

## Measurement of Radioactivity Levels in Daily Intake Foods of Erbil City Inhabitants



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### Abstract

This work investigates the natural  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ ,  $^{222}\text{Rn}$ ,  $^{220}\text{Rn}$  and man-made  $^{137}\text{Cs}$  radionuclides in foodstuff elements consumed by Iraqi Kurdistan region population (Erbil). The measurements were carried out by using a high efficiency NaI(Tl) gamma-ray spectrometer and CR-39 solid state nuclear track detectors. The estimated average activity concentrations in foodstuff were found to be  $0.17\text{Bq kg}^{-1}$  for  $^{226}\text{Ra}$ ,  $0.183\text{ Bq.kg}^{-1}$  for  $^{232}\text{Th}$ ,  $515.5\text{Bq kg}^{-1}$  for  $^{40}\text{K}$ ,  $0.11\text{Bq.kg}^{-1}$  for  $^{137}\text{Cs}$  and  $108.46\text{Bq.m}^{-3}$  for  $^{222}\text{Rn}$ . The total annual internal dose resulting from ingestion of radioisotopes in foodstuff was ranged from  $0.01\mu\text{Sv.year}^{-1}$  to  $270.8\mu\text{Sv.year}^{-1}$  which lies within the standard safety range of consumption.

**Keywords:** Radioactivity, gamma spectroscopy, CR-39, Foodstuff.

### 1. Introduction

Food is necessary to everyone to survive and develop. Radioactivity is one of the wide range pollutants contaminate human foods [1]. Radionuclides can migrate from the soil to human's body through the main pathway of plant roots, via food chain. Consumption of foods containing radionuclides make particular hazards [2].

Geographical and geological factors affects the environmental distribution of natural radionuclide concentrations [3].

The natural ( $^{232}\text{Th}$ ,  $^{226}\text{Ra}$  and  $^{40}\text{K}$ ) and man-made ( $^{137}\text{Cs}$ ) radionuclides are known to exist in Food and drinks. After ingestion, they contribute to an effective internal dose. It has been believed that a large portion, at least one-eighth, of the mean

annual effective dose due to natural radioactive sources is caused by the intake of foods [4].

Natural radioactive decay series such as  $^{238}\text{U}$  and  $^{232}\text{Th}$  as well as singly occurring radionuclides such as  $^{40}\text{K}$  exist in the earth and atmosphere in varied levels [5].

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 [6].

Through inhalation and ingestion, radionuclides can enter our body. The ingested radionuclides could be accumulated in certain parts of the body. For example,  $^{238}\text{U}$  concentrated in human lungs and kidney,  $^{232}\text{Th}$  in lungs, liver and skeleton tissues and  $^{40}\text{K}$  in muscles [7]. The

potassium in soils can be considerably altered by agricultural activities. By means of the soil and chemical fertilizers such as phosphate, radioactive elements find their way to man via the food chain [8]. The aim of this study is to determine the activity concentrations of  $^{226}\text{Ra}$ ,  $^{238}\text{U}$ ,  $^{40}\text{K}$ ,  $^{222}\text{Rn}$  and  $^{137}\text{Cs}$  in foodstuff samples commonly used by inhabitants of Erbil city at Kurdistan region-Iraq which were not studied previously for their radioactivity. In addition the annual effective dose from the intake of the studied isotopes has been estimated.

## **2. Materials and methods**

### **2.1 Sampling and Sample preparation**

A total of thirty four foodstuff samples collected from different markets located in the main populated areas of Erbil city in Kurdistan region-Iraq. The collected food types were as follow: eggs, sugar, salt, milk, meat (beef, liver and chicken), Fruits (Melon, Watermelon and Banana), Vegetables (Tomatoes, tomato paste, dill, Celery, Swiss chard, Onion, eggplant, pumpkin, Potato, Cucumber and Okra), Pulses (bean, lentil, chickpea and kidney bean), Cereals (rice and flour) Oil seeds (sunflower oil) spices (black Pepper) and Stimulants (tea).

