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Detection of Natural Radionuclides Concentration in Corchorus Olitorius and Soil as Affected by Different Fertilizers

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The main objective of this work is to trace and measure the activity of natural radionuclides ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in sandy loam soil and leaves of Jew's-mallow plant (Corchorus olitorius). A pot experiment was carried out and Jew's-mallow was cultivated on sandy loam soil with six types of commercial and recommended fertilizers (NPK). The activity concentrations of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in Bq kg^{-1} were measured using the high purity germanium detector to assess the effective dose of Jew's-mallow that is largely consumed by the Egyptian population. Gamma activities, at the end of growing season on sandy loam soil, contain a slightly higher concentration of natural radionuclides than the soil at the beginning, but still lower than the worldwide values. The transfer factor for ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K from soil to Jew's-mallow plants was less than unity in all treatments. The estimated annual effective dose due to the ingestion of Jew's-mallow plant varied from 7.89 - 21.5μSv y^{-1}, which indicated that fertilizer addition was not effective on the level of radionuclide in Jew's-mallow and it's safe for human consumption.

Keywords *Gamma activities; Fertilizers; Sandy loam soil; Jew's-mallow; Transfer factor*

Introduction

All minerals and raw materials contain radionuclides of natural origin. The most important, for the purposes of radiation protection, are the radionuclides in the ^{235}U ($T_{1/2}$=7.04×108 y), ^{238}U ($T_{1/2}$ =4.47×109 y), ^{232}Th ($T_{1/2}$ =1.4×1010 y) decay chains as well as singly occurring types such as ^{40}K ($T_{1/2}$ =1.28×109 y). The most important sources of external and internal exposure are the gamma radiation and alpha particles emitted from the radionuclides of the uranium (^{238}U) series, thorium (^{232}Th) series and ^{40}K present within phosphate rocks. External exposure occurs directly by γ-rays, whereas internal exposure to α-particles arises from the inhalation of radon and its progenies. Consequently, the α-particle dose is delivered directly to the bronchial tissue, creating a potential for radiogenic lung cancer [1-2].

Radionuclides in soil are usually transferred to different plant tissues by direct transfer via the root system, or fallout of radionuclides and resuspension of contaminated soil followed by deposition on plant leaves [3]. The soil-to-plant transfer factor (TF) is regarded as one of the most important parameters used in environmental safety assessment to estimate the amount of radioactivity that could be present in agricultural crops and estimating dose impact to human body [4-5].

The direct contamination of terrestrial vegetation refers to the deposition of radioactive materials from the atmosphere onto the above ground plant parts [6]. Indirect contamination refers to the absorption of radionuclides from the soil by the root system of plants **[7]**. Therefore, it is necessary to determine the activity concentration of radionuclides in vegetables that are highly consumed by the Egyptians either as fresh or cooked food. Jew's-mallow is extremely a popular national Egyptian food.

The present study aims to determine the activity concentrations of radionuclides (^{226}Ra, ^{238}U, ^{232}Th

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and ^{40}K) in Jew's-mallow plant fertilized with different fertilizers.

Materials and Method

Set-up and treatments

The pot experiment was conducted at the Farm of Soil and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt. The experimental site is located at 30° 23' 41.26" N latitude, 31° 23' 41.26" E longitude while the altitude is 26 m above the sea level. Some of experimental soil properties are presented in Table (1). The physical properties were determined according to Klute[8] and chemical properties based on the method reported by Page [9]. The set-up consists of 27 pots (PE) packed with 6 kg of sandy loam soil.

Fertilization treatments

Eight mixed treatments of commercial fertilizers have been used in addition to unfertilized control (T0) (Table 2) and replicated three times. Treatments were arranged as follows:

- Two types of phosphate, the first one (F1) is calcium super phosphate ($H_6CaO_9P_2$) (15 % P) was added at a rate of 125 kg ha^{-1} before planting and the second one (F2) is phosphoric acid (H_3PO_4) (85%) was added at a rate of 30 kg P ha^{-1} after 20 days from planting date.
- Two types of nitrogen, the first one (F3) is ammonium sulphate ($(NH_4)_2SO_4$) (20.6% N) was added at a rate of 250 kg ha^{-1} and the second one (F4) is urea (NH_2CONH_2) (46 % N) was added at a rate of 120 kg ha^{-1}, and
- Two types of potassium F5, F6 potassium sulphate (K_2SO_4) (48 % K), the first one (F5) is Belgian potassium sulphate and the second one (F6) is Egyptian potassium sulphate were added at a rate of 65 kg ha^{-1}.

