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Assessment of the Annual Effective Dose due to Intake of Natural Radionuclides from some Food Samples

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ABSTRACT

Since the main source of ingestion exposure to natural radioactivity originating mainly from foodstuffs, the current study aims to assess the total committed doses from ^{226}Ra, ^{232}Th and ^{40}K from some food products. Thirty food samples such as wheat, beans, meat, chicken, fish, Molokai, coffee, tea and powder milk were randomly collected from some markets in Cairo and dried using an electric oven. Specific activity for the ^{226}Ra, ^{232}Th and ^{40}K concentrations in food samples was measured using a high-purity germanium spectrometer. The effective dose from the resulting food was calculated using the dose conversion factors recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation, 2000. The specific activity for the selected food samples varies from 3.5±0.1 to 8.8±0.2, 1.0± 0.1 to 4.6±2.2 and 20±1.0 to 718±2.0 Bq.kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively. The obtained annual ingestion dose was lower than dose constrain and lower than the public dose which gave indication for radiation food safety.

INTRODUCTION

Ingestion dose is mainly due to ^{40}K and the ^{238}U and ^{232}Th series radionuclides present in foods. Ingestion intake of natural radionuclides depends on the consumption rates of food on the radionuclide concentrations [1].Estimates of uranium and thorium series were determined from market basket evaluations. Regular monitoring of food may become a basic requirement for following the internal natural radiation doses. S. Harb and Rafat M *et al* determined natural radionuclides in tea and spices [2-3]. Vahid Changizi *et al* found

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that the average activity concentrations of primordial radionuclides in wheat and corn samples were found to be 1,67, 0.5, 91.73, 0.01 Bq/kg respectively [4]. S. Harb and Nurul Absar et found that activity concentrations of natural background radiation in some vegetables and fruits samples were within the normal range.[5-6]. Sangbok Lee *et al* assessed the average radioactivity for natural radionuclides in coffee by country origin .They mentioned that the highest concentration of the natural radionuclides was measured in Brazil and the lowest in Ethiopia [7]. The current study aims to assess the total committed doses from ^{226}Ra, ^{232}Th and ^{40}K due to ingestion.

MATERIALS AND METHODS

The radioactivity concentrations of food samples were measured using high purity germanium gamma ray spectrometer (HPGe) (Canberra) with 25% relative efficiency. Thirty food samples of wheat, beans, meat, chicken, fish, Molokai, lantils, coffee, tea, and milk powder which were collected from local markets in Cairo. Each sample was dried in an electric oven at 105 ℃ for 16 h to eliminate any water content. This is in addition to meat, chicken and fish ached at 250 ℃ [8]. Then, the samples were stored for a period of 1 four weeks to establish secular equilibrium between radium and radon daughters . Each sample was counted for 86400 seconds (24 hrs.).The concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the three samples for each type was calculated using efficiency energy relation relationship as shown in Figure1. It represents the relationship between energy and efficiency calibration for standard reference material (IAEA- RGU-1).

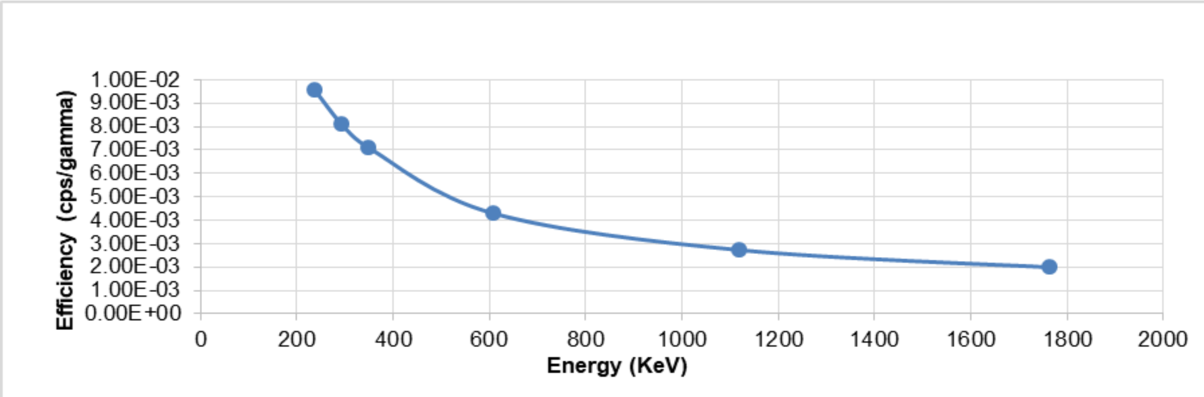

Figure 1 Counting Efficiency for (HPGe)

The secondary standards were calibrated by the primary standard RGU–I with concentration of 4940 $Bqkg^{-1}$. Detector was calibrated to convert channel numbers or spectra into gamma-ray energies. A spectroscopy study was conducted for a source-to-detector distance of 2 cm. The concentration of ^{226}Ra was determined using the 609 keV gamma line of ^{214}Bi, while 1462 keV for ^{40}K, and ٥٨٣ keV and 2614.5 keV of ^{208}Tl were used for determining the ^{232}Th activity concentration in the sample. Each sample was analyzed for 24 hours (86400 seconds) to measure the presence of radioactivity in samples. After that, the efficiency term related to detector efficiency (ε) for a particular peak and the energy efficiency curves obtained by the calibration source, by using the following equation (1).

$$\varepsilon = \frac{Np}{y \quad x\, t \times Kc \times Ac} \qquad (1)$$

Where N_p is the net number of counts in a given peak area obtained from each photo peak, and A_c is the activity value of each calibrating source, t is the counting time of a spectrum acquired, y is the emission probability, and K_c is the decay factor for the decay of source during counting time.

