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Nuclear Science and Techniques, Vol.17, No.5 (2006) 297–300
NUCLEAR SCIENCE AND TECHNIQUES

Level of natural radionuclides in foodstuffs and resultant annual ingestion radiation dose

A.ABBADY *
(Physics Department, Faculty of Science Qena, South Valley University, Egypt)

Abstract The natural radioactivities in three major groups of foodstuff widely consumed in Upper Egypt were determined. The specific activities of ^{226}Ra, ^{232}Th, and ^{40}K in cereals, leguminosae, and flour were measured using γ-ray spectroscopy. Another group of hay, water, and soil samples from the same location were also analyzed. Hay samples were found to contain the highest radioactivity concentration among all the samples that were investigated. This increment could be due to the high water content in the shoots which tends to accumulate soluble radionuclides. The average calculated concentrations of soil samples in the present study exhibits the lowest values with respect to those from different countries. In the case of water samples, the average activities of both ^{232}Th and ^{40}K were similar to those for soil while ^{226}Ra was twice that of water sample. The annual ingestion dose from each radionuclide was calculated. The computed annual dose owing to daily intake of radium, thorium, and potassium via wheat flour, lentils, and bean in the present study (214.8 μSv) is ten times lower than the global average annual radiation dose (2400 μSv) from the natural radiation sources as proposed by UNSCEAR. The obtained results show that the dose values are quite low and carry insignificant radiation dose to the public.

Key words Radioactivity, Soil, Water, Foodstuffs, Annual dose
CLC numbers X125, R144, R155.5

1 Introduction

Naturally occurring radionuclides, ^{226}Ra, ^{232}Th, and ^{40}K, are present in the earth's crust. They usually enter the human body through the food chain and also through the inhalation of the suspended dust in the air. They are removed from soft tissues in a rather short time, but accumalate in the skeleton for a very long period of time and thus impart radiation dose to it. At certain sites in the vicinity of nuclear facilities, these radionuclides may find their way into food chains. Their intakes in that case may be increased, leading to increase in radiation dose to the public [1].

Much studies on food contamination radionuclides in the environment and its transfer or pathway mechanism to plant, animals, and human population have been reported [2-4]. Contamination of the food chain occurs as a result of direct deposition of these radionuclides on the plant leaves, root uptake of radionuclides from contaminated soil or water, and animals ingesting contaminated plants, soil, or water. Considerable efforts are being made by many authors in many parts of the world to measure the activity of radionuclides in the food chain and to estimate the soil–plant transfer [5, 6].

Soil–plant–man transfer of radionuclides to a human being is recognized as one of the major pathway for transfer of radionuclides [7]. These naturally occurring radionuclides with long half-life are transferred to plants along with the nutrients during mineral uptake and accumulate in various parts and even reach

*E-mail: mousa_19@yahoo.com
Received date: 2006-01-17

the edible portions. The use of phosphate fertilizers has similarly been shown to cause many-fold accumulative increases in the levels of such radionuclides in treated soils. The uptake of radionuclides by plants from the soil into plants is highly complex and depends on several factors including the plant species, soil conditions, and the radionuclides' concentrations in soil.

Wheat, bean, and lentils are the main stable foods of Upper Egypt; therefore, radionuclides in these foods are of radiological significance when the contribution to the ingestion dose is assessed through the ingestion pathway. The present effort can provide a good opportunity to assess internal doses to the Egyptian population.

In the present study, the activity of natural radionuclides has been measured in large samples of local foodstuffs, mainly cereals and leguminosae in addition to hay and flour. Another type of sample that includes water and soil from Luxor, Upper Egypt was collected and measured using γ spectrometry. The annual effective ingestion dose received by the general public of Upper Egypt has been calculated and compared with reported global annual dose.

2 Method of sampling and measurement

To investigate the level of natural radionuclides and the resultant doses, six groups of different samples were prepared for measurements. Two groups comprising of cereals and leguminosae are largely planted in the area. The cereals include sorghum, durra, zea mays, sesame, and wheat; while the leguminosae group includes basella ceae, chickpea, haricot, bean, fenugreek, and lentil. The other four groups were: wheat, sorghum, and sesame hays; wheat and sorghum flour; soil; and water.

The cereals and leguminosae collected from agricultural fields in Luxor were dried after washing with distilled water. The dried sample was then ground and thoroughly mixed. Sub-samples of 90—150 g were sealed in cylindrical plastic boxes (55 mm diameter and 75 mm height). Powdered soil, hay, and flour samples taken from the same location were dried and sealed in the same boxes. Water used for irrigation was filled and tightly sealed in the same geometry. To achieve radioactive equilibrium, measurements were taken a month later.

