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Radiation Hazards and Transfer Factors of Radionuclides from Soil to Plant at Al-Tuwaitha City-Iraq

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Abstract. Activity concentrations of natural radionuclides, artificial radio-cesium, and soil-to-plant transfer factor in common different plants species grown at Al-Tuwaitha City in the capital Baghdad have been evaluated using NaI(Tl) gamma spectroscopy. Five species of plants have been selected green pepper, cucumber, celery, basil, and mint. The measurements were made on four parts of each plant sample which were included soil, roots, stalk, and leave for knowledge and evaluation the transfer factors. The mean specific activity concentrations of U-238, Th-232 and K-40 in green pepper plant were 8.064±4.222 Bg/kg, 12.774±8.197Bg/kg and 202.541±151.911 Bg/kg respectively. For cucumber was 11.563±6.971Bq/kg, 6.965±4.417, 205.248±138.356 Bg/kg. For celery was 7.847±10.500, 24.895±14.705, 172.003±149.272. For basil was 8.536±4.699, 13.886±16.286, 44.409±60.429. For mint was 12.458±12.476, 27.518±18.014, 201.599±130.214 Bq/kg respectively. The mean soil-to-plant transfer factors for U-238, Th-232, K-40, and Cs-137 were 0.0919, 1.0673, 0.7944, and 0.038 respectively.

The results showed that the uranium, thorium and cesium concentration exceeded the permissible limit in the mint roots. In addition, the concentration of cesium exceeded in the roots of green pepper, cucumber, celery and basil. In addition, it has exceeded its concentration in the stalks of celery and basil. As for potassium concentrations, they will not exceed the internationally permissible limit in all parts of plants under study.

The mean Radium equivalent activity was 61.5871 Bq\kg lower than 370 Bq\kg recommended by UNSCEAR. The maximum absorbed dose rate in root samples was 121.817 nGy/h which is higher than 84 nGy/h, while the mean annual outdoor effective dose equivalent in root samples was 513.887 mSv/y which is higher than 290 mSv/y recommended by UNSCEAR, respectively. The maximum H hazard index was 0.405 in root samples which is less than ≤1 recommended by UNSCEAR. The excess lifetime cancer risk (ECLR) ranged from 14.547×10^{-3} to 449.650×10^{-3}. This value is higher than the world average of 0.29×10^{-3} and 1.16×10^{-3} reported by UNSCEAR.

The ELCR is a function of environmental geology and 40 K has very high soil-to-plant transfer factor compared to other radionuclides in the samples. Therefore, there is a risk of their administration.

Keywords: Natural radioactivity, Transfer Factor, soil, plant, radiological hazards, Al-Tuwaitha

INTRODUCTION

Environmental radionuclides can be transferred into human body through various sources and pathways. Apart from atmospheric release, direct inhalation is the initial source of hazard to human [1,2]. Other sources of exposure of main concern are the radionuclides deposited on soils and on the foliage of crop plants, their uptake by the plant

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and water contaminations. Generally, terrestrial pathways were found to be of more importance than the aquatic pathways [3].

One of the major environmental pathways that lead to human ingestion of radionuclides is the soil-plant-man pathway. The root uptake of radionuclides and the subsequent translocation to the edible plant parts are being influenced by many factors, such as soil characteristics, plant types, physiological processes in each compartment, competing ions, climatic con- ditions, physico-chemical form of the radionuclides and agricultural practices [4]. The modeling of the radionuclide uptake by the root is a compromise between availability of input parameter and scientifically based mechanistic approaches [5].

The International Atomic Energy Agency (IAEA) reviewed data on transfer factor for different foods and made a compilation for research purposes (IAEA, 2010, [6] and IAEA, 2009 [7]). In Markose [8] study of filamentous algae from Jadugida in India, he observed an elevated concentration of 228Ra with a transfer factor that ranged from 8×10^2 to 3.1×10^3. He showed that variation in concentration is dependent on the proximity of the sampling location with respect to the tailing and pond effluent or main water streams. The transfer factor value is in agreement with the value (5×10^2–1.0×10^3) obtained from a Uranium mill by Tsivoglue [9].

The evaluation of soil-to-plant transfer factor of ^{238}U, ^{210}Pb, ^{210}Po and ^{40}K, for various agriculture products (Vegetables, fruit trees and beans) in some districts of south-Syria by Al-Masri et al. [10] reveals that transfer factor of radionuclides were higher in leaves than fruits except for 40K where the transfer factor for both leaves and fruits were similar. In their report of soil-to-plant transfer factor estimation, Vandenhove et al. [11] concluded that the transfer factor values were generally about 10-fold lower for ^{232}Th and ^{210}Po than for ^{238}U, ^{226}Ra and ^{210}Pb. The data compiled in the IAEA TRS-472 [6] was sometimes less than 10, and therefore the present data could provide more information about the transfer factors of radionuclides under equilibrium conditions.

Radionuclides can be transported from the environment deposited in the soil and leaves of crop plants to the human body through their absorption by the plant and water pollution in general. One of the main environmental pathways that lead to humans ingesting radionuclides is the soil pathway between plants and humans. This manuscript aims to find the concentrations of the natural radioactive elements present in each of the plants (), their soil, roots and stems up to their leaves and their severity, as the root absorption of radionuclides and the subsequent transmission of edible parts of the plant are affected, and calculating risk factors for humans as a result of eating them for purpose of verifying environmental safety.

MATERIALS AND METHODS

Collection and Preparation of Samples

Sixteen samples of plant were collected at AL-Tuwaitha city. Fifteen samples of plant and one sample of soil. Three samples parts (root, stailk, leave) for each type of cucumber, green pepper, celery, mint and basil. The samples were dried and crushed with mill to obtain a homogeneous powder. After the grinding process, the powder was sifted through a sieve of 630 microns. After that, the samples were filled in Marinelli Becker and sealed with provisions. The code name for each sample was installed on Marinelli Beckers. Marinelli Beckers were closed for 30 days prior to the screening process in order to achieve a secular equilibrium.

