TF) to plant

		Plant			Soil						Dust					
		226Ra	232Th	40K	226Ra	232Th	40K	TF(Ra)	TF(Th)	TF(K)	226Ra	232Th	40K	TF(Ra)	TF(Th)	TF(K)
Summer	Area (1)	5.19	3.93	107.37	68.00	10.67	210.31	0.076	0.368	0.511	453.32	11.21	94.19	0.011	0.351	1.140
	Area (2)	4.97	3.06	162.72	53.56	20.12	264.75	0.093	0.152	0.615	230.96	9.50	135.41	0.022	0.321	1.202
	Area (3)	3.63	2.55	143.88	42.98	22.35	233.56	0.084	0.114	0.616	28.63	15.79	185.25	0.127	0.162	0.777
	Area (4)	1.78	4.35	151.19	6.80	10.58	183.34	0.262	0.412	0.825	6.80	10.58	183.34	0.262	0.412	0.825
Winter	Area (1)	1.82	0.45	143.23	84.07	15.17	225.68	0.022	0.030	0.635	439.03	10.97	123.13	0.004	0.041	1.163
	Area (2)	1.51	1.16	160.83	19.70	11.23	205.27	0.077	0.103	0.784	168.53	8.14	171.64	0.009	0.142	0.937
	Area (3)	1.50	1.81	144.38	44.61	9.20	176.51	0.034	0.197	0.818	63.04	5.38	153.52	0.024	0.336	0.940
	Area (4)	0.13	0.87	155.07	14.45	15.30	224.77	0.009	0.057	0.690	14.45	15.30	224.77	0.009	0.057	0.690

