Radiological Assessment of Food Crops and Meats in Al-Tuwaitha Village, Southeast of Baghdad

Zainab Maitham[1*], Mohsin Kadhim[2], Musa Kadhim[3]

Abstract

Ingestion of radionuclides in foods is considered as one of the reasons of human beings exposure to radiation doses. The sources of radioactivity in the environment have origins which are natural, terrestrial, extraterrestrial and anthropogenic. Radionuclides may be transmitted to plants by deposition or from soil. This study is to evaluate the activity of radionuclides' concentrations (^{40}k, ^{232}Th and ^{238}U) of 19 samples selected from foods (vegetables, leafy vegetables, fruits and meats). These samples are collected from Al-Tuwaitha village which is located at southeast of Baghdad, Gamma rays are measured by using the sodium iodide detector. The highest activity value of ^{238}U in basil is 3.606 ± 0.585 Bq/Kg, of ^{232}Th in cayenne pepper is 5.984 ± 0.710 Bq/Kg of ^{40}K in tangerine is 2757.032 ± 27.280 Bq/Kg. The least activity value of ^{238}U is 0.038 ± 0.022 Bq/Kg, of ^{232}Th is 0.063 ± 0.031Bq/Kg and ^{40}K is is 36.396 ± 2.171Bq/Kg in one kinds of dates called Khistawi (in Arabic).

Key Words: Gamma Ray Spectroscopy, Activity Radionuclides' Concentrations Absorbed Dose Rate, Annual Effective Dose.

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Introduction

Natural radioactivity accounts for 70% of the total dosage received by the population from all sources (natural and artificial). The ^{40}K and ^{238}U and ^{232}Th decay series are the most important terrestrial sources of natural background radiation. Internal exposure is mostly caused by these radionuclides which are ingested in food and water, as well as in particulates in inhaled air (Gonzalez *et al*, 1989). Natural radioactivity is basically derived from radionuclides like ^{40}K, ^{238}U and ^{232}Th, as well as their decay products which are found in trace amounts in all earth configurations (Tzortzis *et al*, 2004). It's crucial to understand the radionuclide levels that occur naturally because they are responsible for a significant amount of the radiation exposure received by living organisms (Assunta *et al*, 2008).

Radiation from natural and man-made radionuclides exposes individuals to external and interior radiation in a broad sense. These radionuclides are found in close proximity to one another. They are Inhaled or passed on to the next level in the food chain of human body, which will cause an increase in the dose of human body. As a result, it is necessary to observe the radionuclide levels in the human body. It is also crucial to observe them in the environment (Melquiades *et al*, 2001).

Radionuclides primarily enter the human body through two ways: ingestion and inhalation. The intake through ingestion is determined by food habits, which may result in an increased dose to the general public (Thompson *et al*, 1990). Plants collect metals and radionuclides from the soil as well as from deposits on sections of the plant that are exposed to the air, as it is well known. Irrigation with polluted water can also cause pollution (Khairiah *et al*, 2004).

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Poisoning Uranium in vegetables can occur both directly and indirectly. Radionuclides in a sequence vegetables are directly contaminated by bacteria. Radioactive particles from the atmosphere are concentrated on the surface parts. Concentration, interception, and deposition are the three procedures involved in primary direct deposition as well as retention. The sorption of radionuclides from the environment is referred to as indirect contamination. The plant absorbed food from earth and this may help in placing radioactivity on the ground. Wind may re-deposit pollen on plants, which is subsequently transmitted to veggie (Pietrzak-Flis *et al*, 1995).

Materials and Methods

1. Description of the Study Area

Al Tuwaitha village is 60 km southeast of Baghdad Governorate, Iraq. Samples were collected at latitude N 33°11'41.3'' E044°29'47.0'' to N 33°11'46.1'' E044°29'19.0''

