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Full Length Research Paper

Measuring radioactivity level in various types of rice using hyper pure germanium (HPGe) detector

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The radioisotopes and nuclear explosions in upper layers of the atmosphere have vigorously polluted the earth. These radionuclides can be transferred to humans through the food chain. Rice is important and a major source of carbohydrates for humans. Soil contains the natural radionuclide such as Uranium, Thorium and Potassium. A study was conducted to determine the radionuclide content and their level of radioactivity in various types of rice eaten by the Malaysian. Six varieties of rice, Faiza Basmati, white glutinous, black glutinous, Siam, Kurnia and Utara were taken under consideration. Hyper Pure Germanium Detector (HYPe) was used to measure the radioactivity level. The average concentration of Uranium, Thorium and Potassium was found to be in the range of (18.33-25.10)±0.01 BqKg^{-1}, (35.49-64.97)±0.01 BqKg^{-1} and (64.802-109.929) ± 0.001 BqKg^{-1} respectively. Effective dose per annum was resided in the range of 0.02 μSv year^{-1} to 0.03 μSv year^{-1}.

Key words: Radioactivity, rice, uranium, thorium, potassium, Malaysia.

INTRODUCTION

Gamma radiation has always been existed in environment since the big bang occurred. During the last few decades radioisotopes and nuclear explosions in upper layers of the atmosphere contaminated and polluted the earth badly (Myasoedov and Pavlotskaya, 1989). The radioactive nuclides, produced due to those explosions, contaminated the entire environment. At surface layers of soil, these radioactive elements have higher level of concentration because their migration to down to the earth is limited. This exodus depends on the different chemical and physical conditions of the soil system (Quan et al. 2008; Jibiri and Emelue, 2008; Chibowski, 2000; Tsukada et al., 2002a,b; Uchida and Tagami, 2007; Shanthi et al., 2011). The plants absorb these radionuclide from soil with some others minerals during their growth. These dangerous isotopes enter to human beings as food. Most of the non-edible parts in these components are returned to the soil as organic fertilizer where they may again be utilized in the soil–plant pathway and/or are mixed with feed for livestock (Jibiri and Emelue, 2008; Tsukada et al., 2002a,b;). Most of the crops have a small number of the transfer factor (Lieser, 1995; Yanagisawa et al., 2000; Blanco et al., 2002). The critical paths of radionuclide and the critical foods in Japan are different from those in European and North American countries because agricultural products and food customs are different as well as different chemical and physical conditions of the soil system (Shigeo et al., 2007; Uchida and Tagami, 2007). Therefore, the results obtained from the studies of other countries only feasible for restricted areas and did not entertained Malaysian areas.

A large amount of the radiations soaked up by the human are coming from the natural sources. Natural radionuclides incorporate cosmogenic radionuclides such as ^{14}C and ^{3}H, primordial radionuclides, including affiliate nuclides of ^{238}U, ^{235}U, ^{232}Th-series and some independent nuclides such as ^{40}K and ^{87}Rb. Internal dose from these radionuclides depends on environmental conditions,

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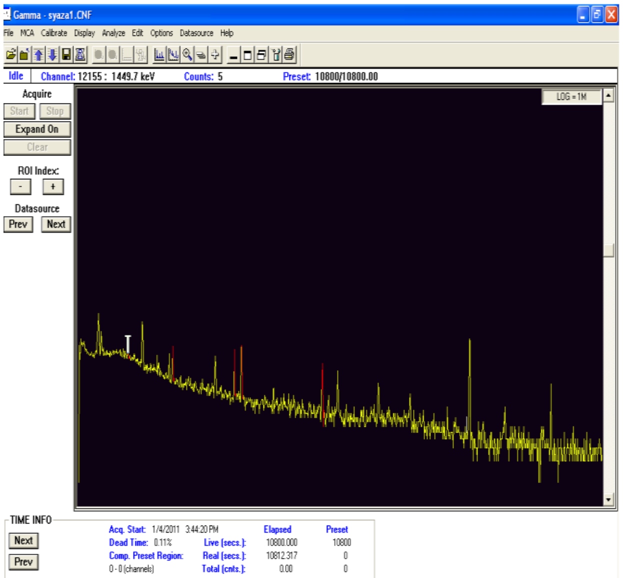

