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Ali Abid ABOJASSIM, Heiyam Najy HADY, Zahrah Baqer MOHAMMED

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Ali Abid Abojassim[1,*]

Heiyam Najy Hady[2,]

Zahrah Baqer Mohammed[2,]

* Corresponding author:
ali.alhameedawi@uokufa.edu.iq

1 University of Kufa, Faculty of Science, Department of Physics. Najaf, Iraq.

2 University of Kufa, Faculty of Education for Girls, Department of Physics. Najaf, Iraq

heiyam_najy@yahoo.com
zahrahalmaliki1992@gmail.com

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ABSTRACT

Radioactivity in Food may be contaminated with radioactive materials due to the natural and a nuclear emergency. The vegetables and fruits will become radioactive by deposit of radioactive materials falling on that from the air or through rain water. The aims of the present work were to measure the specific activity and annual effective dose as a result of the intake of vegetables and fruits collected from local market in Najaf governorate. Natural radioactivity was measured in samples using gamma ray spectrometer in this study. The results show that the average specific activities in vegetables samples for ^{238}U, ^{232}Th and ^{40}K were 5.21, 4.76, and 186.15 Bq kg^{-1}, respectively, the average specific activities for ^{232}Th, ^{40}K in fruit samples were 2.53, 211.64 Bq kg^{-1}, while the total average annual effective dose in vegetables samples for adults, children (10 years old) and infants is estimated to be 0.117, 0.122, and 0.179 mSv, respectively, while the total average annual effective dose in fruit samples for adults, children (10 years old) and infants is estimated to be 0.141, 0.295, and 0.388 mSv, respectively. The values found for specific activity and the annual effective dose in all samples in this study were lower than worldwide median values for all groups according to UNSCEAR (2000) and ICRP (1996) respectively; therefore, these values are found to be safe.

Keywords: Natural Radioactivity. Vegetables and Fruits. Gamma ray spectrometer. Iraq food

RESUMO

A radioatividade em alimentos pode acontecer por meio de materiais radioativos, graças a ocorrências naturais e/ou nucleares. Legumes e frutas tornam-se radioativos por depósito de materiais radioativos que caem a partir do ar ou através da água da chuva. Os objetivos da presente pesquisa foram: medir a atividade específica e dose efetiva anual, como consequência da ingestão de frutas e legumes coletados de um mercado local na província de Najaf, Iraque. Neste estudo, a radioatividade natural foi medida em amostras utilizando espectrômetro de raios gama. Os resultados mostram que as atividades específicas médias em amostras vegetais para ^{238}U, ^{232}Th e ^{40}K foram 5,21, 4,76 e 186,15 Bq kg^{-1} e as atividades específicas médias para ^{232}Th, ^{40}K em amostras de frutas foram 2,53, 211,64 Bq kg^{-1}, enquanto que a dose média anual eficaz total em amostras de vegetais para adultos, crianças (10 anos) e recém-nascidos é estimada como sendo 0,117, 0,122, e 0,179 mSv, ao passo que a dose média anual eficaz total em amostras de frutas para adultos, crianças (10 anos) e recém-nascidos é estimada como sendo 0,141, 0,295, e 0,388 mSv, respectivamente. Os valores encontrados para essa atividade específica e a dose efetiva anual em todas as amostras neste estudo foram inferiores aos valores médios mundiais para todos os grupos de acordo com UNSCEAR (2000) e ICRP (1996), respectivamente; portanto, concluiu-se que tais valores são considerados seguros.

Palavras-chave: Radioatividade natural. Legumes e frutas. Espectrômetro de raios gama. Alimentos iraquianos.

INTRODUCTION

Radionuclides are found throughout nature and it exists in the soil, water and food. These radionuclides have half-lives that are approximately Earth's age or older (i.e. about 4 to 5 billion years).[1] Natural radioactive decay series such as ^{238}U and ^{232}Th as well as singly occurring radionuclides such as ^{40}K exist in the earth and atmosphere in varied levels. The radioactivity present on air or in the agricultural land and in soil may transfer to the crops grown on it. It happens, however, that an amount of some radioactive elements find their way into human bodies.[2] Generally, the plants (vegetables and fruits) may cause accumulation of radionuclides in their organs, which may additional rely on the chemical and physical properties of the soil. So, there may be multiplied risk to human population via food chain. The main sources of components from the environment to plants are: air, water and also the soil[3]. There are two ways for transferring of the radionuclides present in the environment in to plants by indirect and direct methods. The first method (indirect) happens by uptake from soil through roots. When plants are grown in the contaminated soil, the radioactivity is transferred from the soil to the roots and then in shoots plant. In the end, the radioactivity is shifted to the human diet.[3] These radionuclides will get transferred into plants together with the nutrients throughout mineral uptake and accumulation in varied components and even reach edible portions.[4] The second method (direct) happens by absorption through aerial elements of the plants. Presence of emission (alpha, beta and gamma) in plant organs has been reviewed by varied staffs.[2]