Table (1): Some physical and chemical parameters of experimental soil

Parameter	Character/value
Texture	Sandy loam
Clay	7.5 %
Sand	65.2 %
Silt	27.3 %
Field capacity, θ_{FC}	17.33 %
Wilting point, θ_{WP}	9.62 %
pH	8.17
EC_e (Electrical conductivity)	0.56 dS m^{-1}
Na^+	1.41 meq l^{-1}
K^+	0.22 meq l^{-1}
Ca^{++}	2.80 meq l^{-1}
Mg^{++}	1.13 meq l^{-1}
CO_3^{--}	-
HCO_3^-	2.56 meq l^{-1}
CL^-	2.20 meq l^{-1}
SO_4^{--}	0.80 meq l^{-1}

Table (2): Description of fertilization treatments

Treatments	Fertilizer added to soil	Composition
	Non-fertilizer	
T0	-	0
	Fertilizer	
T1	F1 + F6 + F3	$(H_6CaO_9P_2)$+(K_2TO_4)(Egyptian)+$(NH_4)_2SO_4)$
T2	F1 + F6 + F4	$(H_6CaO_9P_2)$+(K_2SO_4)(Egyptian)+(NH_2CONH_2)
T3	F1 + F5 + F3	$(H_6CaO_9P_2)$+(K_2SO_4)(Belgian)+$(NH_4)_2SO_4)$
T4	F1 + F5 + F4	$(H_6CaO_9P_2)$+(K_2SO_4)(Belgian)+(NH_2CONH_2)
T5	F2 + F6 + F3	(H_3PO_4)+(K_2SO_4)(Egyptian)+$(NH_4)_2SO_4)$
T6	F2 + F6 + F4	(H_3PO_4)+(K_2SO_4)(Egyptian)+(NH_2CONH_2)
T7	F2 + F5 + F3	(H_3PO_4)+(K_2SO_4)(Belgian)+$(NH_4)_2SO_4)$
T8	F2 + F5 + F4	(H_3PO_4)+(K_2SO_4)(Belgian)+(NH_2CONH_2)

Cultivated crop and irrigation

The cultivated plant is Jew's-mallow *(Corchorus olitorius)* variety Eskandarany provided by the Agriculture Research Center, Cairo, Egypt. The experiment started on April 1, 2015 and harvested at June 8, 2015. The amount of seeds required was 15 kg seeds ha^{-1}. All pots were kept at same open environmental condition (open-door experiment). After 69 days from planting date, plants were collected.

Irrigation water was applied based on the gravimetric method. Determination of the initial soil moisture and field capacity were done to compensate the loss of water by evapotranspiration. Gravimetric (weight-based) methods that rely on measuring the loss of water from the containers are common techniques for determining when and how much to irrigate [10-11- 12].

Experimental methods

Sample preparation

Soil samples were air dried. For maximum moisture removal, all samples were then dried at 110 ^oC in a microprocessor-controlled furnace for about 24h. The fertilizers samples were crushed to fine powder forms and sieved through a 1mm mesh size to remove the larger grain sizes and making them more homogenous. Then, the samples were dried in a temperature controlled furnace at 110 ^oC for 24h to ensure that moisture was completely removed. Jew's-mallow samples were washed, peeled when necessary, and dried in air. After that, they were oven dried at 80 ^oC for approximately 16h [13].

The dried samples of soil, fertilizer and Jew's-mallow were packed and sealed in plastic containers, i.e., normal cylindrical plastic containers (6cm diameter and 8cm height) made from polyethylene. Then the samples were left for 4 weeks before the measurements in order to get the secular equilibrium to achieve radioactive secular equilibrium between radioactive materials and daughter nuclei [14].

Radioactivity measurements

The activity concentration of natural radionuclides in soil, fertilizers and Jew's mallow were measured in the laboratories of Department of Radiation Protection and Civil Defense, Nuclear Research Center, Atomic Energy Authority, Egypt using high purity germanium (HPGe) semiconductor detector, type CANBERRA (HPGe) detector of relative efficiency 50% coupled to a 4096 channel analyzer. The outstanding advantage of the HPGe detector is its ability to measure gamma radiation directly from the original sample without the need for chemical separation and high resolving power.