Figure 1. Gamma ray spectrum.

lifestyle and so on (Quan et al., 2008; Myasoedov and Pavlotskaya, 1989). The contamination level of the natural radioactivity in our environment has been under intensive investigation because of public concern of radiation- induced health hazard (Abu-Haija et al., 2010; Amakom and Jibiri, 2010; Mücella, 2010; Kinyua et al., 2011; Manigandan, 2009; Akkurt et al., 2010; Hatem, 2010).

Rice is the staple food of Asia, including Malaysian community. An average quantity of rice taken by an adult is about 100 g per day. The quantity is seen to be very small, but without realizing there are radionuclides present in the rice that can affect the body. Amount of radionuclides accumulated in the body can be known by measuring the concentration of radionuclide contained in the rice. Present study was conducted to measure and compare the concentration of uranium, thorium and potassium in the different samples of rice. The effective dose per annum contributed was also accounted as well.

MATERIALS AND METHODS

To determine the natural radioactivity of the sample using gamma ray spectrometry; the Hyper Pure Germanium (HPGe) detector (with relative efficiency 20% of the energy resolution at 1332.5 keV energy peak is 1.8 keV) was connected to a multi-channel analyzer (MCA). HPGe detectors was placed in the lead shield 47 cm thick, 10 coated with tin and copper with a thickness of each of 1 mm and 1.6 mm to reduce the effects of radiation emanating from the building and the cosmic. Gamma ray spectrometry system was calibrated using a mixture of radioactive sources ^{22}Na, ^{60}Co and ^{137}Cs. Activity concentration of ^{238}U, ^{232}Th and ^{40}K was respectively determined by the peak energy 609.4 keV (^{214}Bi) and 352.0 keV (^{214}Pb), 583.1 keV (^{208}Tl) and 911.1 keV (^{228}Ac) and 1460.3 keV (^{40}K).

In the detection of gamma rays, HPGe detector was chosen because it has a high cross section. Germanium has high atomic number and density. Hyper pure germanium detectors-semiconductor crystal detectors are used without any added impurity. It consists of a cylinder-shaped n type germanium crystal, touching on the outside and kind of touching on the surface of the p axis.

The concentration of uranium, thorium and potassium was measured for each variety of rice: white glutinous, black glutinous, Faiza Basmati, Kurnia, Utara and Siam. These genera of rice are originating from Pakistan, Thailand and Malaysia. The samples initially were blended. About 350gram of each sample was taken to carry out further procedure. The sample was set into a beaker; Marinelli, suited for Hyper Pure Germanium (HPGe) detector. It was designed to match the detector's hole. In order to get secular equilibrium, the samples were kept in the beaker for one month. Initially samples were laid in the HPGe detector, and then gamma spectrum was obtained as shown in Figure 1.

The activity of ^{214}Bi and ^{214}Pb was determined from its 609.3 keV and 351.9 keV gamma-ray peak respectively. The activity of ^{226}Ra (^{238}U) was then estimated. While the activity of the daughter radionuclide ^{208}Tl (determined from its 583.1 keV gamma-ray peak) and ^{228}Ac (determined from its 911.1 keV gamma-ray peak) were chosen as an indicator of ^{228}Th (^{232}Th). Potassium-40 was determined by measuring the 1460.8 keV gamma rays emitted during its decay (Jibiri and Emelue, 2008;).

RESULTS AND DISCUSSION

A range of experiments was taken under consideration to investigate the radionuclide contents and their level of radioactivity in various types of rice eaten by the Malaysian. The key upshots of the study are recapped here under this study.

