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Natural Radioactivity Concentration and Annual Effective Dose in Selected Vegetables and Fruits

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Abstract The aims of this study are to determine the mean concentrations of important natural radionuclides and annual effective dose due to the ingestion of Vegetables and Fruits in Qena, Upper Egypt. The levels of ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K were measured in some vegetables and fruits samples were collected from local market in Qena. The content of ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K radioactivity varies from 0.01±0.02 to 2.56±1.11, 0.01±0.06 to 1.06±0.26, 0.01±0.05 to 1.22±0.56, and 26.65±1.24 to (536.64±23.03) Bq.kg^{-1}, respectively.

Keywords Gamma-ray, Gamma spectrometry, HPGe detector, Natural radionuclids, Vegetables and fruits

1. Introduction

Natural radioactivity arises mainly from the primordial radionuclides, such as ^{40}K, and the radionuclides from the ^{238}U and ^{232}Th and their decay products, which are present at trace levels in all ground formations. The knowledge of concentrations and distributions of the radionuclides in these materials are of interest since it provides useful information in the monitoring of environmental radioactivity.

Natural radionuclides occur in soil and they are incorporated metabolically into plants, and ultimately find their way into food and water. Manmade radionuclides behave in a similar manner, and worldwide contamination of the food chains by radionuclides produced during tests of nuclear weapons in the atmosphere has taken place during the past half century [2]. (Golmakani et al 2008).

In some parts of the world, population growth and movement, industrial development and food security have resulted in pressure to use agricultural lands containing relatively high levels of radioactivity, for instance in the monazite areas of India and Brazil, and in parts of Iran with ^{226}Ra anomalies where exposures up to tens of mSv, and in extreme cases 100 mSv, occur annually (UNSCEAR, 2000; Banzi et al., 2000) [1, 2].

In the present work levels of ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K in daily diets were determined in selected vegetables and fruits in Qena, Egypt. The obtained results were used for the estimation of intakes, and annual effective doses of these radionuclides in the adult population of Qena, Egypt.

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2. Materials and methods

2.1. Sampling and Preparing

Twenty – Two vegetables and fruits samples were collected from the local market selected according to use at Qena, Upper Egypt as shown in fig 1. The foodstuff samples were washed with normal water, as for human consumption, weighed and divided into small parts, dried in a stove at a temperature of 80°C for 48 h and ground into powder (Harb, Santos) [3, 4], and filled in 250 mL polypropylene bottles, which were sealed and left for at least 4 weeks before counting by gamma spectrometry in order to ensure that radioactive secular equilibrium.

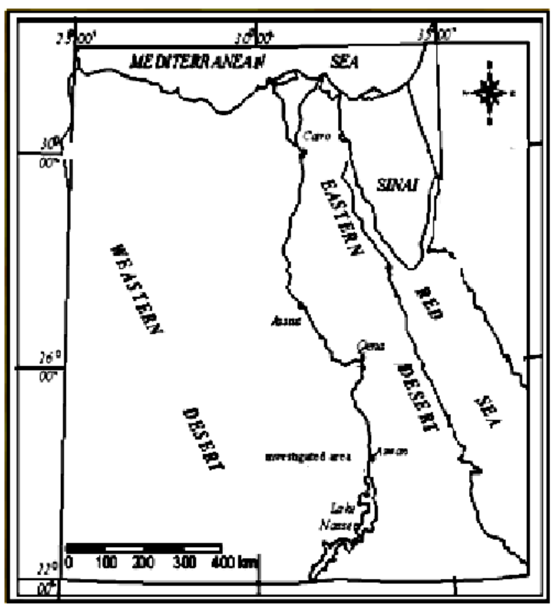

Figure 1. Map of Sampling location (Qena city)

2.2. Gamma Spectrometry

2.2.1. Instrumentation

Direct determination of radionuclides in vegetables and fruits samples without any chemical treatment was performed at the Institute for Radioecology and Radiation Protection (IRS), Hanover University, Germany, using a p-type HPGe coaxial detector (GEM 50198-P) of 35% relative efficiency, with a resolution of 1.78 keV at 1.332 MeV. It is shielded with 10 cm lead and 2 mm copper, and coupled to an 8192-channel analyzer (Harb 2008) [5].