The are many published researches on radioactive food contamination within the environment and its transfer or pathway mechanism to plants, animals and human population. Uptake of natural radionuclides depends on the consumption rate of food, water and also the radionuclide concentrations.[2,4] There are some studies wich found the levels of natural radioactivity in Vegetables and Fruits samples consumed in different counters in the world.[5-13] High level of NORM has already been found in Iraq soil, especially once war 2003. Plants are the first recipients of the radionuclides from soil. These radionuclides will get transferred into plants alongside the nutrients throughout mineral uptake and accumulate in numerous elements and even reach edible parts. In addition to it, it was chosen vegetable and fruits samples for study. As a result of within the surroundings of Iraq it grows around the year and mass folks. Thus, around the year it's a widely taken food for mass individuals. So, the present study aimed to discover radioactive content of the vegetables and fruits consumed by infants, children and adults in Najaf Governorate, Iraq. The present study also aimed to estimate annual effective doses from consumption samples under study among various age groups.

MATERIAL AND METHODS

Sample collection and preparation

This work focuses on the vegetables and fruits consumed by the overall public in Najaf Governorate, Iraqi. Samples from thirty one vegetables and nine fruits samples were collected in study area presented in Table 1 and Table 2 respectively.

The vegetables and fruits samples were cleaned with normal water and weighed as fresh (wet) for human consumption, each sample is placed in a plastic bag and labeled by name and country of origin. Then they were kept moisture-free before radioactivity measurement in an oven for (2-4) days at a temperature of 42-44°C in order to reach a constant weight and avoid any humidity adsorption. Then the samples were crushed electronically, using electric mill for homogeneity (the loss ratio of samples when are sieved that it is very small according to mass of fresh samples), the samples were sieved (0.8-mm-pore-size sieve). Samples were packed in marinelli beakers that it is constant volume, to attain a good homogeneity around the NaI(Tl) detector. The weighting of samples were measured using digital weighing balance (using a high sensitive digital weighting balance with a percent of ± 0.06%). At the end, the marinelli beakers were stored for about 1 month before measuring, to permit secular equilibrium to be investigated between ^{226}Ra and ^{222}Rn.

NaI(TI) Gamma Ray Spectroscopy

Gamma ray spectroscopy with scintillation detector NaI(TI) from ORTEC has an active area of "3×3" inches (Figure1), energy resolution 7.9% and efficiency of 4.6% at the 662 KeV. Energy calibration

Table 1. Food categories of vegetables samples.

No.	Scientific Name	Trade Name	Code of samples	Country of origin
1	*Solanum lycopersicum*	Tomato	Veg1	Iraq (Kufa)
2	*Solanum tuberosum*	Potato	Veg 2	Iraq (Kufa)
3	*Solanum melongena*	Eggplant	Veg 3	Iraq (Kufa)
4	*Allium cepa*	Onion	Veg 4	Iraq (Kufa)
5	*Abelmoschus esculentus*	Okra	Veg 5	Iraq (Babylon)
6	*Abelmoschus esculentus*	Okra	Veg 6	Iraq(Kwt)
7	*Cucurbita pepo*	Pumpkin	Veg 7	Iraq (Kufa)
8	*Cucumis melo flexuosus*	Cucumis	Veg 8	Iraq(Yousefah)
9	*Cucumis sativus*	Cucumber	Veg 9	Iraq (Kufa)
10	*Capsicum annuum*	Pepper	Veg 10	Iraq (Kufa)
11	*Apium graveolens*	Celery	Veg 11	Iraq (Kufa)
12	*Petroselinum crispum*	Parsley	Veg 12	Iraq (Kufa)
13	*Beta cicla*	Chard	Veg 13	Iraq (Kufa)
14	*Brassica oleracea var. capitata*	Cabbage	Veg 14	Iraq (Kufa)
15	*Mintha virdis*	Spearmint	Veg 15	Iraq (Kufa)
16	*Ocimum basilicum*	Basil	Veg 16	Iraq (Kufa)
17	*Allium porrum*	Leek	Veg 17	Iraq (Kufa)
18	*Trigonella foenum-graecum*	Fenugreek	Veg 18	Iraq (Kufa)
19	*Portulaca oleraceae*	Purslane	Veg 19	Iraq (Kufa)
20	*Solanum lycopersicum*	Tomato	Veg 20	Iran
21	*Solanum tuberosum*	Potato	Veg 21	Iran
22	*Solanum melongena*	Eggplant	Veg 22	Iran
23	*Allium cepa*	Onion	Veg 23	Iran
24	*Anethum graveolens*	Dill	Veg 24	Iran
25	*Lactuea sativa*	Lettuce	Veg 25	Iran
26	*Cucurbita pepo*	Zucchini	Veg 26	Iran
27	*Daucus Carota*	Carrot	Veg 27	Iran
28	*Brassica oleracea var. botrytis*	Cauliflower	Veg 28	Iran
29	*Capsicum annuum*	Pepper	Veg 29	Iran
30	*Capsicum annuum*	Chili Pepper	Veg 30	India
31	*Allium sativum*	Garlic	Veg 31	China