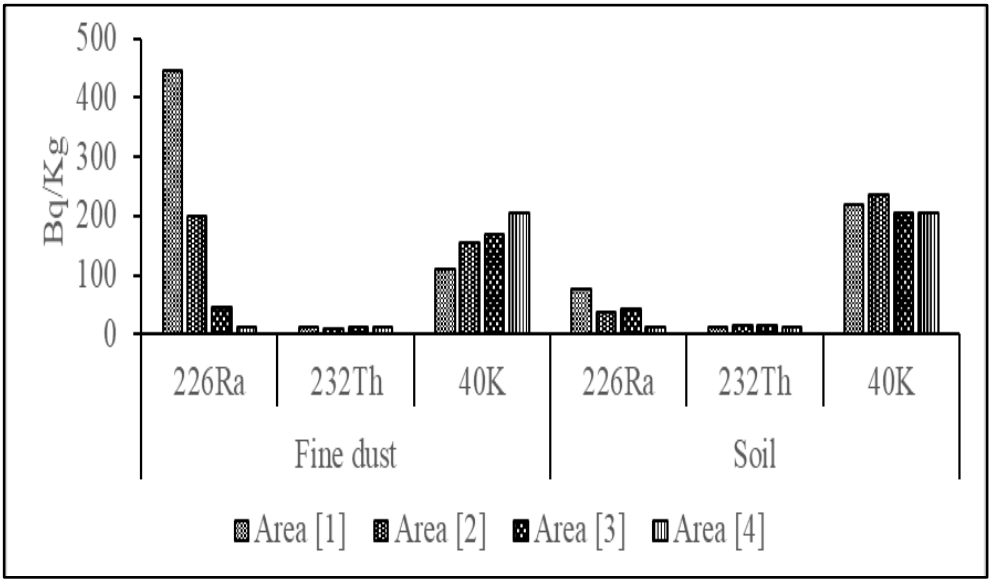


Figure (1): The average activity concentration of dust and soil samples

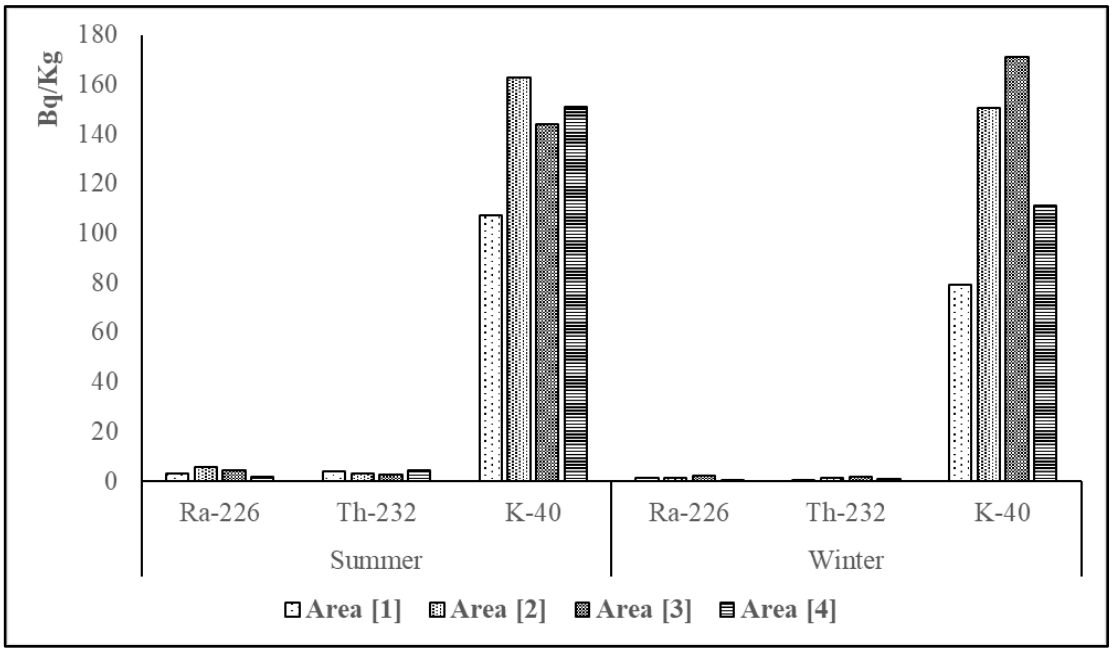


Figure (2): The average activity concentration of plant samples of different areas number

Table (2): Pearson correlation coefficients for radionuclides in the different samples

		Leaves			Soil			Dust		
		^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K
Leaves	^{226}Ra	1.00								
	^{232}Th	0.44 *								
	^{40}K	-0.45*	-0.31							
Soil	^{226}Ra	0.53**	-0.07	0.49*						
	^{232}Th	0.33	-0.06	0.30	0.22					
	^{40}K	0.48 *	-0.04	0.22	0.36	0.83**				
Dust	^{226}Ra	0.49 *	0.01	-0.55**	0.83**	-0.11	0.25			
	^{232}Th	0.01	0.11	-0.10	-0.09	0.56**	0.45*	-0.15		
	^{40}K	0.69**	-0.19	0.60**	-0.83**	0.16	-0.10	-0.88**	0.40	1.00

