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Assessment of Natural Radioactivity Level and Annual Effective Dose of Amber Rice Samples Cultivated in the South of Iraq

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Abstract. In this work, the activity concentrations of naturally occurring radioactive material including ^{238}U, ^{232}Th, and ^{40}K were measured of some amber rice samples cultivated in southern Baghdad and Al Najaf governorate and used in Baghdad governorate, Iraq in 2018, using gamma-ray spectrometer with NaI (Tl) detector. The results show that the activity concentrations for ^{238}U ranged from (2.68 to 10.81) Bq/kg with average 5.94 Bq/kg, ^{232}Th ranged from (B.D.L to 3.37) Bq/kg with average 2.65 Bq/kg, and for ^{40}K ranged from (4.48 to 35.7) Bq/kg with average 16.84 Bq/kg. The annual effective dose from rice consumption by adults for ^{238}U, ^{232}Th, and ^{40}K ranged from (0.41 to 1.6) $x10^{-5}$ Sv/y with average 0.9 $x10^{-5}$ Sv/y, (B.D.L to 0.42) $x10^{-5}$ Sv/y with average 0.2 $x10^{-5}$ Sv/y, and (0.17 to 1.2) $x10^{-5}$ Sv/y with average 0.45 $x10^{-5}$ Sv/y respectively. All values of the average specific activities are less than the global average values of ICRP, and the annual effective dose from rice consumption by adults was lower than the permissible limit of (1 m Sv/y) recommended by the International Commission on Radiological Protection.

1 Introduction

Radionuclides are found throughout nature and exist in the soil, water and food. These radionuclides have half-lives that are approximately the 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 in 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]. When plants are grown in the contaminated soil, the radioactivity is transferred from the soil to the roots. 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].
It is well known that traces of radionuclides are found in air, soil, water and human bodies, we inhale and ingest radionuclides every day of our lives and radioactive materials have been ubiquitous on earth since its creation [1,5].

Natural Uranium is considered as one of the most important primordial radionuclides in the earth's crust. It is found in varying soil but small amounts, for example, rocks, soils, water, air, plants, animals and in all human beings. On average, about (90 µg) of uranium exist in the human body which comes from the normal intakes of food, water, and air. Approximately (66%) was found in the skeleton, (16%) in liver, (8%) in kidneys and (10%) in other tissues of the body [6, 7].

The physiological behaviour of uranium compounds depends mainly on their solubility, when ingested, uranium might be concentrated within the bones; it increases the probability of bone cancer, or in the red bone marrow (leukemia).[8,9]

The kidney is considered the target for uranium chemical toxicity, which causes irreversible damage to the kidney leading to growth of tumours. A large quantity of uranium in the kidney can impair renal function. [10, 11, 12,13,14].

The Aim of the study is to determine the specific activities of natural 0radionuclides (^{238}U, ^{232}Th, and ^{40}K) in amber Iraqi rice samples cultivated in the middle and the south of the country using Gamma spectroscopy technique with NaI(Tl) scintillation detector.
And to evaluate the annual effective dose from the rice consumption by individual consumers due to intake of the concerned the above radionuclides.

2 Materials and Methods

Three rice samples (1 kg weight of each sample) were collected from fives farming fields (two from south Baghdad and three samples from Al-Najaf governorate farming fields area are shown in table (1), these samples are kept in Marinally beakers and stored for 30 days before gamma ray analysis is done to allow ^{226}Ra and its short-lived progenies to reach secular equilibrium between uranium and thorium with respective progenies.

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Table 1. Rice Samples collected locations

Sample	Location
S1	southern Baghdad
S2	southern Baghdad
S3	AL Najaf governorate
S4	AL Najaf governorate
S5	AL Najaf governorate

Measuring the Specific activity of natural Radionuclides is done by using NaI(Tl) scintillation detector (The sodium iodide NaI(Tl) (CANBRA-USA) to PC-MCA (4096 channel) operating voltage (750V), (3×3inch), and 60% efficiency and the delectability of the energy detector values (1332)MeV. The detector is surrounded by a lead shield to reduce the background radiation.

The energy calibration of gamma spectrometer were carried out using standard sources in one litter marinelli beaker mixed radio nuclides with energies (59.53, 88.34, 661.7, and 1178) keV for ^{214}Am, ^{109}Cd , ^{137}Cs , and ^{60}Co respectively (figure :1)

The software (GIENE 2000) program is used to quantify the measurements and to analyze the results.