All food samples were pre-treated. Except (Sugar, salt, black pepper, Sunflower oil, milk and tomato paste) samples without any pre-treatments were sealed in a Marinelli beaker. The fruit, vegetable, cereal, pulses, meat, tea and egg samples were washed by water; the non-edible parts were removed and peeled, when necessary. Afterwards, they were dried in the oven at  $110^\circ\text{C}$  for 24 hours. After drying, the samples were grounded into a fine powder by using Mill Machine. After that the sample was sieved by using 2mm mesh to obtain uniform particle size. Then the dried samples were weighed and

transferred into Marinelli beakers and sealed for four weeks to ensure that it reaching the secular equilibrium [5].

The CR-39 nuclear track detector sheets of 500  $\mu\text{m}$  thick obtained from TASTRACK (Track Analysis Systems) Company, UK, were cut into small pieces each of (1cm $\times$ 1cm) area. About 85g of the dried samples were transferred into a PVC plastic cylinder of radius (3.5cm) and height (30 cm). A piece of the cut CR-39 detectors were placed in the bottom of each cylindrical cover (with samples at the bottom of cylinder) and sealed for 70 days. After that the collected CR-39 detectors were chemically etched using a 6.25 M solution of NaOH, at a temperature of  $70^\circ\text{C}$ , for 6 hours. Then an optical microscope with a power of 150X compiled with computer were used to count the number of tracks per  $\text{cm}^2$  in each detector and subsequently the average Radon ( $^{222}\text{Rn}$ ) concentration in ( $\text{Bq}\cdot\text{m}^{-3}$ ) have been calculated.

### **2.2 Experimental Techniques**

The activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  radionuclides in foodstuff samples were determined by a gamma ray spectrometry using a SILENA spectrometer (Model No. 3S3). This system had a NaI(Tl) detector (3 $\times$ 3) inch, connected to the multichannel analyzer MCA (512channel) and analytical CASSY software. A detector surrounded by a 130mm thick cylindrical lead shield with an inner layer of 2mm thick copper. The counting time for each sample was 21600 s. Energy calibration of detector was performed by using  $^{226}\text{Ra}$  standard source with an activity of 37kBq. The Efficiency calibration was performed using a  $^{226}\text{Ra}$ ,  $^{152}\text{Eu}$ ,  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  standard sources with activities 37kBq, 10MBq, 37kBq and 37kBq, respectively. The detector has

an energy resolution (FWHM) of 7.4% at the line energy of 661.6KeV for <sup>137</sup>Cs. The selected line energies 583KeV, 609.3KeV, 1461KeV and 661.6KeV were depended for the detection of the radionuclides: <sup>232</sup>Th(<sup>208</sup>Tl), <sup>226</sup>Ra(<sup>214</sup>Bi), <sup>40</sup>K and <sup>137</sup>Cs, respectively.

**2.3 The activity concentration**

Using the gamma-ray spectrometer, the activity concentrations of each of the radionuclides in the foodstuff samples were obtained using the expression [9]:

$$A = \frac{C}{M_s \cdot \epsilon \cdot p_\gamma} \dots\dots\dots (1)$$

where, A is the specific activity of each radionuclide in the foodstuff (Bq kg<sup>-1</sup>), C is the net count rate of nuclide n (counts/s), ε is the detector efficiency of the specific γ-ray and P<sub>γ</sub> the absolute transition probability of the specific γ-ray and M<sub>s</sub> is the mass of the sample (in kg)

The minimum detectable activity (MDA) can be obtained using the expression [10]

$$MDA = \frac{2.71 + 4.66S_b}{\epsilon \cdot p_\gamma \cdot t \cdot M_s} \dots\dots\dots (2)$$

Where S<sub>b</sub> is the standard error in the net background count for photo peak, t is the counting time in second. In this study, the minimum detectable activity (MDA) were approximately estimated to be 0.0805, 0.08, 0.725 and 0.031Bq.kg<sup>-1</sup> for <sup>226</sup>Ra, <sup>232</sup>Th, <sup>40</sup>K and <sup>137</sup>Cs respectively.