Radioactivity Measurement

Detection of natural radioactivity for U-238, Th-232, and K-40 in different parts of plants (cucumber, green pepper, celery, mint, basil) and soil powdered samples were carried out with gamma spectrometry technique using 3×3 inch NaI(Tl) detector, Alpha Spectra Inc., scintillation detectors, Model 12/12/3, Serial (031215G), Made in United States of America (U.S.A). The detector had 90% relative efficiency and energy resolution of 28.74 keV at 1332 keV of Co-60 gamma ray.

The multichannel analyzer used is a digital analyzer of type Bright SPEC model bMCA (blug-on Multi-channel analyzer. It analyzes the gamma spectrum for gamma rays at 4096 channels. Note that this analyzer can be controlled and changing the characteristics and number of channels through a specialized computer program (bMCA). It contains a red light indicator for the intermittent gamma-rays to the detector and it coupled to a computer by USB cable to transmit the signal to bMCA program and finally, display the analyzed spectrum on the screen.

The quality assured standard samples for the calibration and the absolute efficiency of the detector recommended by the International Atomic Energy Agency (IAEA) was used for the calibration and the absolute efficiency of the detector. The mixture of radionuclides (with corresponding energies) included Am-163 (59.3keV), Co-60 (1173.24 and 1332.50 keV), Cs-137 (661.66 keV). To measure the environmental gamma background, an empty identical Marinelli Beaker was used. All samples and the background were counted for 7200sec. After measurement, the activity concentrations were calculated by subtraction of the background values. The activity of U-238 was given by the line of gamma of its product decay Bi-214 (1764.5 keV). The activity of Th-232 was inferred from the weighted mean activities of the gamma peaks of Tl-208 (583.19 and 2614.5 keV). The K-40 and Cs-137 concentrations were measured by determining their characteristic gamma lines of energies, 1460.8 and 661.61 keV respectively. In addition, the minimum average detectable activity concentrations of U-238, Th-232, K-40, and 137Cs using NaI(Tl) detector were 0.065 , 1.708, 13.539Bq/kg, respectively.

RESULTS AND DISCUSSION

Specific Activity

The activity specified is the activity per unit block, the unit used is either Ci/kg or Bq/g. It can be calculated from the following equation [12]:

$$A_i(E,\gamma) = \frac{N}{\varepsilon\,(E_\gamma)\times\, I_\gamma\,(E_\gamma)\times t\times m} \quad (1)$$

Where: N is the counting of gamma rays (i. e. area under the photo peaks) and m is the sample mass in kg.

Absorbed Dose Rate D

According to the United Nations Scientific Committee on the Effects of Atomic Radiation, (UNSCEAR, 1988, 2010) [13, 14], the outdoor absorbed dose rate can be calculated using the following equation:

$$D_{out}(nGyh^{-1}) = 0.427\,A_U + 0.662A_{Th} + 0.043\,A_K \quad (2)$$

Where, A_U, A_{Th} and A_K are the activity concentrations in (Bq/kg) of uranium, thorium and potassium respectively. The indoor gamma ray dose imparted by of U-238, Th-232, and K-40 radionuclides present indoor can be calculated by converting the absorbed dose rate to effective dose, the following equation is used to calculate the indoor dose rate, given by UC European Commission, 1999 [15]:

$$D_{in}(nGyh^{-1}) = 0.92\,A_U + 1.1A_{Th} + 0.081\,A_K \quad (3)$$

Radium Equivalent Activity Ra_{eq}

For uniformly distributed with respect to the exposure to radiation (UNSCEAR, 2000) [5] has defined the radium equivalent activity expressed by the following equation:

$$Ra_{eq}(Bq.kg^{-1}) = A_U + 1.43\,A_{Th} + 0.077\,A_K \quad (4)$$

The activity conversion rates of U-238, Th-232 and K-40 are the outcome in same gamma dose rate at maximum permissible limit of Ra_{eq} index is 370 $Bqkg^{-1}$ as recommended by (UNSCEAR, 2000) [5].

Hazard Index H

The external (H_{ex}) and internal (H_{in}) hazard indices are due to external exposure to gamma ray. The external hazard index can be calculated from the following equation (UNSCEAR, 2000) [5]:

$$H_{ex} = \frac{A_U}{370\,Bq.kg^{-1}} + \frac{A_{Th}}{259\,Bq.kg^{-1}} + \frac{A_K}{4810\,Bq.kg^{-1}} \quad (5)$$

The internal radiation exposure is quantified by the internal hazard index (H_{in}) given by (UNSCEAR, 2000) [5]:

$$H_{in} = \frac{A_U}{185\,Bq.kg^{-1}} + \frac{A_{Th}}{259\,Bq.kg^{-1}} + \frac{A_K}{4810\,Bq.kg^{-1}} \quad (6)$$

Provided that for safety consume the upper limit of the above indexes should be less than unity for the radiation hazard to be regarded as insignificant, as reported by (UNSCEAR, 2000) [5] and (ICRP, 2007) [16].