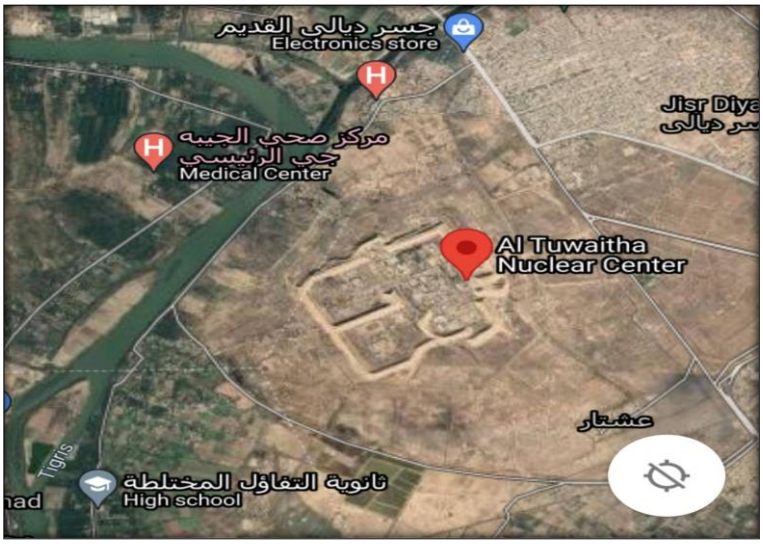

Figure 1. The Tuwaitha nuclear research center

The debris of nuclear reactors attacked by Iran in (1980), Israel in (1981), and the United States in (1991) are located at the "Tuwaitha nuclear research center" or Baghdad nuclear research facility. It is used to store spent nuclear fuel as well as medical and industrial waste. The radioactive substance might be used in a dirty bomb instead of a fission one. In 2003 hundreds of Iraqis steal the facility because of the Iraq invasion (Hickey *et al*, 2009).

The Tuwaitha nuclear research center is the Iraq's base of nuclear-material-therapy facility. It begins in 1967, when three main nuclear power plants and a waste disposal facility are placed into service. The radioisotope manufacturing facility, the IRT 2000 research reactor, and the dumping station are all parts of the project (waste store). The IRT 2000 reactor is upgraded to the IRT 5000 reactor and sundry more nuclear facilities are built on the site (UNSC, 1946).

The facility structure is stolen, especially the lead scarp, during the American occupation. On-site, lead-lined barrels and containers are emptied and moved to a nearby alternative lead foundry in which they are melted into ingots. There are two stages for that process. The first is a meticulously planned event that necessitated the use of industrial machinery while the second is involving the theft of significant chunks of shielding from the damaged reactors. So this is considered as another reason for the spread of nuclear waste in that village (Kusumi *et al*, 2005).

2. Sample Collection and Preparation

Nineteen samples of vegetables, leafy vegetables, fruits and meat are collected from AL-Tuwaitha village as shown in Table (1). All samples are cleansed with regular water and weighed as fresh (wet) for human consumption; then, each sample is put in a nylon bag which is tagged with it's name and country of origin. After that, they are kept in a moisture-free oven for (1-4) days at 50°C to achieve a consistent weight and eliminate any humidity absorption before the radioactivity detection. After that, the samples are electronically crushed by using an electric mill to ensure homogeneity (the loss ratio

of samples when Filtering is very low). To achieve a good homogeneity around the NaI (Tl) detector, the weight of the samples is determined by using a digital weighing balance (a high-sensitivity digital weighing balance with a percent of 0.07 percent).

Table 1. Foods categories samples

No.	Name	Trade Name	Scientific Name	Code of Samples
1	Meat	Fish	Pisces	M1
		Chicken	Gallus gallus	M2
2	Vegetables	Cucumber	Cucumis sativus	V1
		Okra	Abelmoschus esculentus	V2
		Cayenne pepper	Capsicum annuum	V3
		Sweet pepper	Capsicum annuum	V4
		Eggplant	Solanum melongena	V5
		cowpeas	Pumpkin	V6
3	Leafy Vegtables	Basil	Ocimum basilicum	L.V1
		Jew's mallow	Corchorus olitorius	L.V2
4	Fruits	pomegranate	Punica granatum	F1
		Fig	Ficus carica	F2
		orange	Citrus sinensis	F3
		tangerine	Citrus reticulata	F4
		Pomelo	Citrus maxima	F5
		Bitter orange	Citrus aurantium	F6
5	Date	Khistawi Variet	Phoenix dactylifera	D1
		Zahdi Variety		D2
		Barben Variey		D3

NaI(TI) Gamma Ray Spectroscopy

Gamma ray spectroscopy with scintillation detector NaI(TI) from ORTEC has an active area of "3×3" inches Figure (2). Energy calibration and efficiency calibration of gamma spectrometer are carried out by using (^{60}Co, ^{137}Cs, ^{22}Na, ^{109}Cd, ^{109}Ba, and ^{54}Mn) from the Nuclear Lab., in the Physics department, which has eight gamma-ray emitters ranged from 81 KeV to 1173.228 KeV.