2.4 For Solid State Nuclear Track Detector (SSNTDs) the activity concentrations of radon in (Bq/m<sup>3</sup>) for foodstuff samples have been obtained using the expression [11]:

$$C_{Rn} = \frac{\rho}{K \cdot T} \dots\dots\dots (3)$$

Where ρ is the radon track density (track/cm<sup>2</sup>), T is the exposure time (70 days), and K<sub>Rn</sub> is the calibration factor equal to (0.237 tracks.cm<sup>-2</sup>.d

<sup>-1</sup>/Bq.m<sup>-3</sup>), and effective radium content in (Bq/kg) was obtained using the expression [12]:

$$C_{Ra} = \frac{\rho h A}{K T_e M} \dots\dots\dots (4)$$

A is the cross section area of the chamber in m<sup>2</sup> (A= πr<sup>2</sup>, r is the radius of the chamber equal to 0.0355 m), M is the mass of the samples (0.085 kg), h is the distance from the track detector to the top of sample surface (0.30m), T<sub>e</sub> is the effective exposure time (64.48 days) obtained by:

$$T_e = T - \lambda^{-1}(1 - e^{-\lambda T}) \dots\dots\dots (5)$$

Where λ is the decay constant of radon.

**2.5 Annual effective dose**

Ingestion dose occurring through the intake of radionuclides depends on the consumption rate of foodstuff and the concentration of the radionuclide involved. The annual effective dose from consumption of foodstuff was calculated using the following formula [13]

$$D = AEI \dots\dots\dots (6)$$

Where D is the annual effective dose (Sv year<sup>-1</sup>), A is the activity concentration for the radionuclide (Bq.kg<sup>-1</sup>), E is the dose conversion factor for the radionuclide (Sv.Bq<sup>-1</sup>), and I is the annual intake of foodstuff (kg year<sup>-1</sup>). Since E is age-dependent, the calculation for the annual effective dose D was performed for both age groups separately. The values of E for each studied radionuclide were shown in Table 1.

Table 1: Dose conversion factors (μSv.Bq<sup>-1</sup>) of <sup>238</sup>Ra, <sup>232</sup>Th, <sup>40</sup>K, and <sup>137</sup>Cs, for the adult age (ICRP, 1996) [14] .

<sup>226</sup> Ra(μSv.Bq <sup>-1</sup> )	<sup>232</sup> Th(μSv.Bq <sup>-1</sup> )	<sup>40</sup> K(μSv.Bq <sup>-1</sup> )	<sup>137</sup> Cs(μSv.Bq <sup>-1</sup> )
0.28	0.23	6.2x <sup>10-3</sup>	1.3x10 <sup>-2</sup>

**3. Results and discussion**

The activity concentrations for <sup>226</sup>Ra, <sup>232</sup>Th, <sup>40</sup>K, <sup>137</sup>Cs and <sup>222</sup>Rn radionuclides in the 34 foodstuff samples have been presented in

Tables 2 and 3 and shown in Figures 1 and 2, respectively.  $^{226}\text{Ra}$  was detected in most samples with a minimum value of  $0.39 \pm 0.08 \text{ Bq kg}^{-1}$  in  $S_{15}$  (bean) and a maximum of  $8.33 \pm 0.39 \text{ Bq.kg}^{-1}$  in  $S_{12}$  (potatoes). As it's clear from the graph samples of potato, Swiss chard, and chickpea have higher concentrations of  $^{226}\text{Ra}$  than others, which may be attributed to the crops laying either underground (potato) or in a direct contact with the soil, and hence facilitating the transfer to the crops.

$^{232}\text{Th}$  was detected in most samples with a minimum value of  $0.036 \text{ Bq.kg}^{-1}$  in  $S_{24}$  (flour) and a maximum of  $0.417 \text{ Bq kg}^{-1}$  in  $S_6$  (dill).  $^{40}\text{K}$  was detected in all samples with a minimum

value of  $2.407 \pm 0.29 \text{ Bq.kg}^{-1}$  in  $S_{29}$  (sunflower oil) and a maximum of  $1892.2 \pm 9.21 \text{ Bq kg}^{-1}$  in  $S_6$  (dill). It is known that both of  $^{232}\text{Th}$  and  $^{40}\text{K}$  were of earth's crust origin and hence those crops having long seeds (wheat and sunflower) acquire little of these isotopes than those lying close in or near to the ground (dill).

$^{137}\text{Cs}$  was detected in some samples with a minimum value of  $0.01 \pm 0.003 \text{ Bq.kg}^{-1}$  in  $S_1$  (melon) and a maximum of  $0.441 \pm 0.021 \text{ Bq.kg}^{-1}$  in  $S_{31}$  (tea). The presence of the man-made radionuclide  $^{137}\text{Cs}$  in some foodstuff samples is associated with fallouts, which of course having greater probability to attach to leaf like crops (tea) which is reflected in the recorded results

Table 2: Specific activities for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  radionuclides in the studied Food stuff samples.