Annual Effective Dose Equivalent (AEDE)

The outdoor annual effective dose equivalent ($AEDE_{out}$) was estimated to convert the outdoor absorbed dose in air to effective dose. While the indoor annual effective dose equivalent ($AEDE_{in}$) is estimated from indoor absorbed dose in air to convert it to the effective dose. (UNSCEAR, 2000) [5] reported the value 0.7 $SvGy^{-1}$ as conversion coefficient from absorbed dose in the air to the effective dose received by adults. While 0.2 and 0.8 represent the outdoor and indoor occupancy factors respectively. The annual effective dose equivalent can be calculated from the following equations as reported by (UNSCEAR, 2000) [5]:

$$AEDE_{out}(\mu Sv/y) = D_{out}(nGy/h) \times 8760(h/y) \times 0.20 \times 0.7(Sv/Gy) \times 10^{-3} \quad (7)$$

$$AEDE_{in}(\mu Sv/y) = D_{in}(nGy/h) \times 8760(h/y) \times 0.80 \times 0.7(Sv/Gy) \times 10^{-3} \quad (8)$$

Life-Time Cancer Risk (ELCR)

The excess life-time cancer risk ($ELCR$) was estimated from annual effective dose equivalent using the equation given by Taskin et al. 2009 [17]:

$$ELCR_{out} = AEDE_{out} \times DL \times RF \quad (9)$$

$$ELCR_{in} = AEDE_{in} \times DL \times RF \quad (10)$$

Where; DL, and RF are the duration of life (70 years), and risk factor ($0.05/Sv$), respectively. Defined the risk factor as fatal cancer risk per Sievert is assigned a value of 0.05 by ICRP, 2012 [18] for the public for random effects, for low-level radiations.

ESTIMATION OF SOIL-TO-PLANT TRANSFER FACTOR (TF)

IAEA, 2010 [6] has adopted the methodology outlined in the protocol developed by the Working Group of International Union of Radioecologists [19] for standardizing the rooting depth to define soil to plant transfer factor. A standardized soil layer was adopted in this work. For grass, this soil depth value is 10 cm and for all other) it is assumed as 20 cm. Using IAEA guidelines, the soil-to-plant transfer factor TF was estimated as [6]:

$$TF = Cp / C \quad (11)$$

where Cp is radionuclide concentration in plant (Bq/kg) and Cs is radionuclide concentration in soil (Bq/kg) The soil-to-plant transfer factors have been calculated for soil samples analyses for radioactivity to evaluate the rate of migration of radionuclides from soil to the plants in the study area.

RESULTS AND DISCUSSION

The activity concentrations of U-238, Th-232 and K-40 in pepper, cucumber, celery, basil, mint and soil in AL-Tuwaitha city. The results are summarized in Table 1. As tabulated in Table 1. for pepper the activity concentrations of U-238 varied from 5.938 to 4.653 Bq/kg with average value 8.064±4.222 Bq/kg and from7.974 to 3.323 Bq/kg for Th-232, respectively. In addition, the activity concentrations of K-40 ranged from13.539 to 155.052 Bq/kg with average of 202.541±151.911 Bq/kg and1.291 to 1.047 Bq/kg with an average value1.600±0.521 Bq/kg, for Cs-137. For cucumber the average activity concentrations are 11.563±6.971, 6.965±4.417, 205.248±138.356, 9.999±40.445and 1.879±0.893 Bq\kg. For celery 7.847±10.500, 24.895±14.705, 172.003±149.272 and 1.379±0.980 Bq\kg. For basil 8.536±4.699, 13.886±16.286, 44.409±60.429 and 2.289±0.888 Bq\kg. For mint 12.458±12.476, 27.518±18.014, 201.599±130.214 and 1.843±1.014 Bq\kg. For U-238, Th-232 and K-40, respectively. While the average activity concentration of Cs-137 for all samples was lower than the unit. But basil average activity concentrations are 2.289±0.888 Bq\kg. All these values are significantly lower than the permissible limits (33, 45, and 412 Bq/kg for U-238, Th-232 and K-40 respectively) reported by (UNSCEAR, 2010) [14].

As shown in Fig. 1 the activity concentrations of K-40 in Pepper –root sample had the highest activity concentration 105.632 Bq/k. while sample basil - leave had the lowest value0.311 Bq/kg. For all samples, the activity concentration values of K-40 were lower than the acceptable value 412 Bq/kg as recommended by (UNSCEAR, 2010) [14].

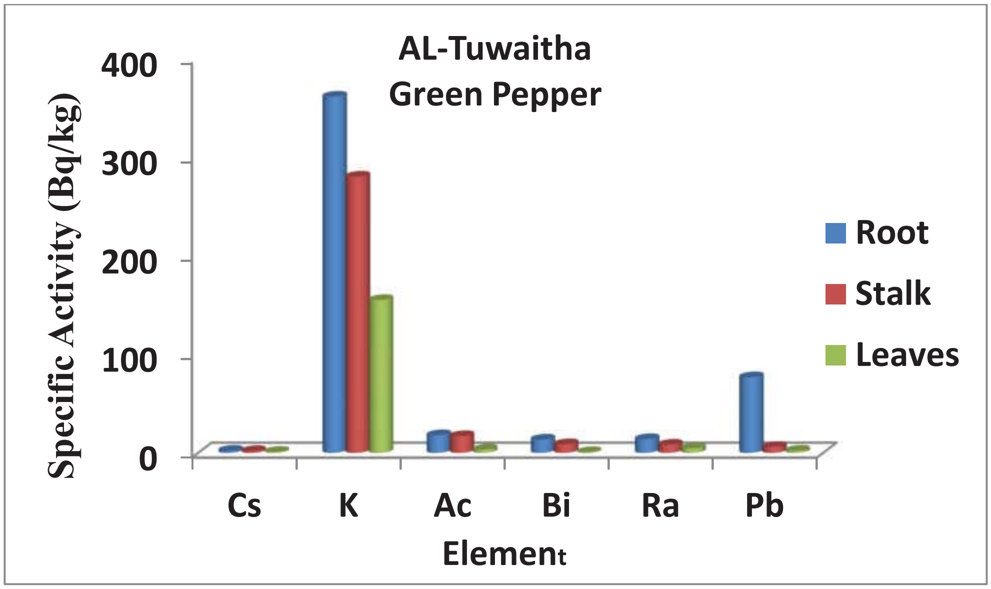

FIGURE 1. Specific Activity of Green Pepper Sample in AL-Tuwaitha City.