Concentration of uranium, thorium and potassium

The results were evaluated and tabulized in Tables 1 and 2. The data plotted is shown in Figure 2, and 3. The concentration of U^{238}, Th^{232} and K^{40} for each sample was calculated by the using following arithmetic expression:

$$\frac{N_s}{N_P} = \frac{C_s}{C_p} \quad (1)$$

$$\text{concentration } (ppm)\ C_s = \frac{N_s}{N_p}\ C_p \quad (2)$$

Where C_s is concentration of sample, N_s is net activity sample, N_p is net activity standard and C_p represents the standard concentration (U^{238}, Th^{232} and K^{40}).

Results show that concentration of uranium was immense in white glutinous with a value 2.04 ± 0.11 ppm, while the deprived concentration was in the Siam with a value 1.49 ± 0.12 ppm. Outcomes depicted that the

Table 1. Average concentration of uranium, thorium and potassium in research samples.

No.	Sample	Average concentration of Uranium (ppm)	Average concentration of Thorium (ppm)	Average concentration of Potassium (ppm)
1	Utara	1.79 ± 0.12	10.99 ± 0.10	2838.30 ± 0.07
2	Black glutinous	1.67 ± 0.12	11.55 ± 0.10	2953.71 ± 0.07
3	Kurnia	1.76 ± 0.11	11.66 ± 0.10	2102.58 ± 0.07
4	Faiza Basmati	1.82 ± 0.11	9.78 ± 0.11	2254.05 ± 0.07
5	Siam	1.49 ± 0.12	8.80 ± 0.11	3566.81 ± 0.06
6	White glutinous	2.04 ± 0.11	16.11 ± 0.09	2845.51 ± 0.07

Table 2. Specific Activity, A_s for each sample in unit Bq kg^{-1}.

No.	Sample	Specific Activity, A_s (Bq kg^{-1})		
		^{238}U (A_U)	^{232}Th (A_{Th})	^{40}K (A_K)
1	Utara	22.02 ± 1.48	44.32 ± 0.40	87.476 ± 0.002
2	Black glutinous rice	20.55 ± 1.48	46.58± 0.40	91.033 ± 0.002
3	Kurnia	21.65 ± 1.35	47.02 ± 0.40	64.802 ± 0.002
4	Faiza Basmati	22.39 ± 1.35	39.44± 0.44	69.470 ± 0.002
5	Siam	18.33 ± 1.48	35.49 ± 0.44	109.929 ± 0.002
6	White glutinous rice	25.10 ± 1.35	64.97 ± 0.36	87.699 ± 0.002