Food category	Sample code	Food type	Specific activity $A_s(\text{Bq.Kg}^{-1})$			
			Ra-226	Th-232	K-40	Cs-137
Fruits	S1	Melon	0.132±0.01	0.137±0.018	56.06±1.41	0.01±0.003
	S2	Watermelon	ND	0.083±0.014	19.294±0.83	0.036±0.006
	S3	Banana	0.182±0.02	0.198±0.021	138.85±2.22	0.107±0.01
	S4	Tomatoes	0.107±0.01	0.285±0.026	1457.8±7.18	0.106±0.01
	S5	tomato paste	0.107±0.01	0.234±0.023	474.25±4.1	ND
	S6	dill	0.174±0.02	0.417±0.031	1892.2±8.18	ND
Vegetables	S7	Celery	0.07±0.01	0.111±0.016	796.75±5.31	ND
	S8	Swiss chard	0.503±0.03	0.151±0.019	1728.5±7.82	0.097±0.01
	S9	Onion	0.256±0.02	0.25±0.021	532.03±4.34	ND
	S10	eggplant	0.284±0.02	0.313±0.027	903.69±5.66	0.071±0.008
	S11	pumpkin	0.151±0.02	0.153±0.019	1515.3±7.32	ND
	S12	Potato	0.741±0.03	0.046±0.01	726.67±5.07	0.228±0.015
	S13	Cucumber	0.216±0.02	0.294±0.026	1332.2±6.87	ND
	S14	Okra	0.076±0.01	0.222±0.023	918.48±5.57	0.077±0.009

Pulses	S15	Bean	0.034±0.01	0.385±0.03	622.34±4.69	0.107±0.01
	S16	Lentil	0.1±0.01	0.137±0.018	356.17±3.55	0.028±0.005
	S17	Chickpea	0.41±0.03	0.134±0.018	419.5±3.85	ND
	S18	Kidney bean	0.192±0.02	0.227±0.023	478.84±4.12	0.112±0.011
Meats	S19	Meat	0.203±0.02	0.172±0.02	324.83±3.39	0.091±0.001
	S20	Chicken	0.167±0.02	0.1±0.015	398.95±3.76	0.132±0.011
	S21	Liver	0.139±0.02	0.218±0.022	369.74±3.6	0.132±0.011
Cereals	S22	Rice	0.1±0.01	0.073±0.013	11.541±0.64	ND
	S23	wheat Flour	0.113±0.01	0.129±0.017	152.59±2.32	0.09±0.009
	S24	wheat Flour	0.051±0.01	0.036±0.009	44.209±1.25	0.107±0.01
Milk	S25	Sheep's milk	0.123±0.01	0.169±0.02	71.655±1.59	0.143±0.12
	S26	Goat's milk	0.113±0.01	0.229±0.023	87.25±1.76	ND
	S27	Cow's milk	0.085±0.01	0.191±0.021	74.204±1.62	ND
	S28	Powder Milk	0.13±0.01	0.269±0.025	337.1±3.45	ND
Oil seeds	S29	Sunflower oil	0.144±0.02	0.134±0.018	2.4074±0.29	0.118±0.011
spices	S30	black Pepper	0.054±0.01	0.044±0.01	449.12±3.99	0.054±0.007
Stimulants	S31	Tea	0.062±0.01	0.19±0.021	633.25±4.37	0.441±0.021
Other	S32	egg	0.134±0.01	0.139±0.018	185.03±2.56	0.018±0.004
	S33	Salt	ND	ND	10.52±0.61	ND
	S34	Sugar	0.118±0.01	ND	8.3076±0.54	ND