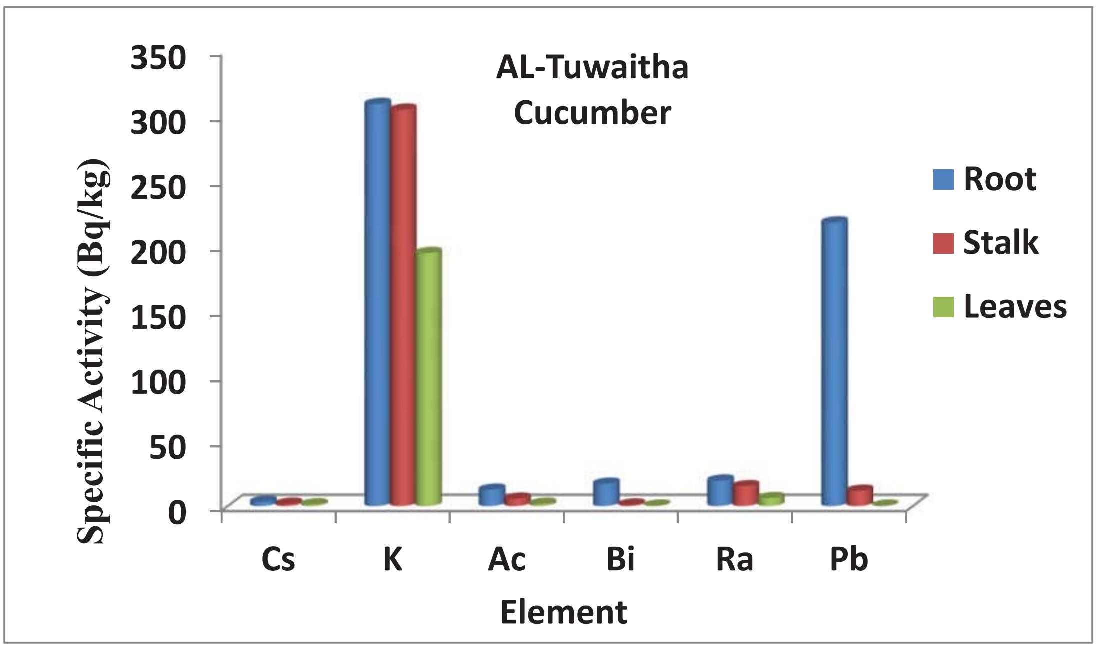

FIGURE 2. Specific Activity of Cucumber Sample in AL-Tuwaitha City.

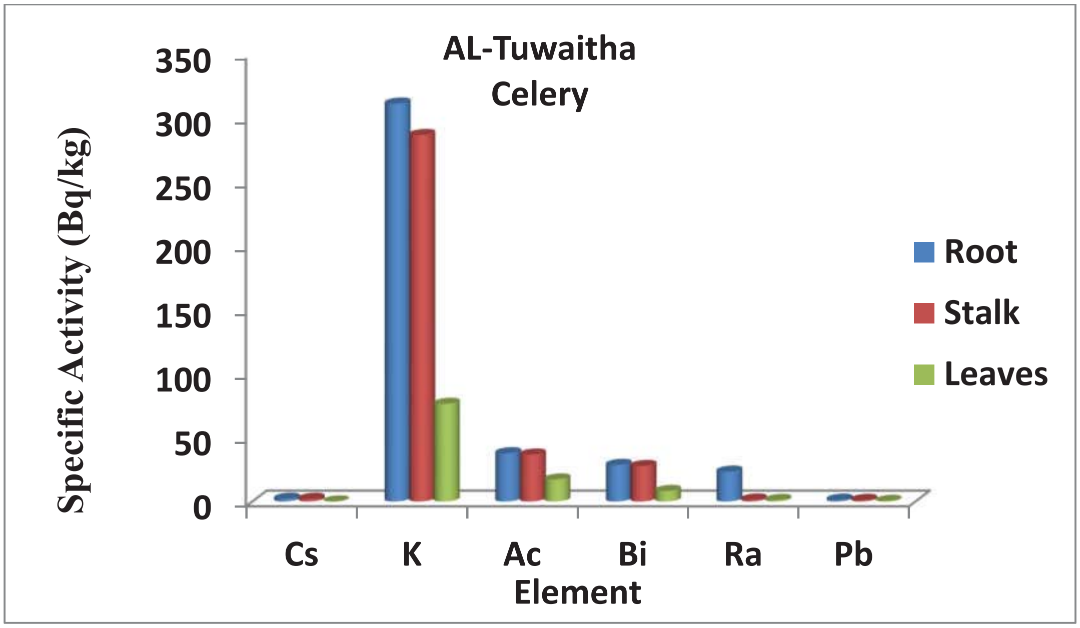

FIGURE 3. Specific Activity of Celery Sample in AL-Tuwaitha City.