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 is of stainless steel with width (30 mm) and the second layer is lead (100 mm).

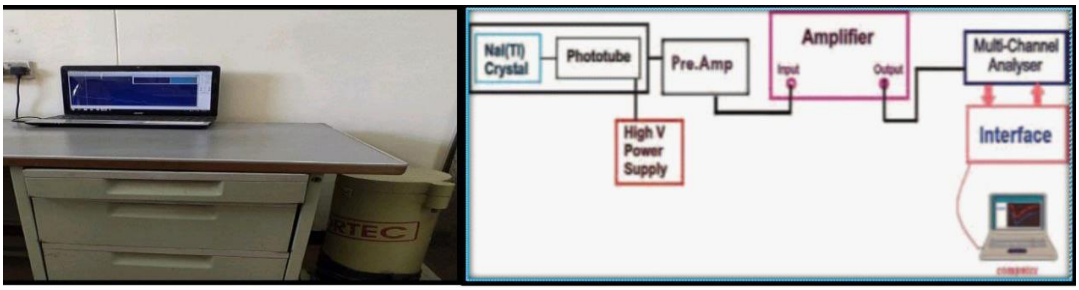

Figure 2. The diagram of the NaI(Tl) detector

Mathematical Formula

The specific activity of ^{238}U and ^{232}Th is measured by using property of secular equilibrium with their decay products such as transition lines of ^{214}Bi (1764 KeV) and ^{208}Tl (2614 KeV) respectively. While ^{40}K is measured directly from the photo peak at 1460 KeV. The measuring time for each sample under study is 180000 second.

1. Activity Concentrations

The activity concentrations for the natural radionuclides in the measured samples are calculated by using the following relation (Giri *et al*, 2013):

$$A\ (Bq/Kg) = N/(\varepsilon .t \cdot I\gamma \cdot M) \pm \sqrt{N}/(\varepsilon .t \cdot I\gamma \cdot M) \quad (1)$$

A: activity in(Bq/Kg)

N: net number of count of the corresponding full-energy peak,

t: counting time in a second

Iγ: absolute transition gamma emission probability,
m: sample weight (Kg).

ε: efficiency of the detector in particular gamma energy and the activity.

2. Radium Equivalent Activity (Raeq)

It is the most paramount to assess the radiation hazards and can be expressed by using the formula (Yu *et al*, 1992):

$$Ra_{eq}\ (Bq/Kg) = A_U + 1.43A_{Th} + 0.077\ A_K \quad (2)$$

Where A_U, A_{Th},and A_K are the specific activity levels (Bq/Kg) of ^{226}Ra, ^{232}Th and ^{40}K respectively. The

maximum values of Ra_{eq} must be less than 370 Bq/Kg (Al-Saleh *et al*, 2007).

3. Absorbed Dose Rate in Air (AD)

In order to assess radiological risk, external exposure to radiation arising from naturally occurring radionuclides can be determined in terms of the absorbed dose rate in air at 1 m above the ground surface. The conversion factors used to compute absorbed dose rate in air per unit activity concentration in Bq/l corresponds to 0.462 nG/h for ^{226}Ra, 0.621 nG/h for ^{232}Th and 0.0417 nG/h for ^{40}K (Jose *et al*, 2005).

$$AD\ (nGy/h) = 0.462A_u + 0.604A_{Th} + 0.0417A_K \quad (3)$$

Where AD: is the dose rate, Au, A_{Th} and A_K are the activity A_U, A_{Th} and A_k are the concentration of uranium, thorium and potassium.

4. Internal Radiation Hazard (Hin)

The internal exposure to ^{222} Rn and its radioactive progeny are managed by H_{in}.The internal hazard index originating from short lived radon will be calculated as follows (Huy *et al*, 2006):

$$Hin\ (Bq/Kg) = AU/150 + ATh/259 + AK/4810 \quad (4)$$

Hin must to be less than one.