Table 2. Food categories of Fruits samples

No.	Scientific Name	Trade Name	Code of samples	Country of origin
1	*Citrus aurantium*	Rearrange	Fr1	Iraq
2	*Punica granatum*	Pomegranate	Fr2	Iraq
3	*Pyrus communis*	Pear	Fr3	Iraq
4	*Citrullus lanatus*	Watermelon	Fr4	Iran
5	*Malus domestica*	Apple	Fr5	Iran
6	*Musa acuminata*	Banana	Fr6	Egypt
7	*Citrus sinensis*	Orange	Fr7	Egypt
8	*Citrus limon*	Lemon	Fr8	Turkey
9	*Prunus armeniaca*	Apricot	Fr9	Turkey

and efficiency calibration of gamma spectrometer were carried out using (^{60}Co, ^{137}Cs, ^{22}Na and ^{54}Mn) from the Nuclear Lab. in Physics department, which has seven gamma-ray emitters ranged from 511 KeV to 2500 KeV. The lowest limit of detection (BLD) for ^{238}U, ^{232}Th and ^{40}K were 3.17 Bq.kg^{-1}, 1.2 Bq.kg^{-1} and 11.54 Bq.kg^{-1} respectively.

The standard source put over the detector with a geometric match exactly to the geometrical sample form and with same distance between the sample and the detector.

In some circumstances, there may be radioactive sources present in the counting room, other than the one being measured (called radioactive background).

Thus, shield must be used to reduce the radioactive background; the shielding used in this study consists of two layers: the first one of stainless steel with width (30 mm) and the second layer lead (100 mm).

The specific activity of ^{238}U and ^{232}Th was measured using property of secular equilibrium with their decay products such as transition lines of ^{214}Bi (1765 KeV) and transition lines of ^{208}Tl (2614 KeV) respectively. While ^{40}K was measured directly from the photo peak at 1460 KeV. The measuring time for all samples under study was 24 h.

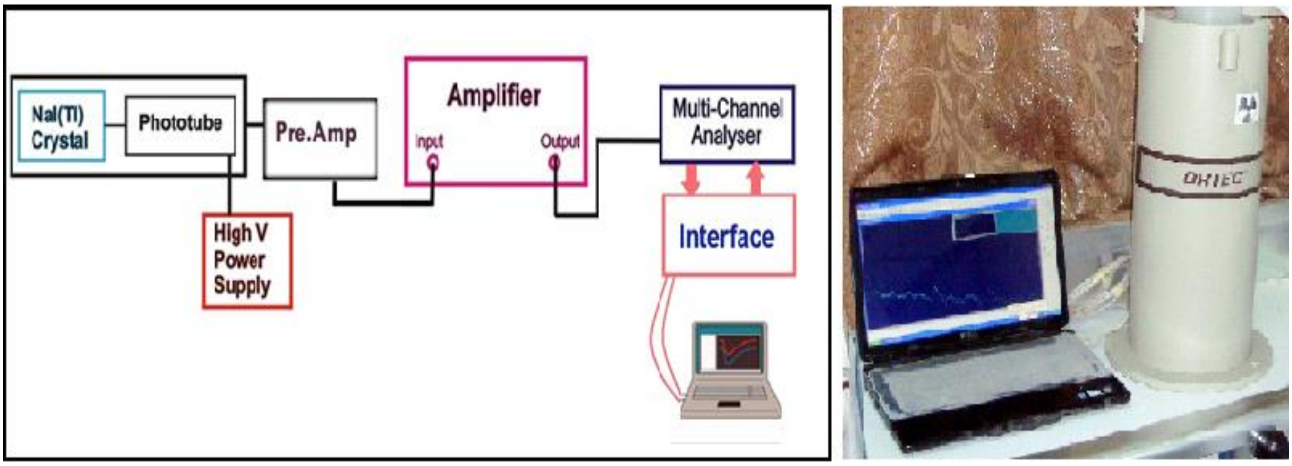

Figure 1. The diagram of the NaI(Tl) detector.