2.1 Mathematical equations

The activity calculated in $Bqkg^{-1}$ as presented in equation (2). It was used to find out the activity concentration for potassium, radium and thorium (^{40}K, ^{226}Th, and ^{232}Th) radioactive elements.

$$A = \frac{N \times 100}{\varepsilon P W} \qquad (2)$$

Where: Activity in $Bq.kg^{-1}$

N: Sample Count- Background count

ε: Efficiency percentage

P: Photon energy probability emission

W: Sample weight in kilogram.

2.2 Effective dose due to ingestion

The ingested dose per year for ^{226}Ra, ^{232}Th and ^{40}K concentrations is presented is given by equation (2).

$$\mathbf{Dose}\left(\frac{Sv}{y}\right) = \mathbf{Concentration}\left(\frac{Bq}{kg}\right)\ \mathbf{X\ Annual\ intake}\left(\frac{kg}{y}\right)\ \mathbf{X\ DCF}\left(\frac{Sv}{Bq}\right)\ (2)$$

DCF is the dose conversion factor; 3.6E-07 Sv/Bq for ^{226}Ra, 2.3E-07 Sv/Bq for ^{232}Th and 2.1E-09 Sv/Bq for ^{40}K [9].

RESULTS

The specific activity for ^{226}Ra, ^{232}Th and ^{40}K concentrations due to ingestion are presented in Table 1. It varies from 3.5 ± 0.1 to 8.8 ± 0.2, 1.0 ± 0.1 to 4.6 ± 2.2, and 210 ± 1.0 to 718 ± 2.0 $Bq.kg^{-1}$, respectively. The ingested dose per year is presented in Table 2. The obtained total doses with the mean and typical range of international worldwide internal background presented as shown in Table 3.

Table 1. Mean Activity concentrations ($Bq.kg^{-1}$) of ^{226}Ra, ^{232}Th and ^{40}K for each type of food.

Sample Type	^{226}R	^{232}Th	^{40}K
Wheat	6.3±0.02	4.6±2.20	210±1.0
Beans	4.5±0.10	4.2±1.70	604±5.3
Meat	4.6±0.10	3.1±0.10	544 ±0.6
Chicken	4.2 ± 0.7	4.4±2.50	605±1.0
Fish	3.5±0.10	3.3±1.40	457±1.0
Coffee	15± 0.10	3.3±0.03	259±0.6
Lantils	4.3±0.10	1.2±0.01	189±1.0
Molokai	4.3±0.02	1.7±0.01	718±2.0
Tea	3.6±0.10	1.0±0.10	449 ±3.6
Powder Milk	8.8±0.20	1.3±0.02	318±1.0

Table 2. The mean Annual committed effective ingestion dose ($\mu Sv\ year^{-1}$).

Sample Code	Food consumed ($kg\ year^{-1)}$ [9]	^{226}Ra	^{232}Th	^{40}K
Wheat	12.1	13.1	3.3	5.30
Beans	21.0	12.7	6.7	15.9
Meat	7.3	13.3	2.4	13.4
Chicken	7.3	9.90	3.2	11.1
Fish	5.5	4.90	*4.4*	*6.30*
Coffee	0.2	0.10	0.1	0.15
Lantils	٤٣	٦٣.٨	*12.6*	65.3
Molokai	18.0	20.2	*7.0*	65.3
Tea	2.1	1.50	0.5	2.00
Powder Milk	10.0	4.40	1.5	6.6
Sum	126.5	133± 6.6	36± 2.5	153 ± 20

Table 3. Average effective dose per year ($mSv\ year^{-1}$) and comparison with previous studies.

Organization/author	Average Ingestion exposure ($\mu Sv.y^{-1}$)
UNSCEAR,2000 [1]	290
UNSCEAR,2008 [10]	290
Tukka Turtiainen, 2010 [12] [3]	800
Soma Giri *et al*, 2013 [13]	300
T,Van et al, 2018 [14]	320
L.Sangbok et al, 2021 [15]	320
Rong He *et al*, 2022 [16]	330
Current Study	320

DISCUSSION

The total committed doses from ^{226}Ra, ^{232}Th and ^{40}K have been estimated from dietary intakes for some food samples. The sum of annual ingestion effective dose to ^{226}Ra , ^{232}Th and ^{40}K due to intake of nine types of Egyptian diet was 0.32 mSv .It is in a good agreement with the typical range of 0.2-1 mSv [10].The highest annual effective doses due to food intake was found in beans and wheat which are considered main breakfast diet. The internal effective dose per year from dietary habit contained ^{226}Ra decayed to stable lead in approximately 50 minutes and after about 6 hours . In addition to the recommendations of ICRP, Gastrointestinal tract model indicates that within few hours the food is digested by the stomach so the food will absorb by small intestine with low doses. The Annual effective doses for ^{40}K was 153 µSv which is within the range of the total body burden of ^{40}K deposited in the total body and the total ingestion doses were within the dose range of internal natural radiation [11]. The ^{226}Ra and ^{234}Th contents of grains and leaves powder food samples depend on ^{226}Ra and ^{234}Th present in nearby soil where they are grown. The plants of molokhia uptake radium isotopes existing in soil throughout their growth by their extensive root system.

CONCLUSION

As a result of our study, we can conclude the followings. In general, radionuclides ^{226}Ra, , ^{232}Th and ^{40}K were measured in seven types of food samples. We noticed that the mean and standard deviation for activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were 80.1± 6.6, 29.1± 2.5 and 126.1 ± 20 respectively. The obtained results are considered a baseline data for future reference dose levels. The obtained annual ingestion dose was lower than dose constrain and lower than the public dose which gave indication for radiation food safety.

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