5. Activity Concentration Index (Iγ)

The radioactivity level index I_γ used to measure radiation inside the human body and the risk level of radionuclides in human body when exposed to an amount of indoor or outdoor annual effective doses of γ- radiations from radioactive nuclides. The estimated values of I_γ should be less than or equal to one [13]. Values of I_γ were calculated from following formula (Issa *et al*, 2013):

$$I\gamma\ (Bq/Kg) = A_U/150 + A_{Th}/100 + A_K/1500 \quad (5)$$

6. Annual Effective Dose (AED)

The annual effective dose is coming from consumption of food samples. This quantity is considered as the most important one due to the proportional relationship between its value and induced health effect from the intake of radionuclides (Giri *et al*, 2013).

Annual estimated average effective dose equivalent received by a member is calculated by using a number of hours in a year (24 x 365 = 8760 h/year), a conversion factor of (0.7 Sv/Gy), which is used to convert the absorbed rate to human effective dose equivalent with occupancy of 80% for indoors (Jose *et al*, 2005). The annual effective doses are determined as follows:

$$(AED)\ (\mu Sv/y) = AD\ (nGy/h) \times 8760\ h/y \times 0.7\ Sv/Gy \times 0.8 \times 10^{-6} \quad (6)$$

Where AED: Annual effective dose.

AD: Absorbed dose.

Results and Discussions

From Table (2) and figure (3) the specific activity value of ^{238}U, ^{232}Th, and ^{40}K in food for 19 samples are collected from Al-Tuwaitha village with an average of ^{238}U 0.890 ± 0.146 Bq/Kg, for range 0.038 ± 0.022 Bq/Kg to 3.606 ± 0.585 Bq/Kg, the average of ^{232}Th 1.378 ± 0.176 Bq/Kg with a range 0.063 ± 0.031 Bq/Kg to 5.984 ± 0.710 Bq/Kg. The specific activity of ^{238}U and ^{232}Th within the allowed limit. The average of ^{40}K 683.923 ± 12.025 Bq/Kg from 36.396 ± 2.171 Bq/Kg to 2757.032 ± 27.280 Bq/Kg. The specific activity of ^{40}K values are higher than worldwide median value in (chicken, cucumber, okra, cayenne pepper, sweet pepper, pomegranate, orang, tangerine, pomelo and bitter orange). Table (3) and figure (4) show radium equivalent values with an average 685.275 ± 27.521 Bq/Kg, for range 36.456 ± 2.205 Bq/Kg to 2758.293 ± 27.521 Bq/Kg; the radium equivalent values are higher than worldwide median value 370 Bq/Kg in in (chicken, cucumber, okra, cayenne pepper, sweet pepper, pomegranate, orang, tangerine, pomelo and bitter orange), the average of absorbed dose rate values which are 29.556 ± 0.678 nGy/h with a range 1.575± 0.120 nGy/h to 115.429 ± 1.384 nGy/h so the absorbed dose rate values (cucumber, okra, sweet pepper, tangerine) are higher than worldwide median value 55 nGy/h as seen in figure (5), the average of Internal radiation hazard value is 0.150 ± 0.003 Bq/Kg with a range 0.008 ± 0.001 Bq/Kg to 0.578 ± 0.008 Bq/Kg, so all samples within the allowed limit that is less than one as shown in Figure (6), Table (4) and figure (7) indicate to the average of annual effective dose values which are 0.144 ± 0.003 µSv/y with a range 0.007 ± 0.001 µSv/y to 0.566 ± 0.006 µSv/y; therefore all samples within the allowed limit (less than one). Figure (8) shows the average of activity concentration index values that are 0.471± 0.010 Bq/Kg with a range 0.025 ± 0.001 to 1.844 ± 0.022 Bq/Kg, the activity concentration index values for (cucumber, sweet pepper, tangerine) are higher than worldwide median value 1 Bq/Kg as shown in Figure (8).