The samples were analyzed at the Gamma-Ray Spectrometry Laboratory, Faculty of Science, Qena, Upper Egypt. The applied low-level γ-ray spectrometer consists basically of a sodium iodide detector (NaI(Tl) 3 × 3 inch ORTEC) with its electronics and 2048 multi-channel analyzer model 100U. The detector was shielded in a 50-mm thick lead cylinder to reduce background radiations. The applied detector has the following characteristics: resolution is 7.5 % for 662 keV; peak efficiency at 1.33 MeV ^{60}Co is 4.8 × 10^{-5} and operation bias voltage is 700—750 V DC.

The counting time (36000 s) was sufficient to produce strong peaks at γ-emitting energies of 1460 keV for ^{40}K 609 keV for ^{214}Bi, and 911 keV, which were used to estimate the concentrations of ^{226}Ra and ^{232}Th, respectively.

To achieve statistically significant counting results, each sample was counted for 36000 s continuously thrice and the average was calculated. The detection efficiency was determined with primary calibration sources of known activity concentrations in the same geometry. Background radiations were measured frequently and corrections were made.

3 Results and discussion

3.1 Activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in samples

The data on radioactivity in soil and cereals generally show that they contain low concentrations of the primordial radionuclides. A considerable increase in the three radionuclides' levels could be observed in certain cases. The concentrations of radionuclides in cereals and leguminosae can be indicative of ingestion dose to man. The average concentrations of natural radionuclides analyzed in cereals, leguminosae, flour, and hay collected from agricultural fields in Luxor are shown in Table 1. From the table, the average of both ^{226}Ra and ^{232}Th in cereal samples were in the same order of magnitude and do not vary in a wide range, whereas ^{40}K content varies clearly with the sample type. The level of ^{232}Th and ^{40}K activity values in leguminosae samples is comparable to that in cereals but ^{226}Ra values are less. Appreciable increase in the measured activities of ^{226}Ra, ^{232}Th, and ^{40}K in the hay

samples could be noticed while the flour of wheat and sorghum has comparable values as leguminosae. The observed increment for ^{226}Ra and ^{232}Th, especially in hay samples are due to the high water content in shoots and leaves which tend to accumulate soluble radionuclides.

Table 1 Average natural radionuclides activities in foodstuff, flour, and hay samples

Sample type		Activity concentration / Bq·kg^{-1}		
		Ra-226	Th-232	K-40
Cereals	Sorghum	3.0 ± 0.6	9.2 ± 2.2	145.0 ± 12.0
	Durra	3.0 ± 0.6	18.2 ± 4.3	65.4 ± 8.1
	Zea mays	2.5 ± 0.5	13.0 ± 2.4	62.9 ± 7.9
	Sesame	2.5 ± 0.5	11.5 ± 2.5	125.5 ± 11.2
	Wheat	3.4 ± 0.6	9.7 ± 2.3	104.8 ± 10.1
Leguminosae	Basella ceae	1.4 ± 0.1	14.2 ± 3.8	203.2 ± 14.3
	Chickpea	0.5 ± 0.1	17.2 ± 4.1	101.2 ± 10.0
	Haricot	3.4 ± 0.6	20.1 ± 4.5	208.9 ± 14.4
	Bean	0.6 ± 0.1	12.8 ± 1.6	110.5 ± 10.5
	Fenugreek	2.0 ± 0.4	17.4 ± 3.4	284.1 ± 16.8
	Lentils	2.1 ± 0.3	16.1 ± 3.3	176.1 ± 13.2
Flour	Sorghum	0.6 ± 0.1	22.0 ± 4.7	131.7 ± 11.4
	Wheat	1.3 ± 0.1	16.5 ± 3.7	91.7 ± 8.3
Hay	Sesame	3.0 ± 0.6	48.4 ± 6.9	258.6 ± 16.0
	Wheat	12.1 ± 2.1	67.6 ± 8.2	299.3 ± 13.2
	Sorghum	15.5 ± 3.0	17.0 ± 3.9	177.7 ± 9.3

The average activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K for cereals, leguminosae, flour, hay, soil, and water are shown in Fig. 1. From Fig. 1, there is an appreciable increase in the content of the three radionuclides in the hay samples while flour has the lowest value of ^{226}Ra content and cereals have minimum value of ^{40}K.

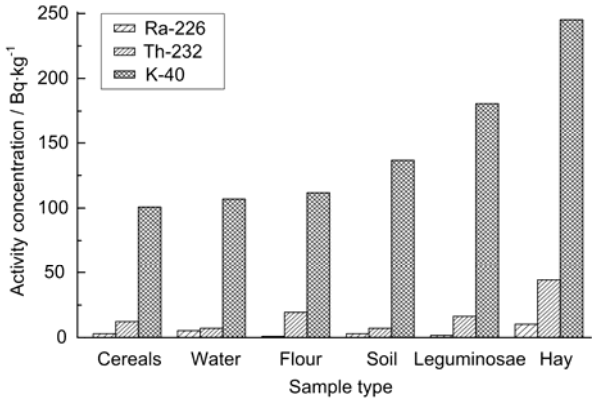

Fig. 1 Average activity concentration (Bq·kg^{-1}) in the measured sample.