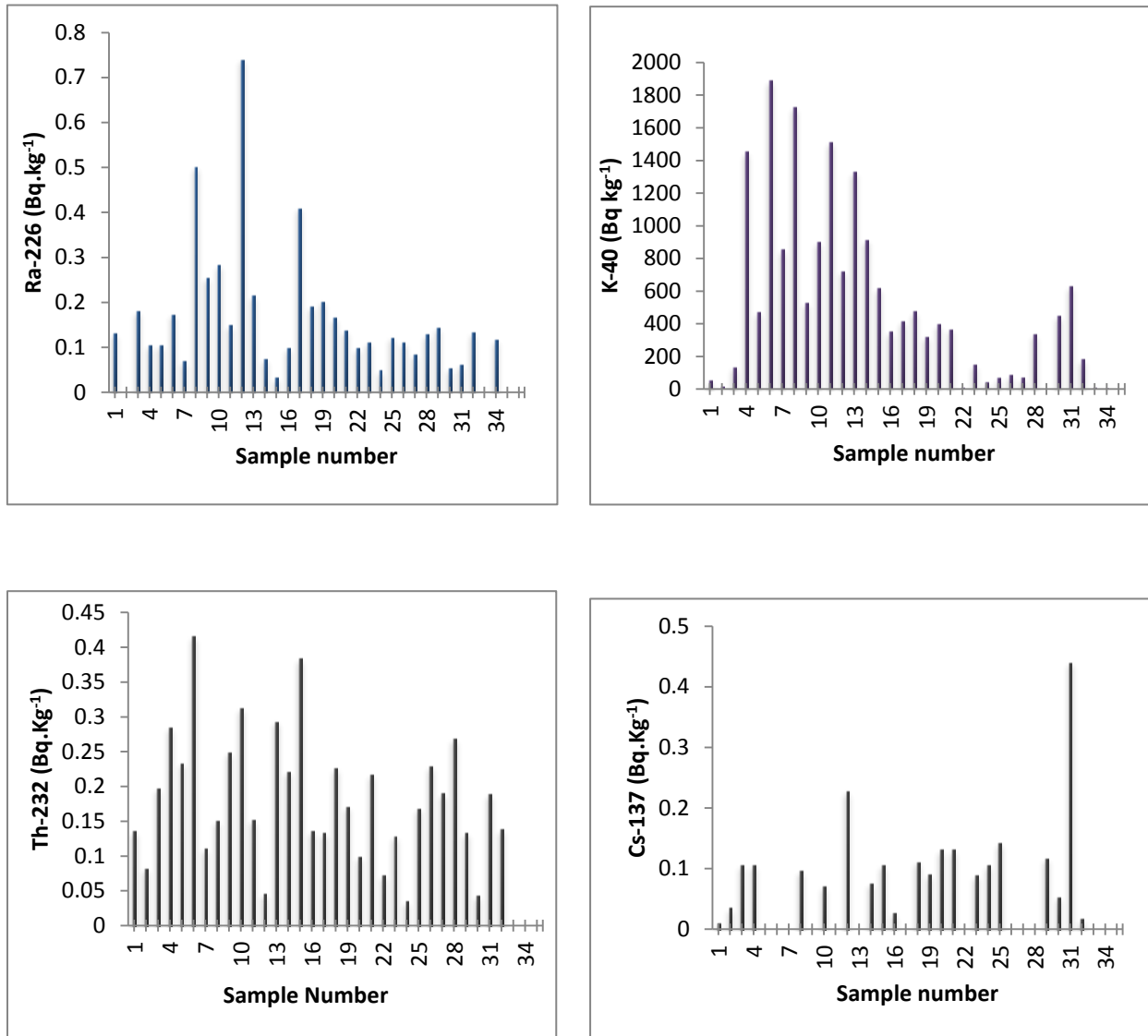


Fig. 1. Concentration of natural radionuclides ( $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ ) and man-made radionuclide ( $^{137}\text{Cs}$ ) in ( $\text{Bq.kg}^{-1}$ ) for each sample.

$^{222}\text{Rn}$  was detected in the different type samples with a maximum value of  $299.8 \text{ Bq.m}^{-3}$  at  $W_7$  (potato) and a minimum of  $24.17 \text{ Bq m}^{-3}$  in  $W_{10}$  (been) which were within the limit determined by (ICRP 1987)[14].

The average concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  were  $0.17 \pm 0.017 \text{ Bq.kg}^{-1}$ ,  $0.183 \pm 0.022 \text{ Bq.kg}^{-1}$ ,  $515.5 \pm 3.7 \text{ Bq kg}^{-1}$  and  $0.11 \pm 0.097 \text{ Bq.kg}^{-1}$ , respectively.