Table 2. The specific activity of ^{238}U, ^{232}Th, and ^{40}K in foods samples

No.	Code of Samples	Specific Activity (Bq/Kg)		
		^{238}U	^{232}Th	^{40}K
1	M1	0.688 ± 0.106	0.284 ± 0.075	119.115 ± 4.439
2	M2	2.488 ± 0.186	0.727 ± 0.112	489.800 ± 8.312
3	V1	0.632 ± 0.153	1.750 ± 0.283	1983.419 ±27.280
4	V2	0.901 ± 0.144	0.744 ± 0.146	1430.661 ± 18.269
5	V3	0.027 ± 0.136	5.984 ± 0.710	526.031 ± 19.006
6	V4	1.45 ± 0.245	0.924 ± 0.217	1602.699 ± 25.893
7	V5	0.816 ± 0.124	0.211 ± 0.070	211.482 ± 6.364
8	V6	0.454 ± 0.117	1.651 ± 0.249	155.373 ± 6.893
9	L.V1	3.606 ± 0.585	2.468 ± 0.538	289.256 ± 16.644
10	L.V2	0.801 ± 0.032	0.728 ± 0.109	68.748 ± 3.044
11	F1	0.792 ± 0.104	0.372 ± 0.079	407.667 ± 7.496
12	F2	0.839 ± 0.203	0.428 ± 0.161	286.684 ± 11.955
13	F3	0.605 ± 0.121	0.659 ± 0.140	532.512 ± 11.405
14	F4	0.877 ± 0.146	0.090 ± 0.052	2757.032 ± 26.038
15	F5	1.378 ± 0.177	0.853 ± 0.155	1079.375 ± 15.818
16	F6	0.269 ± 0.060	0.266 ± 0.066	611.542 ± 9.113
17	D1	0.038 ± 0.022	0.063 ± 0.031	36.396 ± 2.171
18	D2	0.349 ± 0.052	0.481 ± 0.068	117.425 ± 3.034
19	D3	0.385 ± 0.052	0.453 ± 0.073	289.322 ± 5.306
Av.		0.890 ± 0.146	1.378 ± 0.176	683.923 ± 12.025
Min.		0.038 ± 0.022	0.063 ± 0.031	36.396 ± 2.171
Max.		3.606 ± 0.585	5.984 ± 0.710	2757.032 ± 26.038
Worldwide median value (UNSCEAR, 2000)		35	30	400

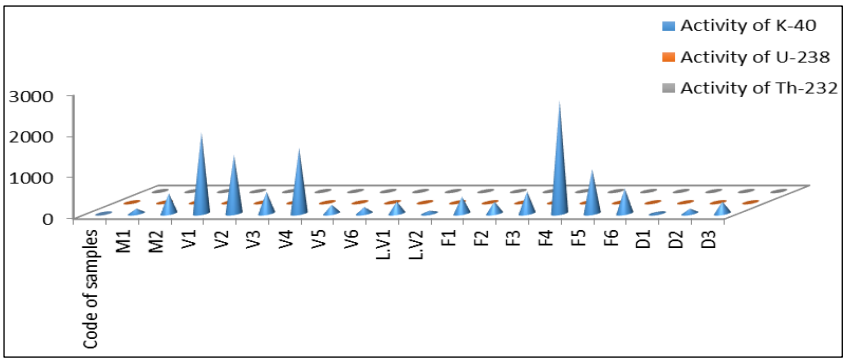

Figure 3. The specific activity of (^{238}U, ^{232}Th, and ^{40}K) in foods samples

Table 3. Radium equivalent, absorbed dose rate and internal radiation hazard. Radiation Hazard