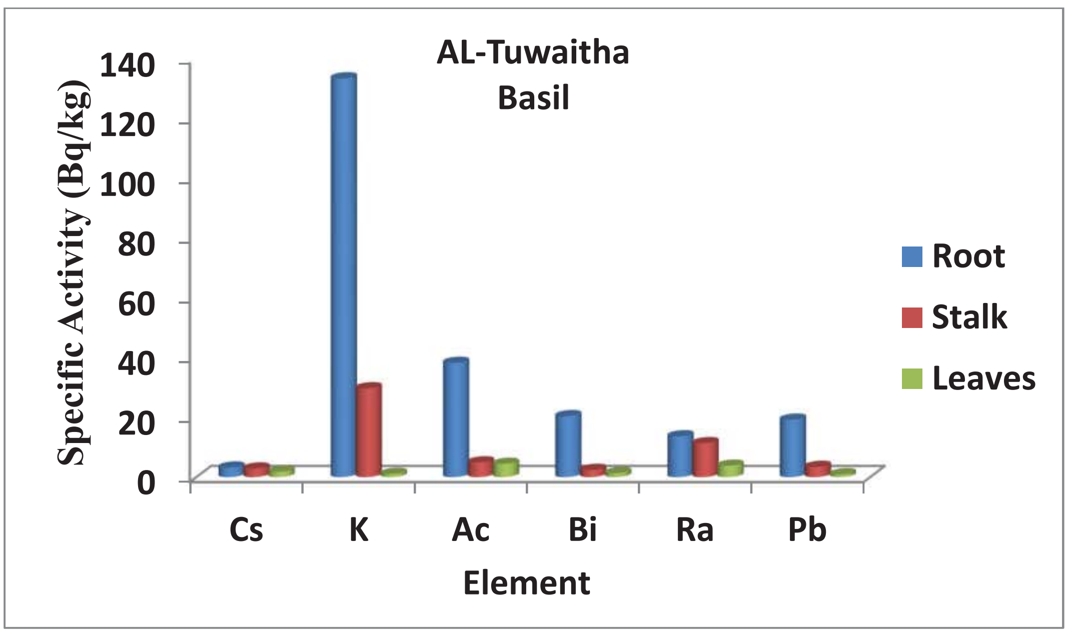

FIGURE 4. Specific Activity of Basil Sample in AL-Tuwaitha City.

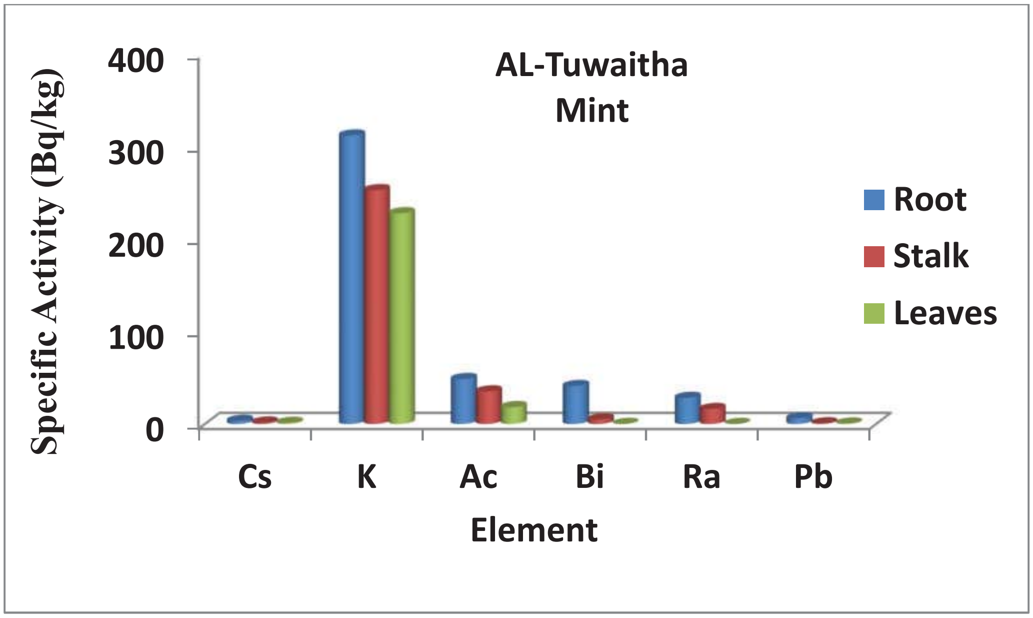

FIGURE 5. Specific Activity of Mint Sample in AL-Tuwaitha City.

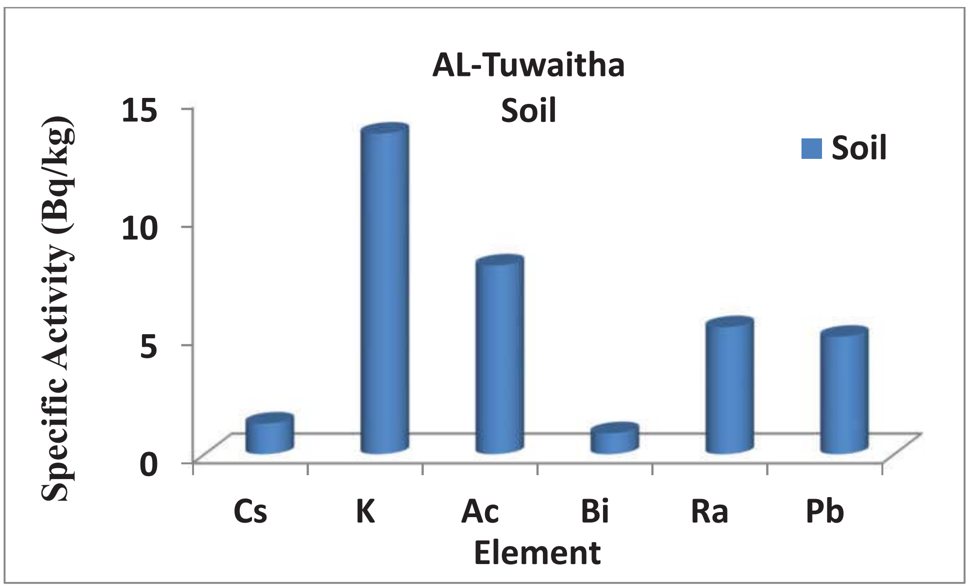

FIGURE 6. Specific Activity of Soil Sample in AL-Tuwaitha City.