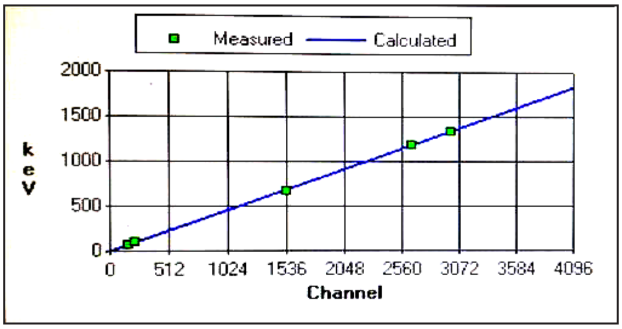

Fig. 1. Energy Calibration Curve.

The efficiency e_f at energy (Eγ) was calculated according to equation:1 below.

$$e_f = \frac{N}{A * I\gamma * T} * 100\% \quad (1)$$

Where:
e_f: The efficiency at energy (Eγ).
N: the net area under the peak at specific peak at energy (Eγ).
A: is the activity of the standard source in (Bq).
Iγ: is the abundance at energy (Eγ).
T: measurement time which equal to (1800s).

To find the efficiencies of other energies of any radioactive isotopes by the efficiency calibration curve as shown in Fig. 2.

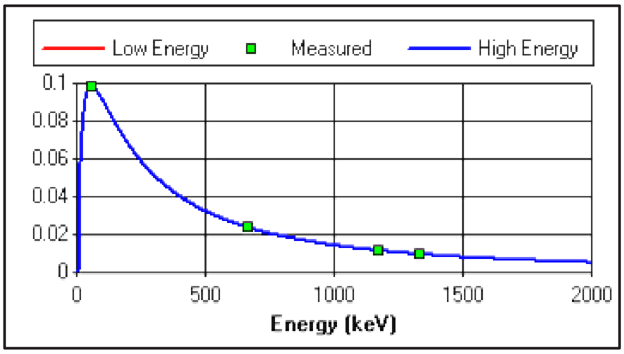

Fig 2. Efficiency Calibration curve

The specific activity of the radionuclides, in (Bq/kg) units, in rice samples were obtained by using equation: 2 [15,16]:

$$A = \frac{N - B.G}{T \times I\gamma \times \mathcal{E}ff \times M} \quad (2)$$

Where:
A: is the specific activity concentration of radionuclide in (Bq/kg), N: is the area under the peak .
B.G: is the peak of background with shielding.
M: is the mass of the sample (kg).
Iγ : is the intensity at energy (Eγ).
Ɛff: is the efficiency at energy (Eγ).
T: is the time of measurement which is equal to (1800s)

The Annual Effective Dose

The annual effective dose was calculated by the following formula [17]:

$$E = C * R * F_C \quad (3)$$

Where: E is the annual effective dose (Sv/y),
C = Concentration (Bq/kg),
R = Consumption rates of food (kg/year) which is equal to 55kg/y.
Fc =Dose conversion factor for ingestion is equal to ($4.5x10^{-5}$ mSv/Bq) for uranium, IAEA 1996 [18, 19].

3 Results and Discussions

The specific activity of natural radionuclides' ^{238}U, ^{232}Th and ^{40}k in rice samples were given in Table 2.

The range of specific activity concentration for ^{238}U varied from (2.68 to 10.81) Bq/kg with average 5.94 Bq/kg, the highest specific activity levels was found in sample S1 (from southern Baghdad), which can be referred to as the cumulative of this radionuclide in the rice and the minimum activity level found in sample S3 from (Al-Najaf governorate) as shown in table 2 and Fig. 3. The range of specific activity for ^{232}Th varied from (B.D.L to 3.37) Bq/kg with average 2.65 Bq/kg, the highest specific activity levels was found in sample S1 (southern Baghdad), and the minimum activity level found in sample S2 and S4 (southern Baghdad and Al-Najaf governorate), as shown in Fig. 4.

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The range of specific activity for ^{40}K varied from (4.88 to 35.7) Bq/kg with average 16.84 Bq/kg, the highest specific activity levels were found in sample S5 (Al-Najaf governorate) and the minimum activity level found in sample S3 (Al-Najaf governorate) as shown in Fig. 5.

The average specific activities of ^{238}U, ^{232}Th and ^{40}K were shown in Fig 6, all values of the average specific activities are less than the global average values [8,22].

As seen in Table 3, the annual effective dose from rice consumption by adults indicates that the annual effective dose in all samples were lower than the maximum permissible limit of (1 mSv/y) recommended by the International Commission on Radiological Protection (ICRP). [17, 18].