No.	Code of Samples	Radium equivalent Ra_{eq} (Bq/kg)	Absorbed dose rate AD (nGy/h)	Internal radiation hazard (H_{in}) (Bq/kg)
1	M1	120.122 ± 4.596	5.461 ± 0.281	0.029 ± 0.0017
2	M2	493.414 ± 8.577	22.025 ± 0.502	0.118 ± 0.003
3	V1	1984.458 ± 27.521	84.087 ± 1.384	0.422 ± 0.007
4	V2	1432.008 ± 18.487	60.537 ± 0.919	0.305 ± 0.005
5	V3	526.881 ± 19.255	25.777 ± 1.296	0.133 ± 0.007
6	V4	1604.845± 26.261	68.077 ± 1.328	0.344 ± 0.007
7	V5	212.666 ± 6.548	9.327 ± 0.366	0.049 ± 0.002
8	V6	156.150 ± 7.080	7.714± 0.496	0.041 ± 0.003
9	L.V1	294.603 ± 17.522	15.261 ± 1.298	0.089 ± 0.008
10	L.V2	68.919 ± 3.099	3.355 ± 0.210	0.017 ± 0.001
11	F1	408.829 ±7.651	17. 597 ± 0.409	0.090 ± 0.002
12	F2	287.918 ± 12.259	12.608 ± 0.693	0.065 ± 0.004
13	F3	533.428 ± 11.589	22.894 ± 0.618	0.116 ± 0.003
14	F4	2758.293 ± 26.251	115.429 ± 1.185	0.578 ± 0.006
15	F5	1081.412 ± 16.084	46.176 ± 0.838	0.235 ± 0.004
16	F6	611.946 ± 9.204	25.791 ± 0.449	0.129 ± 0.002
17	D1	36.456 ± 2.205	1.575 ± 0.120	0.008 ± 0.001
18	D2	117.947 ± 3.114	5.357 ± 0.192	0.028 ± 0.001
19	D3	289.909 ± 5.399	12.524 ± 0.295	0.063 ± 0.001
Av.		685.275 ± 12.248	29.556± 0.678	0.150 ± 0.003
Min.		36.456 ± 2.205	1.575 ± 0.120	0.008 ± 0.001
Max.		2758.293 ± 26.251	115.429 ± 1.185	0.578 ± 0.006
Worldwide median value		> 370 (Al-Saleh *et al*, 2007).	55 (UNSC, 1982).	>1 (Al-Saleh *et al*, 2007).