2.2.2. Efficiency and Calibration

The counting efficiencies of the γ-ray peaks were measured by using QCY48 and QCY40 standard solutions (Physikalisch-Technische Bundesanstalt PTB Germany) and were determined using a certified standard solution containing ^{210}Pb, ^{57}Co, ^{60}Co, ^{85}Sr, ^{88}Y, ^{109}Cd, ^{113}Sn, ^{139}Ce, ^{137}Cs, and ^{241}Am. The geometry of the experimental samples was the same as that of the standard samples (Harb 2008) [5].

2.3. Measurements and Calculation

2.3.1. Calculation of Radionuclides

Following the spectrum analysis, counting rates for each detected photopeak and activity per mass unit for each of the detected nuclides are calculated. The specific activity (in Bq·kg^{-1}) is given by Harb 2004 [6]

$$A_{specific} = (N/t - N_0/t_0)/(I_\gamma \cdot \varepsilon \cdot m) \quad (1)$$

where N is the net counts of a given peak for a sample, t is 18 – 24 h is the counting time for the sample, N_0 is the background of the given peak, t_0 = 72 h is the counting time for background, ε is the detection efficiency, I_γ is the number of gamma photons per disintegration, and m is the mass in kg of the measured sample. If there is more than one peak in the energy analysis range for a nuclide, an average of the peak activities is made and the result is then the weighted average nuclide activity. Based on the measured γ-ray peaks, emitted by specific radionuclides in the ^{232}Th and ^{238}U decay series, and ^{40}K, their concentrations in the samples collected were determined.

Table 1. Dose convection factors C_r for different Radionuclids in Sv Bq^{-1} [8]

Radionuclides	Dose convection factors
^{226}Ra	2.25×10^{-7}
^{210}Pb	8.02×10^{-7}
^{232}Th	3.69×10^{-7}
^{40}K	5.9×10^{-9}

Table 2. The activity concentration of ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K (in Bqkg^{-1}) in some fresh vegetables and fruits and Annual effective dose µSvy^{-1}

No. Of samples	Code of samples	Name of samples	Ra-226	Pb-210	Th-232	K-40	consumption rates kg per year	Annual effective dose µSvy^{-1}
Vegetables								
1	Veg1	Tomato	ND	**0.03±0.06**	0.02±0.05	63.00±2.45	**4.2**	0.082
2	Veg2	Potatos	ND	0.07±0.05	0.06±0.06	121.68±4.57	**23.9**	17.525
3	Veg3	Carrot	0.29±0.15	ND	0.05±0.05	126.15±4.71	**3.7**	2.992
4	Veg4	eggplan	**0.01±0.02**	ND	0.05±0.05	60.62±2.37	**24**	8.601
5	Veg5	Zucchini	ND	0.14±0.08	0.04±0.06	136.91±4.67	**-**	
6	Veg7	watercress	**0.89±0.28**	ND	ND	305.04±13.03	**0.13**	0.259
7	Veg8	Lettuce	0.18±0.07	ND	ND	59.79±2.10	**0.63**	0.248
8	Veg9	Papper	0.01±0.02	0.07±0.09	0.07±0.07	52.31±2.21	**0.1**	0.033
9	Veg10	Cabbage	0.21±0.11	ND	0.24±0.73	76.77±3.07	**0.96**	0.481
10	Veg11	Cueumber	0.05±0.03	0.11±0.06	**0.01±0.03**	58.80±2.07	**-**	
11	Veg12	coriander leaves	2.56±1.11	ND	1.22±0.56	**536.6±23.03**	**-**	
12	Veg13	Okra	ND	0.16±0.13	0.23±0.11	115.6±4.55	**10.054**	7.224
13	Veg14	Onion	0.25±0.05	0.44±0.12	ND	79.7±2.81	**24.2**	15.102
14	Veg16	Jew's Mallow	0.04±0.03	0.04±0.03	0.02±0.03	**41.46±1.55**	**19.178**	5.015
Fruits								
15	Fr1	Apple	0.09±0.04	0.13±0.08	**0.01±0.05**	26.65±1.24	**6.9**	1.428
16	Fr2	Orang	**0.35±0.11**	0.22±0.11	0.04±0.05	64.62±2.32	**8.1**	4.134
17	Fr3	Apricot	0.06±0.09	ND	**0.24±0.17**	114.9±4.52	**-**	
18	Fr4	Banana	0.30±0.09	**0.39±0.21**	ND	**197.6±6.85**	**10.60**	14.005
19	Fr5	Cantalop	**0.03±0.02**	0.14±0.09	0.09±0.07	95.91±3.58	**-**	
20	Fr6	dates	ND	0.12±0.07	0.04±0.03	50.29±2.02	**14.7**	4.770
21	Fr7	Strawberry	0.05±0.04	**0.08±0.08**	0.02±0.05	52.59±2.10	**9.58**	3.246
22	Fr8	Figs	0.05±0.02	0.01±0.06	0.10±0.05	37.25±1.56	**0.685**	0.161