The average activity concentration of ^{232}Th and ^{40}K calculated in soil samples were 7.2 ± 0.6 and 136.6 ± 11.6 Bq·kg^{-1}, respectively. In the water samples, the average value of ^{226}Ra was twice that in soil (5.2 ± 1.5 Bq·kg^{-1}) although the average concentrations of ^{232}Th and ^{40}K were similar.

The obtained results for ^{226}Ra and ^{232}Th have low values of activity concentrations, when compared with the worldwide average values (35 and 30 Bq·kg^{-1} for ^{226}Ra and ^{232}Th, respectively) of these radionuclides in soil [8]. Also, for ^{40}K, the value is less than the worldwide median value (400 Bq·kg^{-1}).

The average specific activities of each radionuclide in the hay samples are much higher than those in cereals, leguminosae, and flour. The uptake of naturally occurring radium, thorium, and potassium by plant from the soil is a result of a very complex behavior of elements in the soil. Yunoki *et al.* [9] have reported that the degree of accumulation of natural radioactive elements is affected by the metal-selective function of plants during the uptake of elements so as to maintain homeostasis in the normal environment.

The natural radioactivity levels of soil in the present study are compared with the values from other countries. The ^{232}Th content of the Upper Egypt soil is lower than the value of ^{232}Th in soil from Vojvodina, India and is similar to that of South Egypt [10, 11]. However, the value of ^{40}K activity is in the lower range when compared to a similar ^{40}K activity worldwide.

There are few reported datasets in the published reports on natural radionuclides in crops, fruits, and vegetables, with which the present dataset can be compared [12]. A comparison with similar studies conducted on certain foodstuff in Nigeria showed good agreement in their activity concentration [13]. However, the radioactivity levels obtained in wheat grains under investigation is much higher than those determined in wheat grains obtained from fertilized Punjab fields [14].

3.2 Ingestion dose to man

Radionuclides activities from uranium and thorium series and ^{40}K present in food and drinking water consumed by man lead to the ingestion dose. The annual effective ingestion dose for adult males in Upper Egypt area due to consumption of wheat grains, bean,

lentils, and wheat flour could be computed. The calculation is based on a daily intake of 50g wheat, 50g bean, 25g lentils, and 50g wheat flour and the standard ingestion dose conversion factors [15] using the equation:

Annual effective dose ($\mu Sv \cdot a^{-1}$) =

Concentration ($Bq \cdot kg^{-1}$) × Annual intake ($kg \cdot a^{-1}$) × Dose conversion factor ($\mu Sv \cdot Bq^{-1}$)

The annual ingestion dose due to each radionuclide is shown in Table 2. The sum total of the dose received from ^{226}Ra, ^{232}Th, and ^{40}K due to consumption of wheat grains alone (74.3 μSv) is nearly equal to that from bean. The value due to consumption of flour is twice the corresponding value of lentils. The computed total annual dose due to daily intake of radium, thorium, and potassium through flour, bean, and lentils, the present study (214.8 μSv) is ten times lower than the global average annual radiation dose (2400 μSv) from the natural radiation sources as proposed by UNSCEAR.

Table 2 Annual dose owing to consumption of flour, wheat grains, lentils, and bean by adult males in Upper Egypt

Radionuclide	Annual committed effective dose / $\mu Sv \cdot a^{-1}$			
	Flour	Wheat	Lentils	Bean
Ra-226	6.64	17.40	5.30	3.10
Th-232	74.02	42.50	35.28	56.10
K-40	10.87	14.40	10.44	13.10
Total	91.53	74.30	51.02	72.30

The total annual dose from ^{226}Ra, ^{232}Th, and ^{40}K due to consumption of wheat grains is almost twice the value from ^{238}U, ^{232}Th, and ^{226}Ra of wheat grains (34.13 $\mu Sv \cdot a^{-1}$) from fertilized Punjab field [14] . However, the obtained results showed that the dose values are quite low and result in mild doses of radiation to the population.

4 Conclusions

Cereals like wheat and bean constitute a major part of the daily diet of Egyptians. The specific activities of the natural radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) in cereals, leguminosae, flour, hay, soil, and water samples from Luxor farms have been determined. The results showed that hay samples contain the highest concentration of natural radionuclides among all the tested samples. However, the average values of radioactivity in all the samples are still lower than the worldwide average value. The computed annual dose owing to intake of radium, thorium, and potassium through wheat grains, bean, and lentils grown in the agricultural fields under the present study is ten times lower than the global average annual radiation dose (2400 μSv) from the natural radiation sources as proposed by UNSCEAR.

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