* **Significant at the 0.05 level** ** **Signfiant at the 0.01 level**

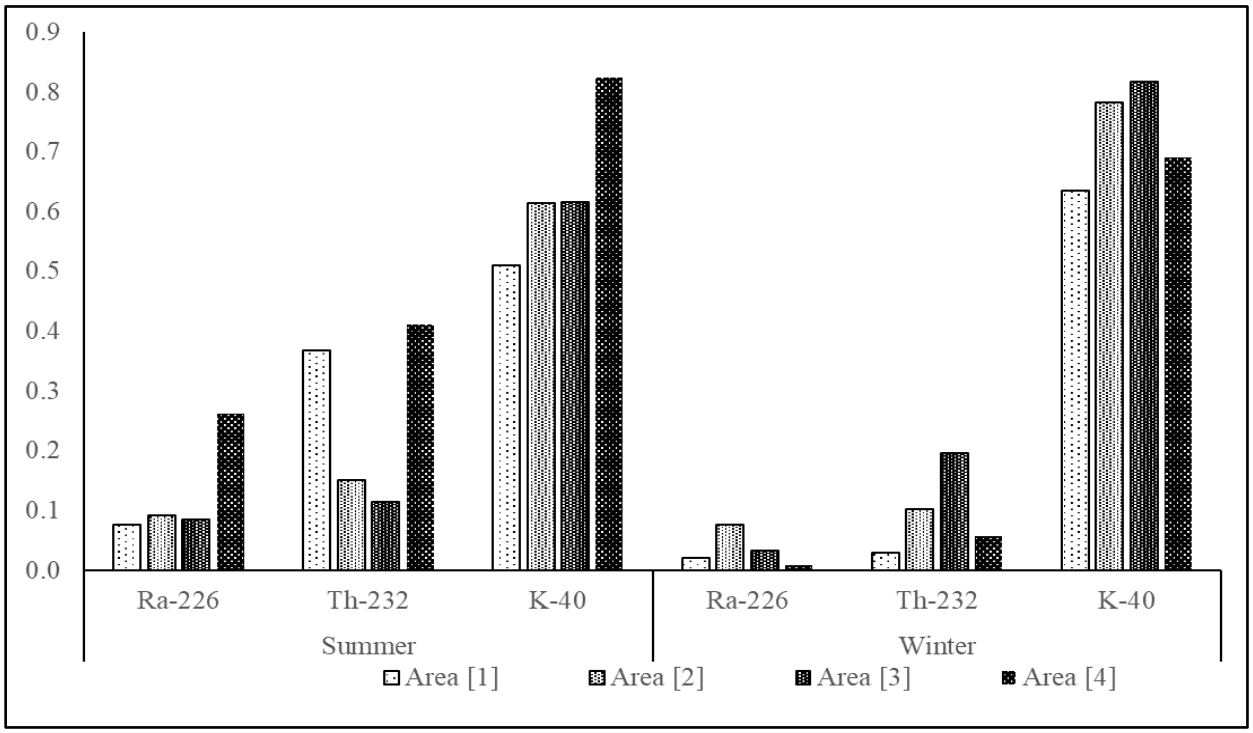


Figure (3): The transfer factor of (^{226}Ra, ^{232}Th and ^{40}K) from soil to plant

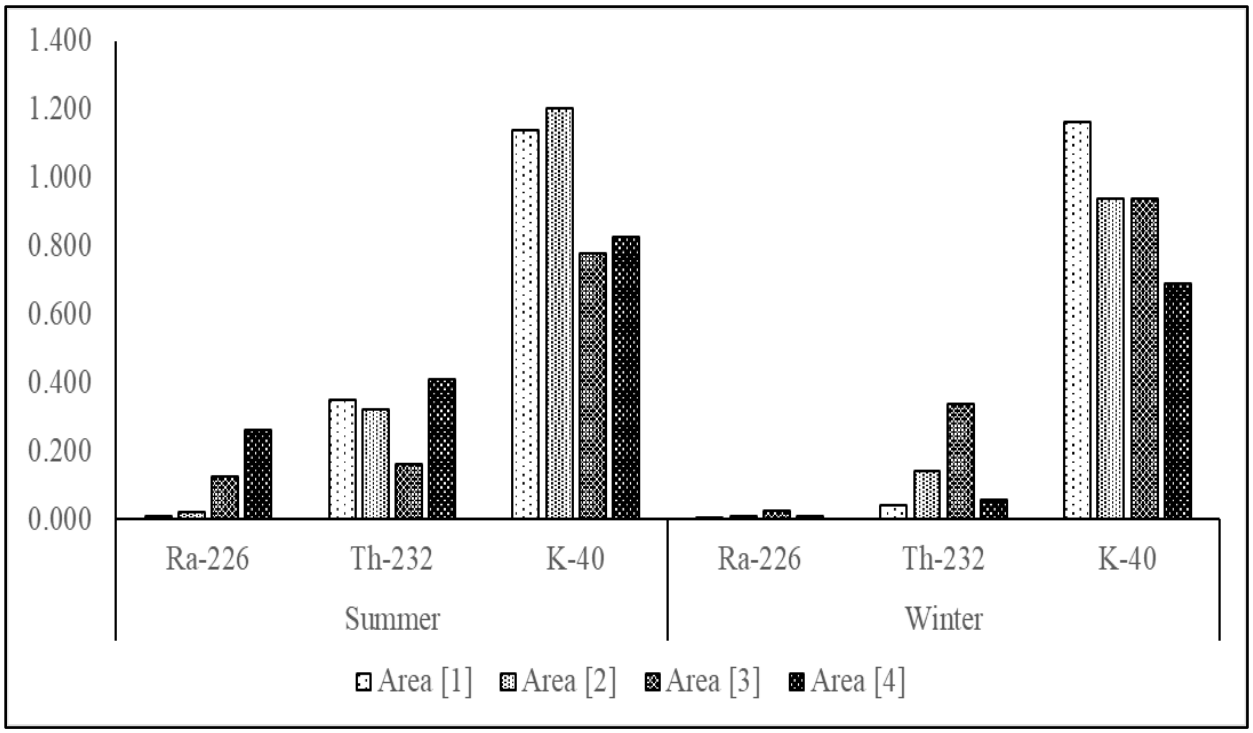


Figure (4): The transfer factor of (^{226}Ra, ^{232}Th and ^{40}K) from dust to plan

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