Data Analysis & Mathematical Formula

The specific activity for each detected photo-peak was calculated in (Bq/kg) by equation:[14-16]

$$A_r\left(\frac{Bq}{kg}\right) = \frac{N - N_o}{I_\gamma\, \varepsilon\, m\, t} \qquad \textbf{Eq.(1)}$$

Where:

A_r is the specific activity of the radionuclide in the sample;

N is the net counts of a given peak for a sample;

N_o is the background of the given peak;

I_γ is the number of gamma photons per disintegration, **ε** is the detector efficiency at the specific gamma-ray energy;

m is the mass of the measured sample (fresh weight in kg); and

t is the measuring time for the sample.

During this study, it was also calculated the annual effective dose. Asa result of the intake of foods was performed supported the metabolic model developed by ICRP[17] which it's can be determined using equation:[5,8,18]

$$D_{rf}\left(\frac{Sv}{y}\right) = \Sigma(C_r\, A_{rf}) * R_f \qquad \textbf{Eq.(2)}$$

Where:

D_{rf} is the annual effective dose;

C_r is the effective dose conversion factor of the nuclide (r) (Table 3);

A_{rf} is the specific activity of the nuclide (r) in the ingested food (f, Bq/kg, fresh weight); and

R_f is the consumption rate of the food item (f, kg/y) table(4).[7,8,19]

Table 3. Dose convection factors for different Radionuclides in $nSv.Bq^{-1}$.[16]

Age Groups	^{238}U	^{232}Th	^{40}K
Adults	280	230	6.2
Children (10year old)	800	290	13
Infant	960	450	42

Table 4. Consumption rates for vegetables and fruits.[20]

Food categories	*Average of Consumption Rates ($kg.y^{-1}$)		
	Adult	Children(10 year old)	Infant
Green vegetables	45	20	10
Potatoes	120	85	35
Root	170	110	60
Fruit	75	50	35

* These rates are the 97.5th percentile of the distribution across all consumers.

Table 5. The specific activity of ^{238}U, ^{232}Th, and ^{40}K in vegetables samples

No.	Code of samples	Specific activity ($Bq.kg^{-1}$)		
		^{238}U	^{232}Th	^{40}K
1	Veg1	5.12±0.22	2.22±0.05	219.99±1.29
2	Veg 2	4.24±0.17	3.11±0.07	116.91±0.07
3	Veg 3	6.47±0.37	10.56±0.18	209.56±1.35
4	Veg 4	3.63±0.20	3.08±0.05	274.65±3.07
5	Veg 5	BLD [a *]	5.15±0.08	138.64±0.86
6	Veg 6	BLD	6.64±0.11	141.51±0.92
7	Veg 7	BLD	6.47±0.13	164.93±1.05
8	Veg 8	BLD	5.67±0.10	193.73±1.17
9	Veg 9	BLD	5.06±0.10	226.56±1.34
10	Veg 10	BLD	5.76±0.12	147.16±0.95
11	Veg 11	BLD	5.14±0.10	156.67±0.96
12	Veg 12	BLD	5.23±0.10	206.35±1.21
13	Veg 13	BLD	4.38±0.11	140.95±0.90
14	Veg 14	BLD	4.90±0.09	131.52±0.84
15	Veg 15	BLD	5.12±0.10	179.53±1.14
16	Veg 16	BLD	4.83±0.11	236.39±1.43
17	Veg 17	BLD	6.54±0.14	274.46±1.71
18	Veg 18	BLD	3.75±0.08	276.89±1.35
19	Veg 19	BLD	3.04±0.04	108.99±1.40
20	Veg 20	6.99±0.20	3.95±0.08	155.86±0.99
21	Veg 21	5.02±0.15	2.30±0.04	155.40±0.72
22	Veg 22	6.26±0.01	8.98±0.16	317.75±2.17
23	Veg 23	3.99±0.01	2.84±0.05	238.72±1.49
24	Veg 24	BLD	6.29±0.11	180.98±1.11
25	Veg 25	BLD	2.21±0.05	319.21±1.74
26	Veg 26	BLD	3.11±0.07	139.92±0.88
27	Veg 27	BLD	5.24±0.11	124.06±0.83
28	Veg 28	BLD	3.42±0.07	140.25±0.97
29	Veg 29	BLD	3.96±0.08	139.38±0.91
30	Veg 30	BLD	5.23±0.10	159.27±1.03
31	Veg 31	BLD	3.55±0.09	154.64±1.09
Average ± S.D		5.21±0.47	4.76±0.34	186.15±10.78
Worldwide median value [b]		35	30	400

* BDL a, below detection limit and b Data from UNSCEAR.[21]

Table 6. The specific activity of ^{238}U, ^{232}Th, and ^{40}K in fruit samples.