Transfer factors

Radionuclides in soils are usually transferred to different plant tissues by direct transfer via the root system, as well as radionuclide fallout and resuspension of contaminated soil followed by deposition on plant leaves [15]. In Equation (1) the transfer factor (TF) values are calculated according to the following equation:

$$TF = \frac{Activity\ of\ radionuclides\ in\ plant\ weight\ (Bq/Kg\ dry\ weight)}{Activity\ of\ radionuclides\ in\ soil\ weight\ (Bq/Kg\ dry\ weight)} \quad (1)$$

Effective dose due to ingestion

Effective dose in food stuffs is a useful concept that enables the radiation doses from different radionuclides and sources of radioactivity to be added **[16].** When analyzing the total annual effective dose (AED) to the human population from natural sources, the dose received by ingestion of long-lived natural radionuclides must be considered. Effective doses resulting from the intake of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K, may be determined directly from external measurements of their concentrations in the body or estimated from intake concentrations of materials such as air, food and water. Radiation doses ingested are obtained by measuring radionuclide activity in foodstuffs (Bq kg^{-1}) and multiplying these by the masses of food consumed over a period of time (kg d^{-1} or kg yr^{-1}). A dose conversion factor (Sv Bq^{-1}) can then be applied to give an estimate of ingestion dose. Thus, the effective dose *E* (Sv yr^{-1}) due to intake of a radionuclide with the ingested material is calculated using the following Equation (2) [17]:

$$E = C \sum A_i\, DCF_i \quad (2)$$

Where:

E : The effective dose due to ingestion of natural radionuclide (Sv yr^{-1}),

C : Mean annual consumption of foodstuff (kg yr^{-1}),

A_i : Activity concentration of radionuclide *i* in the ingested material (Bq kg^{-1}), and

DCF_i : The standard dose conversion factor (Sv Bq^{-1}), which is equal to 2.8 x 10^{-7} Sv Bq^{-1} for ^{226}Ra, 2.2 x 10^{-7} Sv Bq^{-1} for ^{232}Th, 6.2 x 10^{-9} Sv Bq^{-1} for ^{40}K and 4.4 x 10^{-8} Sv Bq^{-1} for ^{238}U **[18-19]**.

Excess lifetime cancer risk

Excess Lifetime Cancer Risk (ELCR) can be defined as the excess probability of developing cancer at a lifetime due to exposure level of human to radiation. Excess Lifetime Cancer Risk (ELCR) was calculated by using the following Equation (3) [20-21-22]:

$$ELCR = E \times D_L \times R_F \quad (3)$$

Where *E* is the effective dose due to ingestion of natural radionuclide (Sv yr^{-1}), D_L is duration of life (approximately 70 year) and R_F is risk factor (Sv^{-1}) fatal cancer risk per Sievert. For stochastic effects, ICRP 60 uses values of (R_F = 0.05) for public. The worldwide recommended value is 0.29×10^{-3} **[23].**

Results

Concentrations of natural radionuclides in fertilizer

The measured concentrations of natural radionuclides ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in fertilizer samples are presented in Table (3). In chemical fertilizers, the concentration of ^{226}Ra varies from ND (not detection) to 1121 Bq kg^{-1} with an average value of 198.10 Bq kg^{-1}, the concentration of ^{238}U varies from ND to 720 Bq kg^{-1} with an average value of 121.87 Bq kg^{-1}, the concentration of ^{232}Th varies from ND to 6.8 Bq kg^{-1} with an average value of 2.47 Bq kg^{-1}, whereas the concentration of ^{40}K exists in the range from ND-248.36 Bq kg^{-1} with an average value of 62.1 Bq kg^{-1}. For F1, F2, F3, F4, F5 and F6 fertilizer, the average activity of all natural radionuclides (^{226}Ra, ^{238}U, ^{232}Th and ^{40}K) were 460.25, 16.70, 4.93, 20.15, 62.09 and 12.68Bq kg^{-1}, respectively. In comparison with reference value, NPK fertilizers added at F5 treatment emitted the highest radiation while other treatments were less.