Table 2. The average Specific activities of natural radionuclides in rice samples

Sample	Specific Activity Concentration (Bq/kg)		
	^{238}U	^{232}Th	^{40}K
S1	10.81	3.37	12.2
S2	4.42	B.D.L	13.9
S3	2.68	3.18	4.88
S4	6.23	B.D.L	17.5
S5	5.55	1.41	35.7
Max.	10.81	3.37	35.7
Min.	2.68	B.D.L	4.48
Average	5.94	2.65	16.84

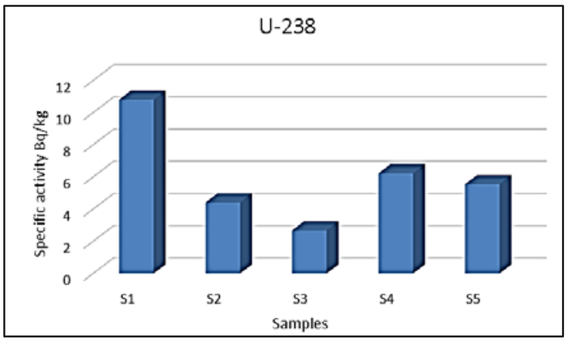

Fig. 3. The specific activity of 238U in rice samples

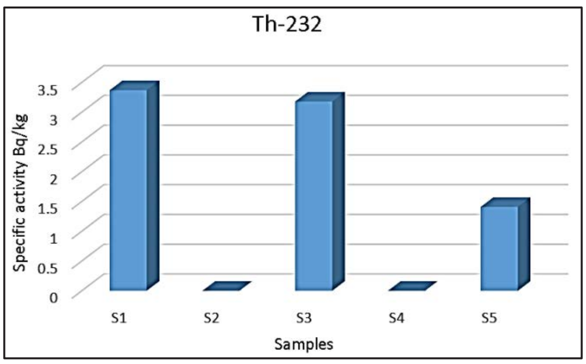

Fig. 4. The specific activity of ^{232}Th in rice samples

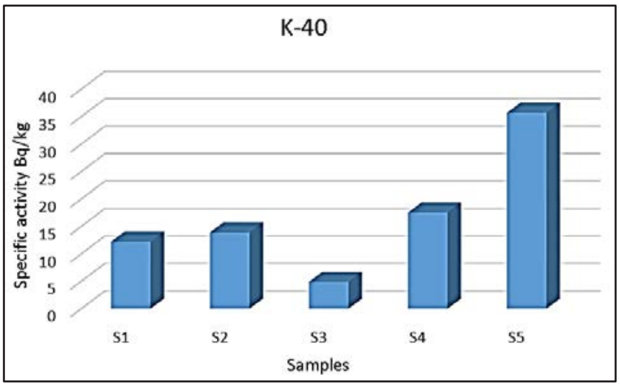

Fig. 5. The specific activity of ^{40}K in rice sample

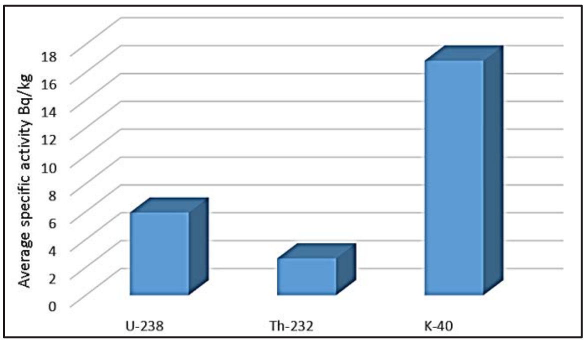

Fig. 6. The average specific activities of ^{238}U, ^{232}Th and ^{40}K in rice samples

Table 3. The annual Effective Dose in rice samples

Sample	Annual Effective Dose $\times 10^{-5}$ (Sv/y)		
	^{238}U	^{232}Th	^{40}K
S1	1.6	0.42	0.42
S2	0.68	B.D.L	0.47
S3	0.41	0.40	0.17
S4	0.96	B.D.L	0.60
S5	0.85	0.18	1.2
Max.	1.6	0.42	1.2
Min.	0.41	B.D.L	0.17
Average	0.9	0.2	0.45

4 Conclusions

The Specific activities of Natural radionuclides (^{238}U, ^{232}Th and ^{40}K) in all samples are lower than the worldwide median values reported by UNSCEAR.[8]

Also it was found that the annual effective doses due to the ingestion of all three natural radionuclides by adults are below the recommended limit by the International Commission on Radiological Protection for radiological safety ICRP.[11, 12,13,14]

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