No.	Code of samples	Specific activity (Bq.kg^{-1})		
		^{238}U	^{232}Th	^{40}K
1	Fr1	BLD	2.85±0.06	285.83±1.85
2	Fr2	BLD	2.04±0.05	223.74±1.51
3	Fr3	BLD	2.51±0.06	206.61±1.38
4	Fr4	BLD	2.63±0.06	144.35±1.20
5	Fr5	BLD	2.14±0.05	185.73±1.27
6	Fr6	BLD	2.92±0.05	154.26±0.94
7	Fr7	BLD	2.58±0.06	195.50±1.46
8	Fr8	BLD	2.73±0.06	218.57±1.46
9	Fr9	BLD	2.37±0.05	290.20±1.78
Average ± S.D		BLD	2.53±0.106	211.64±17.96
Worldwide median value [b]		35	30	400

* BDL [a] , below detection limit and [b] Data from UNSCEAR.[21]

RESULTS AND DISCUSSION:

The results of specific activity in the food samples for natural radionuclides such as ^{238}U, ^{232}Th and ^{40}K, are given in Table(5) and Table(6). The highest concentrations displayed in Table 5 correspond to the naturally occurring radionuclide ^{40}K.The highest concentration of $^{40}K$was 319.21±1.74 Bq kg^{-1} which it is measured in sample Veg $_{25}$ (Lettuce, made in Iran). The spread of measured values is rather large, sample Veg$_{19}$ (Portulaca, made in Iraq) was the lowest concentration: 108.99±1.40 Bq kg^{-1} with an average 186.15±10.78 Bq kg $^{-1}$. ^{40}K was found to be the highest contributor to the activity in all food samples. In this context, ^{40}K is a key biological element in human tissue through metabolic control. Sample Veg $_{20}$ (Tomato, made in Iran) was the food type that contained the highest concentration of ^{238}U, at 6.99±0.20 Bq kg^{-1}, while the lowest concentration, at 3.63±0.20 Bq kg^{-1}, was measured in sample Veg $_{4}$ (Onion, made in Iraq) with an average 5.21±0.47 Bq kg^{-1}. The highest concentration of ^{232}Th was 10.56±0.18 Bq kg^{-1} in sample Veg $_{3}$ (Eggplant, made in Iraq), the lowest concentration of ^{232}Th was 2.21±0.05 Bq kg^{-1} in sample Veg $_{25}$ (Lettuce, made in Iran) with an average 4.76±0.34 Bq kg^{-1}. ^{238}U and ^{232}Th concentrations in all samples were lower than concentrations from other countries. The highest concentrations displayed in Table (6) correspond to the naturally occurring radionuclide ^{40}K. The highest concentration of ^{40}K was 290.20±1.78 Bq kg^{-1} in sample Fr$_9$ (Apricot, made in Turkey). The spread of measured values is rather large, sample Fr$_4$ (Watermelon, made in Iran) was the lowest concentration 144.35±1.20Bq kg^{-1} with an average 211.64±17.96 Bq kg $^{-1}$. All values of the specific activity of ^{238}U were below limit detection. The highest concentration of ^{232}Th was 2.92±0.05 Bqkg^{-1} in sample Fr$_6$ (Banana, made in Egypt), while the lowest concentration of ^{232}Th was 2.04±0.05 Bq kg^{-1} in sample Fr$_2$ (Pomegranate, made in Iraq) with an average 2.53±0.106 Bq kg^{-1}. As seen in Tables (7),(8) and fig.(2), annual effective dose from vegetables and fruits consumption by infant is larger than the dose from consumption by adults and children. This larger value for infant is due to the dose conversion factor for the radionuclide. This indicates that the annual effective dose in all vegetables and fruits samples was lower than the permissible limit of 1 mSv recommended by the International Commission on Radiological Protection.[17] The table (9) consist of comparison of specific activity (Bq.Kg^{-1}) of ^{238}U, ^{232}Th and ^{40}K, in the in vegetables and fruits samples at different countries.

Table 7. Summation of annual effective dose in vegetables samples at different age groups (adults, children (10year old) and infants).