Concentration of natural radionuclide in soil

The values of specific activity for ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K Bq kg^{-1} of the studied soil samples before sowing and after harvesting are illustrated in Table (4). The average ^{238}U and ^{232}Th activities in the soil samples were lower than the worldwide average depending on geologic structure of the region. ^{226}Ra and ^{40}K activity level in soil sample was slightly higher than worldwide average in T6 for ^{226}R and T8 for ^{40}K, while all other treatments indicated that the value of ^{226}Ra and ^{40}K was lower than the worldwide average. A comparison held between the beginning and end of growing seasons showed that the fertilized soil contains slightly higher concentrations of natural radionuclides than the non-fertilized soil, but is still in the recommended value except T6 [fertilized by phosphoric acid (H_3PO_4), urea $CO(NH_2)_2$ and potassium sulphate K_2SO_4 (Egypt)] which contain high concentration of ^{226}Ra and for T8 [fertilized by phosphoric acid (H_3PO_4), ammonium sulphate $(NH_4)_2SO_4$, and potassium sulphate K_2SO_4 (Belgian)] which contain slight high concentration of ^{40}K .

Table (3): The activity concentrations of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K (Bq kg^{-1}) in chemical fertilizers

Chemical fertilizers	^{226}Ra Bq kg^{-1}	^{238}U Bq kg^{-1}	^{232}Th Bq kg^{-1}	^{40}K Bq kg^{-1}	Average Bq kg^{-1}
F1	1121±10	720±7	ND	ND	460.25
F2	11±1	2.9±2	3.9±2.5	49±3	16.70
F3	7.2±0.6	3±0.4	1.5±0.6	8±1	4.93
F4	40±3	2.8±1.2	6.8±2	31±2	20.15
F5	ND	ND	ND	248.36±20	62.09
F6	9.4±2	2.5±0.5	2.6±1	36.2±3	12.68
Average	198.10±2.8	121.87±1.85	2.47±1.02	62.1±4.8	62.1±10.47
Range	7.2-1121	2.5-720	1.5-6.8	8-248.36	4.93-460.25

ND: Not detected

Table (4): The average value of specific activity of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in Bq kg^{-1} of studied soil samples without fertilized (T0) and after fertilized (T1-T8)

Treatments	^{226}Ra Bq kg^{-1}	^{238}U Bq kg^{-1}	^{232}Th Bq kg^{-1}	^{40}K Bq kg^{-1}
Non-fertilizer				
T0	**18±1.1**	**13±1**	**20.2±1.9**	**304±3**
Fertilizer				
T1	**22±1.8**	**13±0.9**	**18.5±1**	**325±3**
T2	**22±1.9**	**10.1±1**	**20.1±1.8**	**293±2.9**
T3	**31.5±3**	**15±1.2**	**25.2±1.9**	**367±3.6**
T4	**28.1±2.1**	**14.6±1.2**	**20.2±1.9**	**374±3.7**
T5	**24±2**	**12.1±1.2**	**23.2±1.3**	**330±3**
T6	**72.2±7**	**15±1.1**	**20.2±1.9**	**338±3**
T7	**27.3±2**	**14±1.4**	**24±2.1**	**379±3.7**
T8	**25.6±2**	**12.1±1.2**	**20±1.8**	**422±4**
Average	**31.59±2.73**	**13.23±1.15**	**21.43±1.48**	**353.5±3.36**
Range	**22-72**	**10-15**	**18-25.2**	**293-422**
Worldwide	**32**	**33**	**45**	**420**

Concentration of natural radionuclides in Jew's-mallow plant

The activity concentration of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in Bq kg^{-1} of Jew's-mallow plants fertilized with different fertilizers varied from 0.35-0.77, 0.016-0.1, 0.09-0.22 and 8.52-16.34 Bq kg^{-1}, respectively Table (5). High activity concentration of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in Bq kg^{-1} were recorded with T2, T1, T2, T2 treatments, respectively.

Transfer factor (TF) ^{40}K has the highest values compared to other radionuclides with an average 0.0334 and ranged from 0.0202 to 0.0504 Table (6). The average concentration values of ^{226}Ra, ^{238}U and ^{232}Th in Jew's-mallow were 0.018, 0.0042 and 0.0065, respectively, and having following order $^{40}K > ^{226}Ra > ^{232}Th > ^{238}U$.