Table3: Activity concentrations for radon and effective radium content in the foodstuff samples

Sample code	Food type	P (track.cm <sup>-2</sup> )	Rn-222 (Bq.m <sup>-3</sup> )	Ra <sub>eff</sub> (Bq.kg <sup>-1</sup> )
W1	Tomatoes	1321.54	79.66	1.17
W2	Celery	1134.36	68.38	1.01
W3	Swiss chard	2871.79	173.1	2.55
W4	Onion	2461.54	148.4	2.19
W5	eggplant	2407.69	145.1	2.14
W6	pumpkin	1891.28	114	1.68
W7	Potato	4974.36	299.8	4.42
W8	Cucumber	2312.82	139.4	2.05
W9	Okra	1031.28	62.16	0.92
W10	Bean	401.026	24.17	0.36
W11	Lentil	1167.69	70.39	1.04
W12	Chickpea	2520	151.9	2.24
W13	Kidney bean	2288.21	137.9	2.03
W14	Meat	2155.38	129.9	1.91
W15	Chicken	2115.9	127.5	1.88
W16	Liver	1754.87	105.8	1.56
W17	Rice	756.923	45.63	0.67
W18	wheat	1347.69	81.24	1.2
W19	Flour	625.641	37.71	0.56
W20	Powder Milk	1503.59	90.63	1.34
W21	Tea	985.641	59.41	0.88
W22	egg	1557.44	93.88	1.38

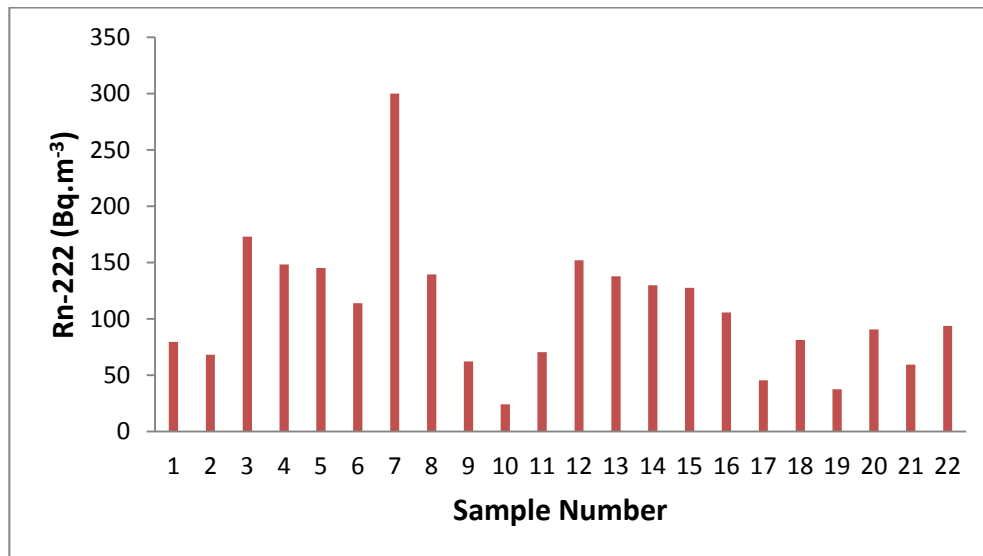


Fig. 2. Concentration of radon (<sup>222</sup>Rn) in (Bq.m<sup>-3</sup>) for each selected sample.

The concentration of  $^{40}\text{K}$  (ranged from  $8.3076 \pm 0.54$  to  $1892.2 \pm 9.21\text{Bq.kg}^{-1}$ ) radionuclide was higher than the other isotopes  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{137}\text{Cs}$ . This can be interpreted by the fact that  $^{40}\text{K}$  has smaller mass than  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{137}\text{Cs}$  which cause it's easily transferring to the crops than higher mass isotopes.

The global average Concentration values of  $^{232}\text{Th}$ ,  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  radionuclides were 45, 32, 412 and  $1000\text{Bq.kg}^{-1}$ , respectively[15, 16]. Through comparison with these values it is obvious that the concentration of  $^{40}\text{K}$  alone exceeds the standard limits, the reason may associated with natural abundance and chemical fertilizers used in agriculture without any scientific control.