No.	Code of samples	Annual effective dose (mSv/y)		
		Adults	Children(10year old)	Infants
1	Veg1	0.147	0.15	0.15
2	Veg 2	0.313	0.493	0.361
3	Veg 3	0.149	0.218	0.196
4	Veg 4	0.136	0.146	0.245
5	Veg 5	0.091	0.065	0.081
6	Veg 6	0.107	0.074	0.088
7	Veg 7	0.112	0.079	0.719
8	Veg 8	0.112	0.082	0.106
9	Veg 9	0.115	0.087	0.117
10	Veg 10	0.1	0.071	0.086
11	Veg 11	0.096	0.069	0.088
12	Veg 12	0.111	0.083	0.109
13	Veg 13	0.084	0.061	0.078
14	Veg 14	0.086	0.062	0.077
15	Veg 15	0.102	0.075	0.098
16	Veg 16	0.114	0.089	0.12
17	Veg 17	0.143	0.108	0.144
18	Veg 18	0.115	0.092	0.132
19	Veg 19	0.068	0.049	0.061
20	Veg 20	0.171	0.173	0.149
21	Veg 21	0.091	0.568	0.432
22	Veg 22	0.258	0.234	0.233
23	Veg 23	0.129	0.141	0.226
24	Veg 24	0.115	0.083	0.788
25	Veg 25	0.111	0.094	0.143
26	Veg 26	0.071	0.054	0.071
27	Veg 27	0.078	0.062	0.113
28	Veg 28	0.074	0.055	0.073
29	Veg 29	0.078	0.058	0.075
30	Veg 30	0.098	0.071	0.089
31	Veg 31	0.07	0.06	0.12
Average ± S.D		0.117±0.009	0.122±0.021	0.179±0.031

Table 8. Summation of annual effective dose in fruits samples at different age groups (adults, children (10 year old) and infants).

No.	Code of samples	Annual effective dose ($mSv.y^{-1}$) Adults	Children (10year old)	Infants
1	Fr1	0.181	0.226	0.464
2	Fr2	0.139	0.435	0.36
3	Fr3	0.139	0.17	0.693
4	Fr4	0.112	0.968	0.253
5	Fr5	0.122	0.151	0.306
6	Fr6	0.121	0.142	0.271
7	Fr7	0.134	0.164	0.327
8	Fr8	0.148	0.181	0.363
9	Fr9	0.174	0.222	0.463
	Average ± S.D	0.141±0.008	0.295±0.094	0.388±0.101

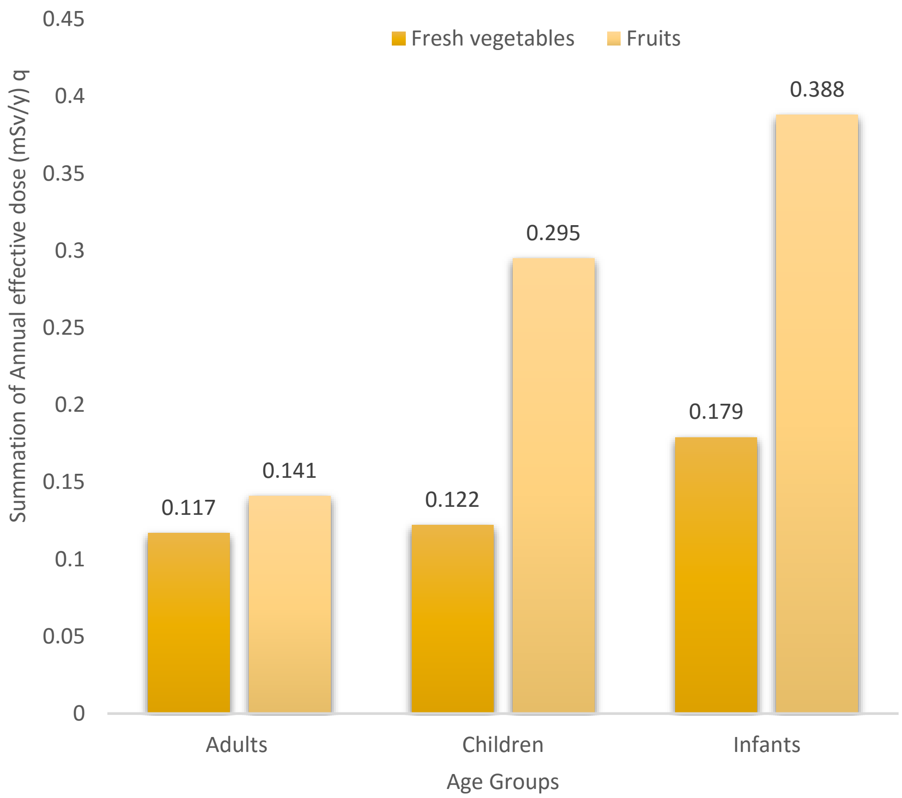

Figure 2. Summation of Annual effective dose ($mSv.y^{-1}$) in vegetables and fruits by all age groups.

Table 9. Comparison of specific activity (Bq/kg) of natural radio-nuclides in vegetables and fruits at different countries.