Table (5): The average value of specific activity of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in Bq kg^{-1} for Jew's-mallow plant

Treatments	^{226}Ra	^{238}U	^{232}Th	^{40}K
	Bq kg^{-1}	Bq kg^{-1}	Bq kg^{-1}	Bq kg^{-1}
		Non-Fertilized		
T0	0.29±0.003	0.05±0.01	0.13±0.01	9.83±0.1
		Fertilized		
T1	0.49±0.004	0.1±0.01	0.13±0.02	14.04±0.4
T2	0.77±0.04	0.06±0.005	0.22±0.007	14.78±0.3
T3	0.35±0.05	0.043±0.008	0.13±0.001	9.2±0.4
T4	0.7±0.004	0.06±0.001	0.14±0.01	ND
T5	0.09±0.006	0.05±0.002	0.09±0.02	13.6±0.7
T6	0.43±0.03	0.03±0.009	0.12±0.02	15.01±0.3
T7	0.73±0.05	0.08±0.001	0.15±0.09	16.34±0.5
T8	0.45±0.05	0.016±0.001	0.11±1.7	8.52±0.8
Average	0.501±0.029	0.055±0.0046	0.136±0.235	11.436±0.425
Range	0.35-0.77	0.016-0.1	0.09-0.22	8.52-16.34
Worldwide	0.05	0.02	0.015	420

Annual effective dose due to ingestion of Jew's-mallow plants

The amount of fresh Jew's-mallow consumed by an adult Egyptian person in one year is 60 kg approximately [23]. The average annual effective dose due to ingestion Jew's-mallow from naturally occurring radioisotopes ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K is 8.421, 0.144, 1.80 and 4.86 µSv y^{-1} and ranged from 1.512-12.94, 0.042-0.26, 1.19-2.90 and 3.17-6.08 µSv y^{-1}, respectively Table (7). Also, the highest annual effective dose due to ingestion of Jew's-mallow was obtained from T2 (21.5 µSv y^{-1}) which contain the highest activity concentration of ^{226}Ra and ^{232}Th, while the lowest annual effective dose due to ingestion of Jew's-mallow appears in T5 (7.89 µSv y^{-1}).

Excess lifetime cancer risk form Jew's-mallow

As seen in Table (8), the range of all ELCR values is between 0.025x10^{-3} – 0.069x10^{-3}. The calculated average value of ELCR for all samples is lower than the world average of 0.29 x10^{-3} [24]. Thus, indication of the possibility of developing cancer cases among individuals can be neglected.

Table (6): Transfer factor for ^{226}Ra, ^{238}U, ^{230}Th and ^{40}K from soil to Jew's-mallow plants

Treatments	^{226}Ra	^{238}U	^{232}Th	^{40}K
Non-Fertilized				
T0	0.016	0.0038	0.0064	0.032
Fertilized				
T1	0.022	0.0077	0.0070	0.0432
T2	0.035	0.0059	0.0110	0.0504
T3	0.011	0.0029	0.0052	0.0251
T4	0.025	0.0041	0.0069	-
T5	0.004	0.0041	0.0039	0.0412
T6	0.006	0.0020	0.0059	0.044
T7	0.027	0.0057	0.0063	0.0431
T8	0.014	0.0013	0.0055	0.0202
Average	0.018	0.0042	0.0065	0.0334
Range	0.004-0.035	0.0013-0.0077	0.0039-0.0110	0.0202-0.0504

Table (7): Annual effective dose due to ingestion of Jew's-mallow plants (µSv y^{-1})

Treatments	^{226}Ra µSv y^{-1}	^{238}U µSv y^{-1}	^{232}Th µSv y^{-1}	^{40}K µSv y^{-1}	Total µSv y^{-1}
Non-Fertilized					
T0	4.87	0.13	1.72	3.66	10.38
Fertilized					
T1	8.230	0.260	1.72	5.22	15.43
T2	12.94	0.160	2.90	5.50	21.50
T3	5.880	0.110	1.73	3.42	11.15
T4	11.76	0.160	1.85	-	13.77
T5	1.512	0.130	1.19	5.06	7.890
T6	7.224	0.080	1.58	5.58	14.47
T7	12.26	0.210	1.98	6.08	20.53
T8	7.560	0.042	1.45	3.17	12.22
Average	8.421	0.144	1.80	4.86	14.62
Range	1.512-12.94	0.042-0.26	1.19-2.9	3.17-6.08	7.89-21.5
Worldwide	6.30	113.32	0.38	170	290