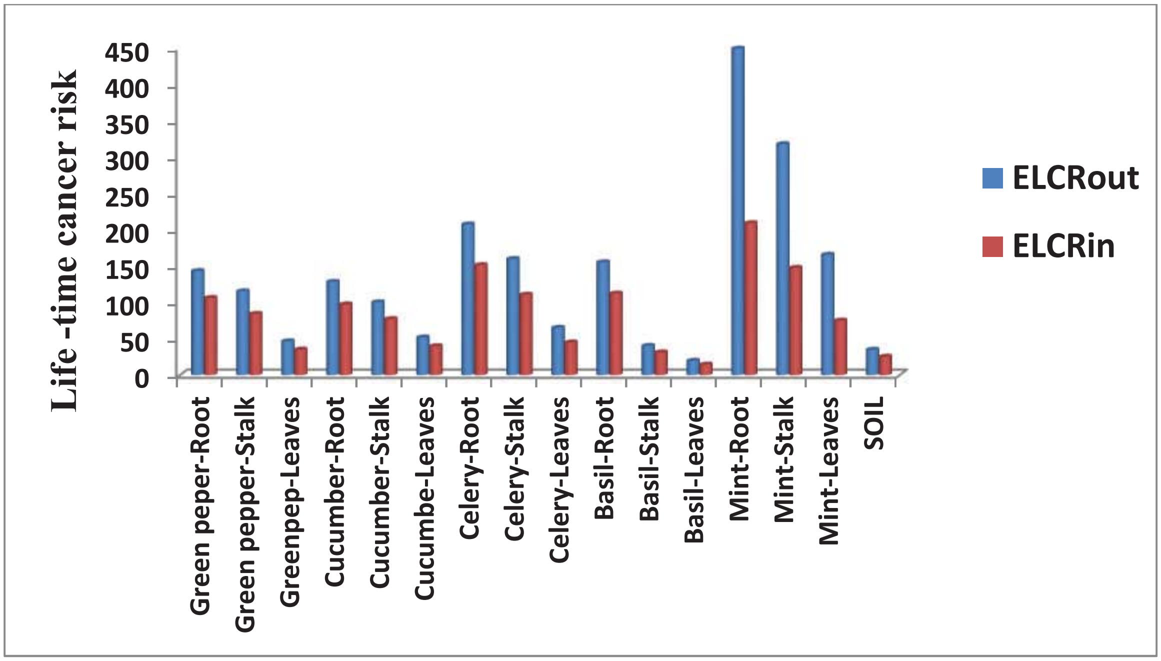

FIGURE 7. Life-time Cancer Risk of Samples in AL-Tuwaitha City.

Table 1 also listed the calculated values of radium equivalent activity. The results showed that the average values of radium equivalent were 40.411±24.469, 37.328±20.273, 56.698±38.712, 31.813±31.449, 67.333±45.929 Bq\kg respectively. These values are less than the permitted limit of 370 Bq/kg recommended by (UNSCEAR, 2000) [5].

TABLE 1. Specific Activity concentrations for (U-238, Th-232, K-40 and Cs-137) and Radium equivalent activity of samples.

Sample	Sample parts	Specific activity concentration (Bq/kg)						Ra_{eq} (Bq\kg)
			U-238		Th-232			
		Ra-186	Bi-214	Pb-214	Ac-228	Cs-137	K-40	
Green pepper	Soil	5.938	0.882	4.960	7.974	1.291	13.539	17.810
	Root	13.938	13.509	76.737	17.957	2.179	361.350	67.441
	Stalk	8.229	8.807	6.024	17.044	1.882	280.222	54.250
	Leaves	4.653	0.757	2.219	3.323	1.047	155.052	21.345
Cucumber	Soil	5.364	0.882	4.960	7.974	1.291	13.539	17.810
	Root	19.537	17.105	217.726	12.519	3.180	308.765	61.215
	Stalk	15.270	1.155	11.753	5.659	1.751	304.438	46.804
	Leaves	6.083	0.324	0.272	1.708	1.294	194.250	23.484
Celery	Soil	5.364	0.882	4.960	7.974	1.291	13.539	17.810
	Root	23.337	28.586	1.392	37.723	2.121	311.362	101.527
	Stalk	1.512	27.745	1.258	36.665	2.084	286.751	76.024
	Leaves	1.175	8.215	0.458	17.236	0.022	76.358	31.703
Basil	Soil	5.364	0.882	4.960	7.974	1.291	13.539	17.810
	Root	13.634	20.364	19.201	38.203	3.189	133.332	78.522
	Stalk	11.349	2.410	3.409	4.926	2.867	29.701	20.680
	Leaves	3.804	1.310	0.922	4.442	1.810	1.067	10.239
Mint	Soil	5.364	0.882	4.960	7.974	1.291	13.539	17.810
	Root	28.250	41.036	5.496	48.637	3.351	311.898	121.817
	Stalk	16.155	4.946	0.762	35.227	1.528	252.956	86.009
	Leaves	0.065	0.075	0.511	18.235	1.203	228.004	43.698
Limit UNSCEAR, 2010 [14]			33 35 UNSCEAR 2008 [21]		45 40 [21]	2.0 UNSCEAR, 1993 [20]	**412** 400 [21]	370 UNSCEAR, 2000 [5]

Table 2 shows the calculated results of radiation hazard indices (absorbed dose, annual effective dose, hazard indices, and risk cancer) for all samples. The values of all the radiation hazard indices were lower than the permissible limits of **≤1** recommended by (UNSCEAR, 2000) [5]. The estimated average values for the absorbed dose rate in pepper, cucumber ,celery ,basil ,mint varied from 121.817nGy/h in mint-root to8.473 nGy/h in basil -leave According to (UNSCEAR, 2010) [14], all results fell high the recommended limit for the average exposure rate 84 nGy/h.