Region/country	Food categories	Specific activity (Bq.kg^{-1}) ^{238}U	^{232}Th	^{40}K	Ref.
Qena/Egypt	vegetables	0.01± 0.02	0.01 ± 0.05	26.65±1.24	[5]
	Fruits	2.56 ± 1.11	1.22 ± 0.56	536.64±23.03	
Bangladesh	vegetables	64.77±38.47	83.53 ± 0.5	1691.45±244.98	[6]
Elazığ/Turkey	vegetables	0.64 ± 0.26	0.65 ± 0.14	13.98 ±1.22	[7]
	Fruits	1.52 ± 0.34	0.98 ± 0.23	18.66 ± 1.13	
Rize/Turkey	Eggplant	0.20 ± 0.02	0.52± 0.06	517.19 ± 51.91	[8]
	Pepper	1.73 ± 0.33	0.57± 0.06	421.20 ± 14.48	
	Cucumber	1.20 ± 0.18	1.37± 0.41	366.17 ± 19.49	
	Tomato	9.43 ± 1.28	1.35± 0.35	373.03 ± 9.67	
	Parsley	8.36 ± 0.92	2.64± 1.51	1014.72 ±42.64	
	Apple	0.50 ± 0.07	0.38± 0.08	49.15 ± 1.17	
	Lemon	0.36 ± 0.04	0.45± 0.07	50.47 ± 1.20	
	Pear	0.29 ± 0.02	0.25± 0.03	40.39 ± 0.74	
South India	Leafy vegetable	0.03±0.01	1.03±0.5	49.5±8.4	[10]
	Cucumber	0.097±0.02	0.14±0.04	29.67±9.1	
	Tomato	0.06±0.03	0.17±0.02	71.92±8.4	
	Banana	0.094±0.02	1.1±0.2	136.2±8.3	
Southwest India	Cucumber	0.07±0.03	0.14±0.06	29.64±9.1	[11]
	Tomato	0.08±0.02	0.17±0.01	71.92±8.4	
	Banana	0.12±0.04	0.965±0.4	136.2±41.1	
Alexandria/Egypt	Carrot	-	-	42.38 ± 3.93	[12]
	Cucumber	-	-	68.55 ± 4.34	
	Tomato	0.96 ± 0.30	-	49.48 ± 3.45	
	Lettuce	1.05 ± 0.48	-	166.0 ± 16.69	
	Potato	0.80 ± 0.49	-	118.75 ± 2.34	
	Green okra	0.86 ± 0.05	-	117.98 ± 7.32	
	Apple	1.25 ± 0.35	-	32.27 ± 2.70	
	Water-melon	0.85 ± 0.32	-	40.37 ± 3.07	
	Root Vegetables	-	-	210 - 448	
	Fruit	-	-	490 - 510	
Paraná/ Brazil	Potato	-	-	166.7	[22]
Najaf/Iraq	Vegetable	5.21±0.47	4.76±0.34	186.15±10.78	Present study
	Fruit	-	2.53±0.106	211.64±17.96	

CONCLUSIONS

Natural radioactivity (^{238}U, ^{232}Th and ^{40}K) and annual effective dose in some samples of vegetables and fruits produced and frequently consumed in Najaf, Iraq were determined in this study. Specific activity of these radionuclides in samples under study were lower than those reported by UNSCEAR. Also it was found that annual effective doses due to the ingestion of all three natural radionuclides by adults, children, and infants are below the recommended limit by the World Health Organization and by the International Commission on Radiological Protection for radiological safety.

AUTHOR CONTRIBUITION

The author Ali Abid Abojassim carried out the Nuclear radiation studies, participated in the sequence alignment and drafted the manuscript. Heiyam Najy Hady read and approved the final manuscript. Zahrah Baqer Mohammed collected and arranged samples, also contributed to the collection of references of scientific.

COMPETING INTERESTS

The authors declare there are no competing interests.

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REFERENCES

1. Raymond Murray L. (1994).'Understanding Radioactive Waste. Battelle Press. Columbus. Ohio: Fourth Edition.

2. U.S. Environmental Protection Agency Radiation Protection Program- Uranium, (2015).

3. The Governorate of the Hong Kong Special Administrative. (2013).'Radiation and food Safety.

4. Adeniji, A.E., O.O. Alatise and A.C. Nwanya, (2013). Radionuclide concentrations in some fruit juices produced and consumed in Lagos, Nigeria. American. *Journal of Environmental Protection*, 2(2), 37-41. DOI 10.11648/j.ajep.20130202.11

5. Harb, S. (2015). Natural Radiospecific activity and Annual Effective Dose in Selected Vegetables and Fruits. *Journal of Nuclear and Particle Physics*, 5(3), 70-73.