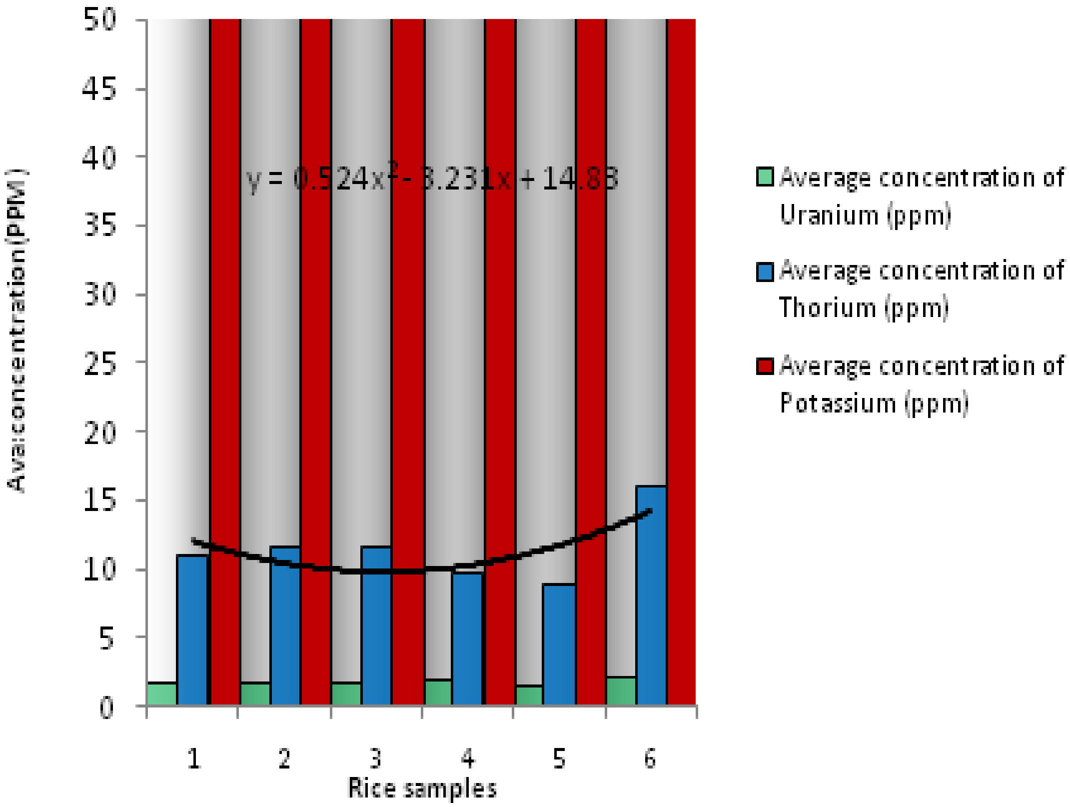

Figure 2. Average concentration of uranium, thorium and potassium in each sample.

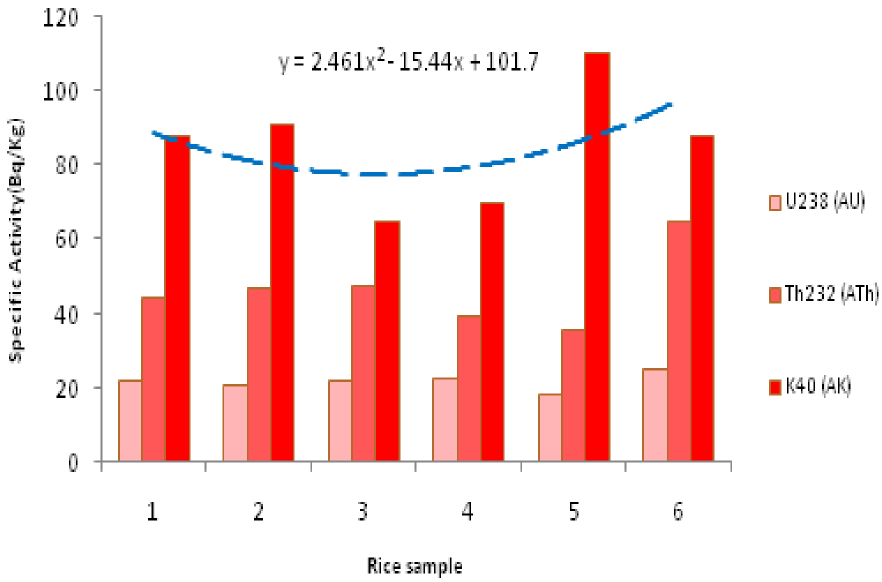

Figure 3. Specific Activity, A_s for each sample in unit Bq kg^{-1}.

Table 3. Effective dose per year (±0.01μSv year^{-1}).

No	Sample	Effective dose per year (± 0.01μSv year^{-1})			
		Uranium	Thorium	Potassium	Total
1	Utara	8.84 x 10^{-5}	6.96 x 10^{-4}	0.020	0.02
2	Black glutinous	8.25 x 10^{-5}	7.31 x 10^{-4}	0.021	0.02
3	Kurnia	8.69 x 10^{-5}	7.38 x 10^{-4}	0.015	0.02
4	Faiza Basmati	8.99 x 10^{-5}	6.19 x 10^{-4}	0.016	0.02
5	Siam	7.76 x 10^{-5}	5.57 x 10^{-4}	0.025	0.03
6	White glutinous	1.01 x 10^{-4}	1.02 x 10^{-3}	0.020	0.02