TABLE 2. Absorbed dose rate, Annual effective dose equivalent, Hazard indices, and Life-time cancer risk.

Sample	Sample Part	D (nGy/h)		AEDE (μSv/y)		Hazard index		ELCR	
		Outside	Inside	Outside	Inside	H_{ex}	H_{in}	Outside $\times 10^{-3}$	Inside $\times 10^{-3}$
Green Pepper	Soil	8.151	14.803	9.997	72.620	0.048	0.062	34.987	25.416
	Root	33.377	61.845	40.934	303.390	0.182	0.219	143.269	106.185
	Stalk	26.876	49.082	32.961	240.771	0.146	0.168	115.366	84.271
	Leaves	10.854	20.496	13.312	100.549	0.057	0.070	46.589	35.190
Cucumber	Soil	8.151	14.803	9.997	72.620	0.048	0.062	34.987	25.416
	Root	29.907	56.756	36.678	278.423	0.165	0.218	128.372	97.447
	Stalk	23.357	44.933	28.645	220.424	0.126	0.167	100.257	77.148
	Leaves	12.081	23.210	14.816	113.861	0.063	0.079	51.856	39.850
Celery	Soil	8.151	14.803	9.997	72.620	0.048	0.062	34.987	25.416
	Root	48.326	88.186	59.267	432.609	0.273	0.336	207.434	151.411
	Stalk	37.248	64.450	45.681	318.621	0.205	0.209	159.883	110.658
	Leaves	15.195	26.226	18.636	128.621	0.085	0.088	65.223	45.028
Basil	Soil	8.151	14.803	9.997	72.620	0.048	0.062	34.987	25.416
	Root	36.182	65.358	45.182	320.622	0.212	0.248	155.307	112.217
	Stalk	9.384	18.266	11.504	84.606	0.055	0.086	40.279	31.361
	Leaves	4.611	8.473	5.655	41.566	0.027	0.037	19.792	14.547
Mint	Soil	8.151	14.803	9.997	72.620	0.048	0.062	34.987	25.416
	Root	104.755	121.817	128.471	597.585	0.328	0.405	449.650	209.154
	Stalk	74.103	86.009	90.879	421.364	0.232	0.275	318.079	147.674
	Leaves	38.587	43.698	47.323	72.617	0.117	0.117	165.630	75.027
Limit		84 UNSCEAR, 2010 [14]		290 UNSCEAR, 2008 [21] 1000 ICRP, 1996 [22]		≤1 UNSCEAR, 2000 [5]		0.29×10^{-3} UNSCEAR, 2000 [5]	1.16×10^{-3} UNSCEAR, 2000 [5]

Table 2 and Figure 8 show the estimation of Life-time cancer risk. The results explain that there is a variation in cancer risk. The Life-time cancer risk within the body was higher than the life-time cancer risk outside the body. The highest life-time cancer risk, in and out of the body, was found in the m int root sample. The same criteria were followed by the celery- root sample. The highest cancer risk in mint samples was in stalk; while in celery the highest cancer risk was in stalk sample.

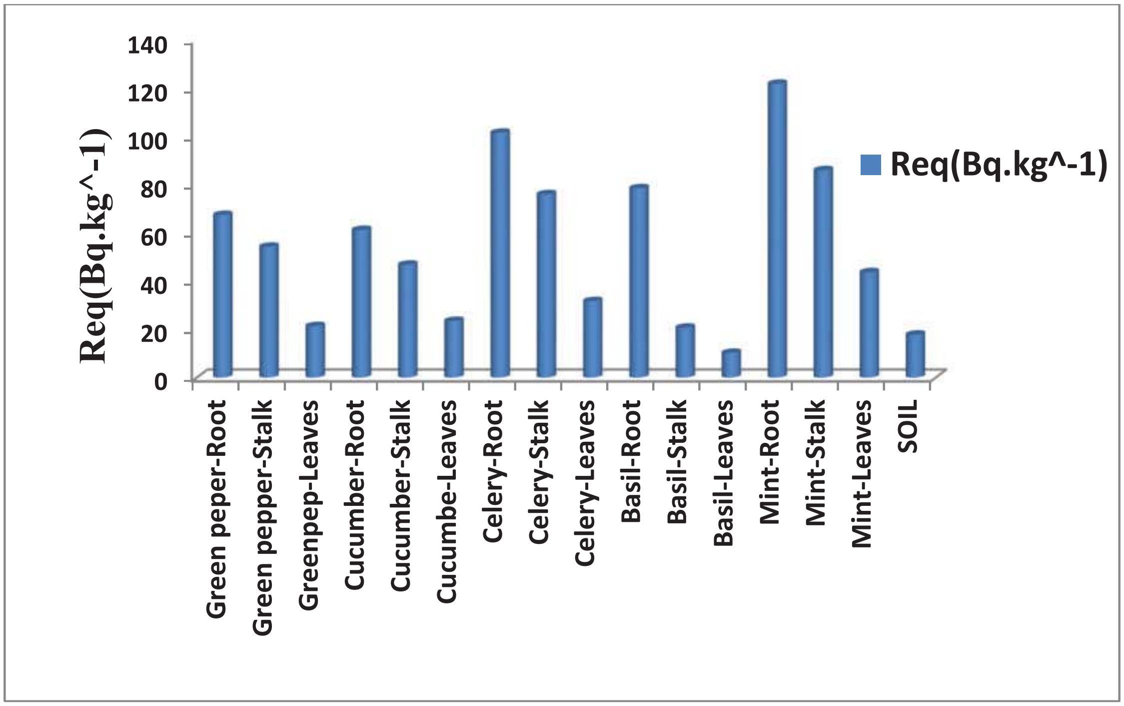

FIGURE 8. Radium Equivalent Activity $\mathbf{Ra_{eq}}$ of Samples in AL-Tuwaitha City.