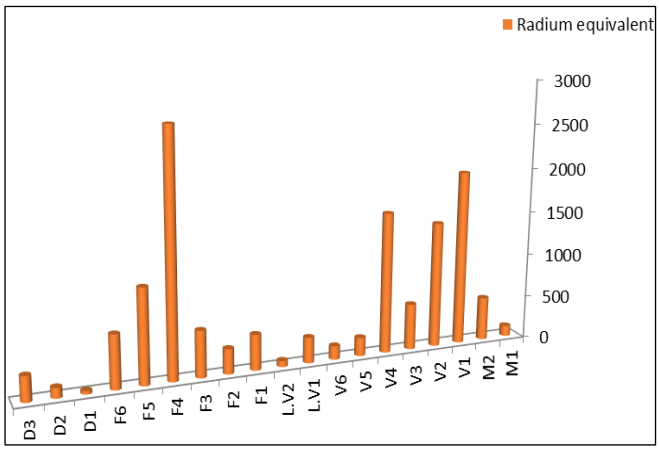

Figure 4. Radium equivalent activity

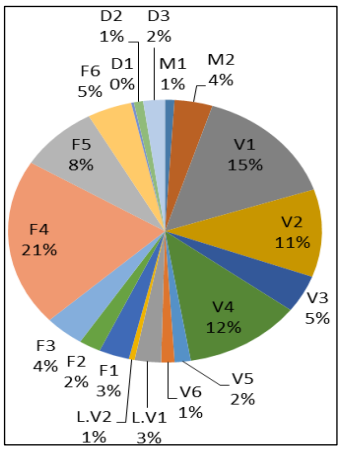

Figure 5. Absorbed dose rate in air

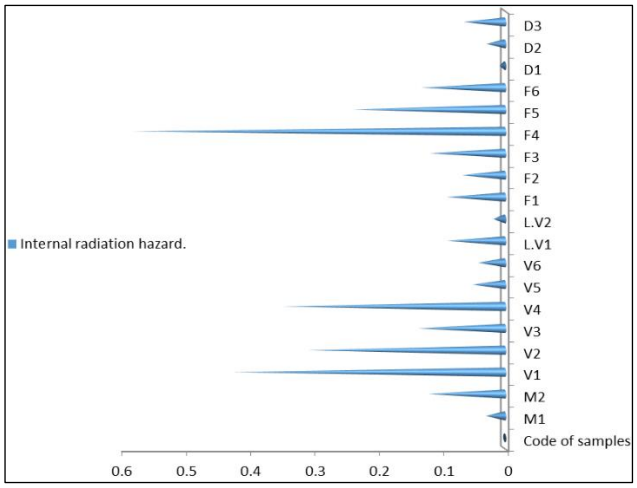

Figure 6. Internal radiation hazard

Table 4. The total annual effective dose and activity concentration index

No.	Code of Samples	Annual effective dose AED (μSv/y)	Activity concentration Index (I_γ) (Bq/Kg)
1	M1	0.026 ± 0.001	0.086 ± 0.004
2	M2	0.108 ± 0.002	0.350 ± 0.007
3	V1	0.412 ± 0.006	1.343 ± 0.022
4	V2	0.296 ± 0.004	0.967 ± 0.014
5	V3	0.126 ± 0.006	0.412 ± 0.020
6	V4	0.333 ± 0.006	1.087 ± 0.021
7	V5	0.045 ± 0.001	0.148 ± 0.005
8	V6	0.037 ± 0.002	0.123± 0.007
9	L.V1	0.074 ± 0.006	0.241± 0.020
10	L.V2	0.016 ± 0.001	0.053 ± 0.003
11	F1	0.086 ± 0.002	0.280 ± 0.006
12	F2	0.061 ± 0.003	0.201± 0.010
13	F3	0.112 ± 0.003	0.365 ± 0.009
14	F4	0.566 ± 0.005	1.844 ± 0.018
15	F5	0.226 ± 0.004	0.737 ± 0.013
16	F6	0.126 ± 0.002	0.412 ± 0.007
17	D1	0.007 ± 0.001	0.025 ± 0.001
18	D2	0.026 ± 0.001	0.085 ± 0.003
19	D3	0.061 ± 0.001	0.199 ± 0.004
Av.		0.144 ± 0.003	0.471 ± 0.010
Min.		0.007 ± 0.001	0.025 ± 0.001
Max.		0.566 ± 0.005	1.844 ± 0.018
Worldwide median value		1 (Shanthi *et al*, 2012).	≥1 (Al-Saleh *et al*, 2007).

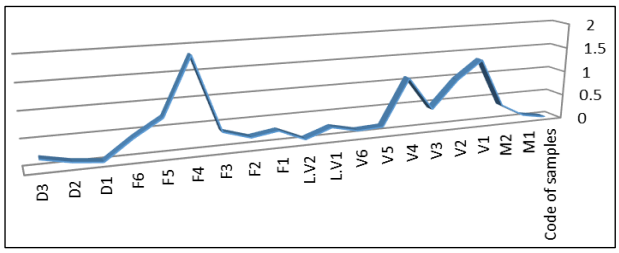

Figure 7. Activity concentration index

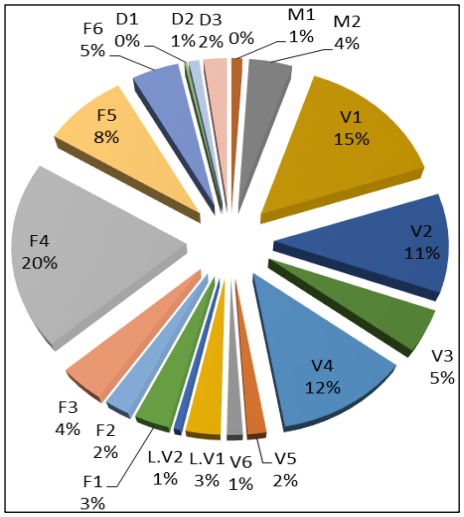

Figure 8. Annual effective dose

Conclusion

The entry of foods contaminated with radionuclides into the human body in this site can present an internal health hazard. Hence, it is not safe for people consumption. The specific activity of ^{40}K values are higher than Worldwide median value for in (chicken, Cucumber, okra, cayenne pepper, sweet pepper, pomegranate, orang, tangerine, pomelo and bitter orange), the radium equivalent values are higher than worldwide median value in (chicken, Cucumber, okra, cayenne pepper, sweet pepper, pomegranate, orang, tangerine, pomelo and bitter orange). The absorbed dose rate values (cucumber, okra, sweet pepper, tangerine) are higher than worldwide median value, and the activity concentration index values for (cucumber, sweet pepper, tangerine) are higher than worldwide median value. The results of this study show that some samples are not safe for consumption.

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