Table (8): Excess lifetime cancer risk (ELCR) of Jew's-mallow after harvesting

Treatments	ELCR from Jew's-mallow (Sv)
Non-Fertilized	
T0	0.036×10^{-3}
Fertilized	
T1	0.049×10^{-3}
T2	0.069×10^{-3}
T3	0.036×10^{-3}
T4	0.044×10^{-3}
T5	0.025×10^{-3}
T6	0.046×10^{-3}
T7	0.066×10^{-3}
T8	0.039×10^{-3}
Average	0.0468×10^{-3}
Range	0.025×10^{-3} – 0.069×10^{-3}
Worldwide	0.29×10^{-3}

Discussion

NPK fertilizers, has an average 226Ra activity concentration, that accounted for 341.73 Bq kg−1 in Iraq [25], and this value is lower than activity concentration values of Egypt, Germany, Brazil and USA samples, and higher than India, Nigeria, Finland and Saudi Arabia samples. This same author found also that the average 232Th concentration is 248.63 Bq kg−1 which is higher than all the reported concentration from Egypt. The average 40K concentration of (5166.43 Bq kg−1) is higher than all the reported concentration values. Results in Table (9) showed that the activity concentration of 232Th series (2.47 Bq kg−1) is very low compared to reference values in all countries, but the activity concentration of 226Ra is higher than those in India, Nigeria, Finland and Saudi Arabia and for 40K is lower than all countries except Egypt.

The uptake of natural radionuclides by Jew's-mallow plant of the present study incomparison with previous studies indicated that the average concentration of 40K is 328±147 Bq kg-1 reported by Gomaa et al. [34] and 171Bq kg-1 for 40K reported by Badran et al. [7]. Jew’s mallow shows a higher concentration of 40K because leafy vegetables seem to absorb more potassium than other crops or the potassium are concentrated in leaves more than in any other parts of the plant. However, ranged from 8.52-16.34 Bq kg-1 for 40K Table (5). In other study in Egypt for local markets in Qena, the levels of 226Ra, 210Pb, 232Th, and 40K were measured by Harb[35] in some vegetables and fruits samples. The content of 226Ra, 210Pb, 232Th, and 40K radioactivity in Jew's Mallow were 0.04±0.03, 0.04±0.03, 0.02±0.03 and 41.46±1.55 Bq kg-1, respectively. The TF depends on vegetation type, soil properties, climatic conditions and the type of radionuclides [5] however the TF from soil to Jew’s mallow crops has been studied in many countries and found a significant difference in values [36-5-37].

Conclusion

The activity concentrations of natural radionuclide 226Ra, 238U, 232Th and 40K as affected by fertilization treatments of sandy loam soil, Jew's-mallow and six chemical fertilizers have been measured using high purity germanium (HPGe). These values have been compared with the worldwide reported data. The average concentrations of natural radionuclide in soil sample are below recommended level. Both the highest and the lowest values present in chemical fertilizers were found in the Jew's-mallow plant. On the other hand, the activity concentration of radionuclide in Jew's-mallow plants was higher than recommended value except 40K is below. The effective dose due to ingestion of Jew's-mallow plants varied from 7.89 - 21.5μSv y-1 which indicated that the use of fertilizer was not effective on the level of radionuclide in Jew's-mallow plants and the possibility of developing cancer cases among individuals is neglected. In other words, the Jew's-mallow is radiological safe and be acceptable for human consumption.

Table (9): Comparison of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Iraqi NPK fertilizer and other countries [25]

Country	^{226}Ra	^{232}Th	^{40}K	Reference
Our study	198.01	2.47	62.1	Present work
Egypt	366	67	4	[26]
India	79	28	1042	[27]
Germany	520	15	720	[28]
Nigeria	143	9	2729	[29]
Brazil	420	80	153	[30]
Finland	54	11	3200	[31]
Saudi Arabia	64	17	2453	[32]
USA	780	49	200	[33]
Iraq	341.73	248.63	5166.43	[25]

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