ND is not detected

Calculations relied on establishment of secular equilibrium in the samples, due to the much smaller lifetime of daughter radionuclides in the decay series of ^{232}Th and ^{238}U. The γ-rays of ^{212}Pb (238.63 keV), ^{208}Tl (583.2 keV) and ^{228}Ac (338.4, 911 and 969 keV) were used to determine the ^{232}Th concentration. The γ-rays of ^{234}Th, and the γ-rays of ^{214}Bi (609.3, 1120.3 and 1764.5 keV) and ^{214}Pb (295.2 and 351.9 keV), for ^{226}Ra. The 1461 keV gamma of ^{40}K was used to determine the concentration of ^{40}K in different samples and the 46.54keV gamma of ^{210}Pb was used to determine the concentration of ^{210}Pb.

The total uncertainty value (Table 2) is composed of the random and systematic errors in all the factors involved in producing the final nuclide concentration result [7].

2.3.2. Calculation of the Annual Effective Dose

Calculation of the annual effective dose due to the ingestion of foods was performed based on the metabolic model developed by the International Commission of Radiological Protection [8]. The effective dose (D_{rf}) from a radionuclide (r) in a foodstuff (f) can be determined by Nasreddine [9]

$$D_{rf} = C_r A_{rf} R_f \quad (2)$$

where D_{rf} is the effective dose by ingestion of the radionuclide (r, Sv y^{-1}), C_r is the effective dose conversion factor by ingestion of the nuclide (r) (i.e. the dose expressed in Sv resulting from the exposure to an activity concentration of 1 Bq of nuclide (r) via oral ingestion) table 1, A_{rf} is the activity concentration of the nuclide (r) in the ingested food (f, Bq kg^{-1} wet weight), and R is the consumption rate of the food item (f, kg y^{-1}) [10, 11]. In this study, the dose calculations are based on the assumption that the annual consumption described in Table 2.

For the total daily intake evaluation, the weighted average for each radionuclide in each vegetable category was calculated, and then multiplied by the respective consumption rate [12] (Table 1).

3. Results and Discussions

In total, 22 samples have been analysed (8 fruits and 14 vegetables).

From the table 2 we can see that the range of concentration are 0.01±0.02 to 2.56±1.11, 0.01±0.06 to 0.39±0.21, 0.01±0.05 to 1.22±0.56, and 26.65±1.24 to 536.6±23.03 ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K respectively. Since phosphate fertilizers may contain considerable levels of radionuclides from uranium, thorium series and ^{40}K, their use in order to increase yield can increase the radionuclide contents in vegetables and as consequence this may raise the internal dose to consumers due to food consumption. The objective of this research was to investigate the influence of fertilizers and agricultural management on ^{210}Pb, ^{226}Ra, ^{232}Th and ^{40}K contents in vegetables. The concentrations of radium and Thorium in the most commonly used Egyptian phosphate and organic fertilizers were determined as well as soil to plant transfer factors for lettuce and carrot [13, 9].

4. Conclusions

This study was described the dose rate intake of gamma-emitting radionuclides for the Upper Egyptian consumer. This studying showed that the activity concentration of the gamma-emitting radionuclide ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K in fruits and vegetables available on Qena City market were 0.01±0.02 to 2.56±1.11, 0.01±0.06 to 0.39±0.21, 0.01±0.05 to 1.22±0.56, and 26.65±1.24 to 536.6±23.03 Bqkg^{-1} respectively. The Range annual effective dose from dietary intake of ^{226}Ra, ^{210}Pb, ^{232}Th, and ^{40}K are estimated from 0.033 to 17.525 µSvy^{-1}.

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