6. Islam A., Begum A., Yeasmin S., Sultana M.S. (2014). Assessment of dose due to natural radio-nuclides in vegetables of high background radiation area in south-eastern part of Bangladesh. *International Journal of Radiation Research*, 12(3), 271-275.

7. Cumhur Canbazoglu and Mahmut Dogru, (2013). A preliminary study on 226Ra, 232Th, 40K and ^{137}Cs specific activity in vegetables and fruits frequently consumed by inhabitants of Elazıg Region, Turkey. *Journal Radioanalytical and Nuclear Chemistry*, 295(2), 1245-1249. DOI 10.1007/s10967-012-1995-4

8. Filiz Korkmaz Görür, Recep Keser, Nilay Akcay, Serdar Dizman, Nilufer as and Nazmi Turan Okumuşoğlu, (2012). Radioactivity and heavy metal concentrations in food samples from Rize, Turkey. *Journal of the science of food and agriculture*, 92(2), 307-312. DOI 10.1002/jsfa.4576

9. A. G. Gharib and M. G. Gharib, (2010). Intakes of Radiologically Important Trace and Minor Elements from Iranian Daily Diets. *Iranian Journal of Science & Technology*, 34(A3), 227-236.

10. Shanthi G., Thampi J. Thanka K., Allan Gnana Raj G., Maniyan C. G, (2010). Natural radionuclides in the South Indian foods and their annual dose. *Nuclear Instruments and Methods in Physics Research*, 619 (1-3), 436-440. DOI 10.1016/j.nima.2009.10.068

11. Shanthi G., Maniyan C. G., Allan Gnana Raj G. and Thampi Thanka Kumaran J., (2009). Radioactivity in food crops from high-background radiation area in southwest India, *Current science*, 97(9), 1331-1335.

12. Ibrahim H. SalehH, Abdelfatah F. Hafez, Nadia H. Elanany, Hussein A. Motaweh and Mohammed A. Naim. (2007). Radiological Study on Soils, Foodstuff and Fertilizers in the Alexandria Region, Egypt. Turkish *Journal of Engineering and Environmental Sciences*, 31(1), 9-17

13. S. Chibowski. (2000). Studies of Radioactive Contaminations and Heavy Metal Contents in Vegetables and Fruit from Lublin, Poland. *Polish Journal of Environmental Studies*, 9(4), 249-253.

14. Harb, S., A. H. El-Kamel, A. I. Abd El-Mageed, A. Abbady, and R. Wafaa. (2008), Concentration of U-238, U-235, Ra226, Th-232 and K-40 for some granite samples in eastern desert of Egypt. In Proceedings of the 3rd Environmental Physics Conference, Aswan, Egypt, 109-117.

15. Ali Abid Abojassim, Husain Hamad Al-Gazaly and Suha Hade Kadhim. (2014). Estimated the radiation hazard indices and ingestion effective dose in wheat flour samples of Iraq markets. *International Journal of Food Contamination*, 1(6), 1-5. DOI 10.1186/s40550-014-0006-7

16. Ali Abid Abojassim, Lubna A. Al-Alasadi, Ahmed R. Shitake, Faeq A. Al-Tememie, and Afnan A. Husain. (2015). Assessment of Annual Effective Dose for Natural Radioactivity of Gamma Emitters in Biscuit Samples in Iraq. *Journal of Food Protection*, 78(9), 1766-1769. DOI 10.4315/0362-028X.JFP-15-067

17. ICRP. (1996). International Committee of Radiological Protection, Age dependant doses to members of public from intake of radionuclides: compilation of ingestion and inhalation coefficients, ICRP publication 72 (Elsevier Science).

18. Nasreddine, L. El Samad, O. Hwalla, N. Baydoun, R. Hamze M. and Parent-Massin, D., (2008) .Specific activity and mean annual effective dose from gamma emitting radionuclides in the Lebananese diet. *Radiation Protection Dosimetry,* 131(4), 545–550. DOI 10.5923/j.jnpp.20150503.04

19. IAEA. (1996). International Atomic Energy Agency, International Basic Safety Standard for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Series No. 115, International Atomic Energy Agency (IAEA), Vienna.

21. UNSCEAR. (2000). Sources and effects of ionizing radiation, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly, with scientific annexes, United Nations, New York

20. Appendix. (2011). Environment Agency food Standards Agency Northern Ireland Environment Agency Scottish Environment Protection Agency.

22. Viviane Scheibel, Carlos Roberto Appoloni. (2007). Radioactive trace measurements of some exported foods from the South of Brazil. *Journal of Food Composition and Analysis*, 20(7), 650-653. DOI 10.1016/j.jfca.2007.04.005