Table(4) and Fig.(3) present the annual effective dose rate for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in foodstuff samples. The total dose rate of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  were  $17.3\ \mu\text{Sv.year}^{-1}$ ,  $12.04\ \mu\text{Sv.year}^{-1}$ ,  $800\ \mu\text{Sv.year}^{-1}$  and  $4.89\ \mu\text{Sv.year}^{-1}$  respectively. The high dose rate associated with tomato ( $270.8\ \mu\text{Sv year}^{-1}$ ), potato ( $101.6\ \mu\text{Sv.year}^{-1}$ ), and wheat ( $119.2\ \mu\text{Sv year}^{-1}$ ) is attributed to high rate consumption of these food types by inhabitants than others.

In general, the estimated total dose rate  $829.7\ \mu\text{Sv.year}^{-1}$  was less than the global value ranged (200-1000)  $\mu\text{Sv.y}^{-1}$ [17].

Table 4: The annual effective dose rate for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in foodstuff samples.

Food category	Sample Code	Food type	Annual effective dose in ( $\mu\text{Sv.year}^{-1}$ )				
			Ra -226	Th-232	K-40	Cs-137	Total
Fruits	S1	Melon	0.2025	0.165	1.9	7E-04	2.268
	S2	Watermelon	ND	0.33	2.15	0.008	2.488
	S3	Banana	0.1544	0.132	2.61	0.004	2.9
Vegetables	S4	Tomatoes	0.8862	1.863	268	0.041	270.8
	S5	Tomato paste	0.0633	0.109	6.23	ND	6.402
	S6	Dill	0.1387	0.262	26.4	ND	26.8
	S7	Celery	0.0563	0.07	14.1	ND	14.23
	S8	Swiss chard	0.4016	0.094	30.5	0.004	31
	S9	Onion	0.6015	0.463	27.7	ND	28.76
	S10	Eggplant	0.1826	0.158	12.9	0.002	13.24
	S11	Pumpkin	0.1617	0.129	36	ND	36.29
	S12	Potato	4.4609	0.219	96.9	0.064	101.6
	S13	Cucumber	0.106	0.113	14.5	ND	14.72
	S14	Okra	0.0062	0.014	1.65	3E-04	1.671
Pulses	S15	Bean	0.0239	0.21	9.57	0.003	9.807
	S16	Lentil	0.0286	0.031	2.25	4E-04	2.31
	S17	Chickpea	0.1377	0.035	3.12	ND	3.293

	S18	Kidney bean	0.1332	0.124	7.36	0.004	7.621
<b>Meat</b>	S19	Beef	0.691	0.458	24.4	0.014	25.56
	S20	Chicken	0.5197	0.243	27.5	0.019	28.28
	S21	Liver	0.0027	0.003	0.16	1E-04	0.166
	S22	Rice	0.4984	0.286	1.27	ND	2.054
<b>Cereals</b>	S23	wheat	3.7374	3.339	112	0.138	119.2
	S24	Flour	1.6791	0.933	32.3	0.164	35.08
	S25	Sheep's milk	0.211	0.228	2.72	0.011	3.17
<b>Milk</b>	S26	Goat's milk	0.1618	0.258	2.76	ND	3.18
	S27	Cow's milk	0.6922	1.22	13.3	ND	15.21
	S28	Powder Milk	0.1563	0.255	9.01	ND	9.421
<b>Oil seeds</b>	S29	Sunflower oil	0.1369	0.1	0.05	0.005	0.292
<b>Spices</b>	S30	Black Pepper	0.0017	0.001	0.31	8E-05	0.313
<b>Stimulants</b>	S31	Tea	0.0147	0.035	3.3	0.005	3.355
<b>Other</b>	S32	Egg	0.1991	0.162	6.07	0.001	6.432
	S33	Salt	ND	ND	0.01	ND	0.01
	S34	Sugar	0.8791	ND	1.37	ND	2.249
	<b>Dose intake</b>			17.33	12	800	0.49