As tabulated in Table 3, the average rate of transition factor in the green pepper sample of U-232, Th-232, K-40, and Cs-137 was 0.325±0.0424, 0.690±0.438, 1.013±0.396, and 0.071±0.024. For the cucumber sample it was 0.044±0.052, 0.362±0.292, 0.514±0.584, and 0.027±0.026. As for celery sample was 0.020±0.007, 1.608±0.588, 1.007±0.235, and 0.051±0.080. While for Basil the average rate of transform factor was 0.110±0.113, 0.855±1.034, 0.556±0.469, and 0.069±0.064. And finally for mint samples the average rate results was 0.010±0.007, 1.821±0.813, 0.881±0.343, 0.011±0.008 respectively.

TABLE 3. Soil-to-plant transfer factor (TF) of natural radionuclides and artificial C-137.

Sample	Sample Parts	Transfer factor			
		U-238	Th-232	K-40	Cs-137
Green Pepper	Root	0.811	0.967	1.378	0.090
	Stalk	0.013	0.919	1.069	0.070
	leaves	0.002	0.185	0.591	0.043
	Average	0.325±0.0424	0.690±0.438	1.013±0.396	0.071±0.024
Cucumber	Root	0.105	0.677	1.178	0.053
	Stalk	0.017	0.316	0.291	0.028
	leaves	0.011	0.099	0.075	0.001
	Average	0.044±0.052	0.362±0.292	0.514±0.584	0.027±0.026
Celery	Root	0.027	1.967	1.187	0.143
	Stalk	0.021	1.924	1.094	0.009
	leaves	0.012	0.929	0.741	0.006
	Average	0.020±0.007	1.608±0.588	1.007±0.235	0.051±0.080
Basil	Root	0.235	2.049	1.047	0.074
	Stalk	0.081	0.271	0.508	0.003
	leaves	0.014	0.245	0.113	0.020
	Average	0.110±0.113	0.855±1.034	0.556±0.469	0.069±0.064
Mint	Root	0.017	2.599	1.164	0.020
	Stalk	0.009	1.887	0.981	0.008
	leaves	0.003	0.976	0.499	0.004
	Average	0.010±0.007	1.821±0.813	0.881±0.343	0.011±0.008

The highest rate for transform factor was 1.821 ± 0.813 recorded in the mint sample at a concentration of Th-232. The lowest rate for the transfer from the root to the leaf was in the mint sample in U-232 concentration at a rate of 0.010 ± 0.007.

We note from the results that the highest rate of transfer factor was to the roots and the highest rate of uranium transmission was 0.235 in the basil plant. The highest transfer rate for thorium was 2.599 in mint roots. The highest transfer rate for potassium is 1.378 to the green pepper roots. While the highest transfer factor for Cs-137 was 0.143 to the celery roots.

As for the highest average rate of Th-232 for the transform factor from root to the leaves was 1.821±0.813 in mint sample. And the lowest average transfer factor rate of U-232 concentration from the root to the leaves was 0.010 ± 0.007 in the mint sample. Between them the transition factor rates for K-40 and Cs-137 concentrations were also for the mint sample.

CONCLUSIONS

In this study, measurement of radioactivity in green pepper, cucumber, celery, basil, mint that are regularly consumed by adults in Iraq were performed. The U-238, Th-232 and K-40 specific activity concentrations, using gamma ray spectroscopy NaI(Tl) detector. The soil-to-plant (root) transfer factors for the K-40 were found to be very high in majority of the study samples with a range 1.047 in Basil root to 1.378 in green pepper root. The extremely high values of transfer factor for K-40 were observed in the cases where the concentration of K-40 in the soil samples was extremely low. This may be due to the continuous accumulation of K-40 through the root uptake over a period of time.

In this study K-40 transfer factors were found to be arranged at the roots. Gradually descending from the roots to the stem and then to the leaves in the five plants selected under study. Where the highest values of K-40 transfer factors were concentrated in the roots and were close to the limit recommended by the Limit UNSCEAR, 2010 [14]. This high absorption i.e. uptake of K-40 by the roots may be due to the essential nutrient characteristic of potassium in plants.

The transfer factors for U-238 varied in the average range of 0.010±0.007 in mint plant to 0.325±0.0424 in green pepper plant. The soil-to-plant transfer factors for Th-232 varied in the range of 0.929 in the leaves of celery plant to 2.599 in the roots of mint plant, with an average range of 0.362±0.292 in cucumber plant to 1.821±0.813 in mint plant. The transfer factors for Th-232 were higher than those obtained for U-238 in this study. The ratio of Th-232/U-238 were 2.123 in pepper plant, 7.772 in basil,8.227 in cucumber plant, 80.4 in celery plant, and 182.1 in mint plant. This result is in agreement with the fact that Th-232/U-238 ratio which must be close but greater than unity in any environmental matrix given by UNSCEAR, 2000 [5].

The soil-to-plant average transfer factors for Cs-137 varied from 0.011±0.008 in mint plant to 0.071±0.024 in green pepper. These transfer factors for Cs-137 are not significant because of their low concentration in environmental samples which was obtained in this study. Whereas ELCR in the root and stems of the mint plant exceeds the recommended limit in addition to the approaching value of ELCR for mint leaves, this forms the highest cancer risk.

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