average concentration of Uranium was in the range of (18.33 to 25.10) ± 0.01 Bq-kg^{-1}. While the concentration of Thorium was (35.49 to 64.97) ± 0.01 Bq-Kg^{-1} and for Potassium this range was (64.802 to 109.929) ± 0.001 Bq-kg^{-1}.The thorium was elevated to white glutinous rice with concentration (16.11 ± 0.09) ppm, while the lowly concentration was for Siam rice with a rate (8.80±0.11) ppm. Both uranium and thorium have shown the highest value for white glutinous rice and the lowest value for Siam. The results depict that the concentration of Potassium was premier in the Siam rice, with a value (3566.81 ± 0.06) ppm, tag along the black glutinous with value (2953.71 ± 0.07) ppm, white glutinous with (2845.51 ± 0.07) ppm, Utara (2838.30 ± 0.07) ppm and Faiza Basmati with (2254.05 ± 0.07) ppm. Kurnia rice predicted a lowly concentration of Potassium with a value (2102.58 ± 0.07) ppm. All together the concentration varied like a parboiled trajectory.

Effective dose per year

The effective dose per year uptake rice was calculated by using the equation as given below;

$$D = A_s \, I \, E \quad (3)$$

Where D is effective dose for rice uptake, A_s is specific activity (Bq-kg^{-1}), I is total rice uptake in a year (assuming a person takes about 100 g rice per day) and E is the dose conversion factor for radionuclide.

Dose conversion factor 'E' depends on radioisotope in the samples and person's age (Siti Zahriah, 2010)). The effective dose per year contributed by each variety of rice was calculated by above formula and enumerated in Table 3.While in Figure 4 the effective dose per year is plotted against each variety of rice. It was revealed that the dose diverged from 0.02 μSv year^{-1} to 0.03 μSv year^{-1}.

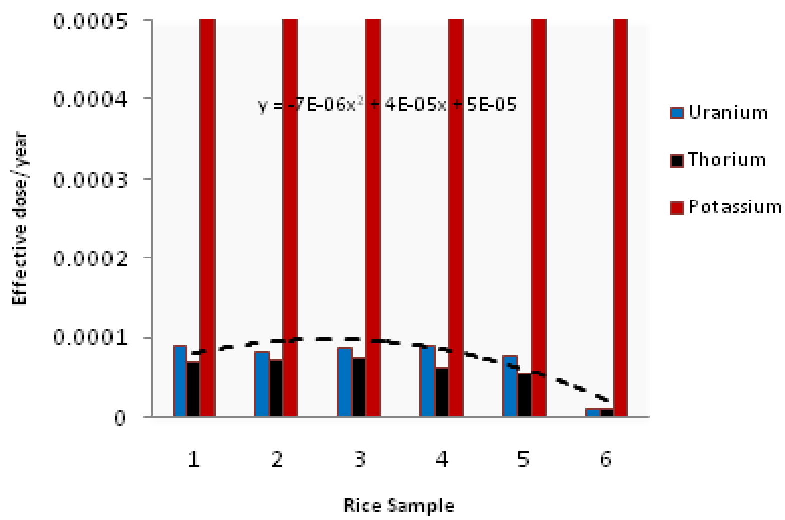

Figure 4. Effective dose per annum (±0.01μSv year^{-1}).

The polyfit curve gave a polynomial of second degree parabola. The maximum dose was contributed by saim with a value of 0.03 μSv year^{-1}.

Conclusion

The experimental results revealed that, the concentration of radionuclides in the diverse verities of the rice used in Malaysia was not an extant to mischief the life. The average concentration was in the range of 18.33 BqKg^{-1} to 25.10BqKg^{-1} for U^{238}, 35.49 BqKg^{-1} to 64.97 BqKg^{-1} for Th^{232} and 64.802 Bq-Kg^{-1} to 109.929 Bq-Kg^{-1} for K^{40}. The dose taken in was about 0.02μSv year^{-1} to 0.03μSv year^{-1} which is less than the International Atomic Energy Agency (IAEA, n.d,; UNSCEAR, 2006) recommended dose in take (1 mSv year^{-1}).

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