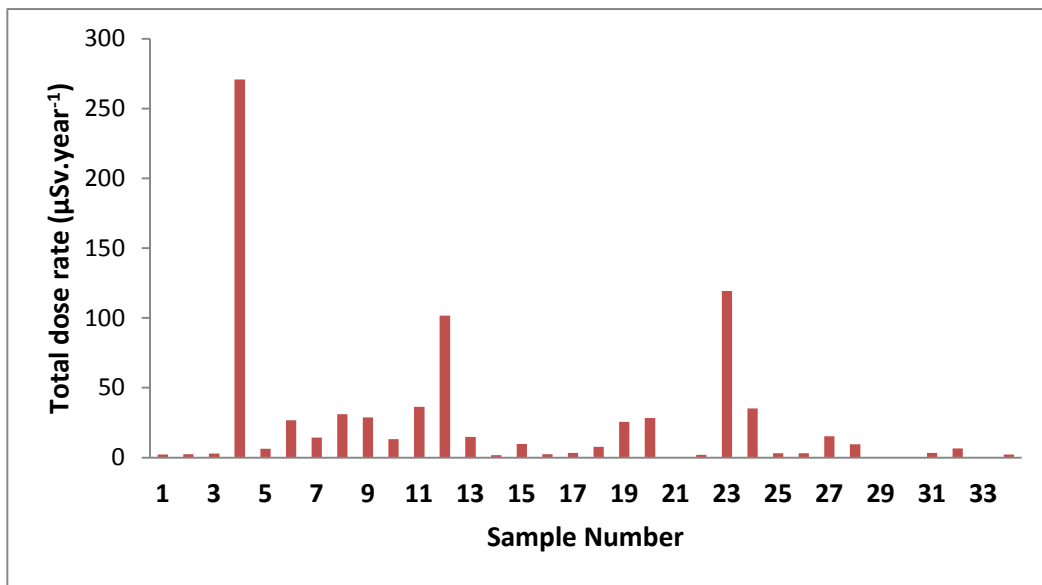


Fig. 3. Total annual effective dose rate in (µSv.year<sup>-1</sup>).

Through both techniques of NaI(Tl) and CR-39 detectors, the relation between <sup>226</sup>Ra content and radon concentration was studied and plotted in

Figure (4) to reveal the expected linear relationship ( $R^2=0.88$ ).

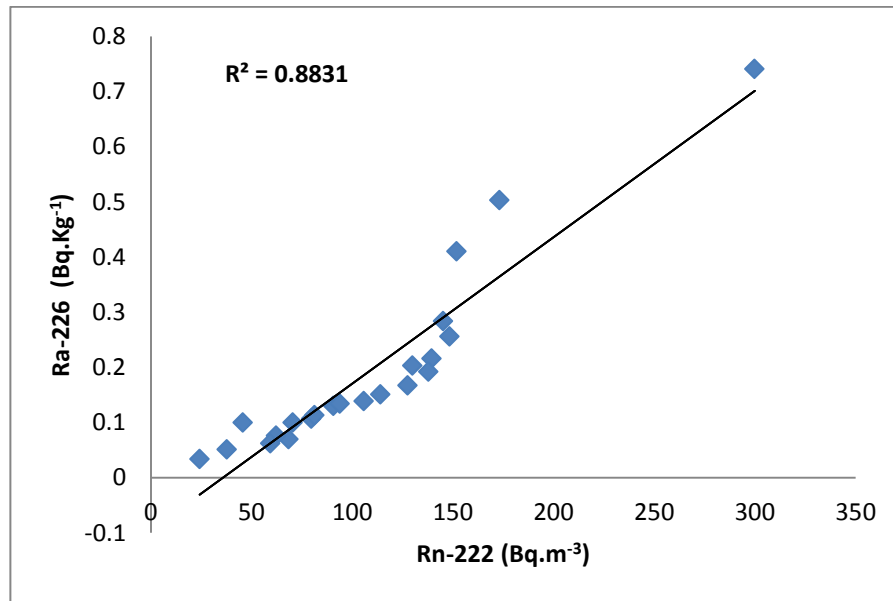


Fig. 4. Correlation between <sup>226</sup>Ra and <sup>222</sup>Rn in the selected samples.

## Conclusion

The measured concentration of <sup>226</sup>Ra, <sup>232</sup>Th, <sup>222</sup>Rn, <sup>220</sup>Rn and <sup>137</sup>Cs were much lower than the world average values. The activity concentration of <sup>40</sup>K in about half of the samples was much higher than the world wide average, <sup>40</sup>K was the largest contributor to the total annual effective

dose rate among the studied isotopes due to higher consumption of foodstuff with high concentration of <sup>40</sup>K and using fertilizers in agricultural activities. The maximum dose rate did not exceed 300.06  $\mu\text{Sv year}^{-1}$  which is less than the permissible safe level of (1000 $\mu\text{Sv.y}^{-1}$ ), which means that the peoples should not worry about the usage of these food types

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