ISSN 1022-8594
JUJS

Vol. 41, No.1, pp.57-66

Measurement of ^{226}Ra, ^{232}Th and ^{40}K in Arum Grown on the Bank of Rupsha River, Khulna, Bangladesh Using HPGe Detector

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Abstract

The radioactivity level in the Arum samples have been analyzed by gamma-ray spectrometry system using a High Purity Germanium detector of 20% relative efficiency, collected from different locations on the Bank of Rupsha River at Rupsha upazilla in Khulna, Bangladesh. A total of 8 Arum samples have been collected from 8 locations of the area under investigation to identify the probable radionuclides, activity concentrations and the radiological risks to human from intake of Arum vegetables. Natural radionuclides such as ^{226}Ra, ^{232}Th and ^{40}K have been found in the samples and no artificial radionuclide has been detected in any of the sample. In Arum samples activity concentrations have been found to be varied from BDL to 8.78 ± 3.08, average 5.77 ± 2.97 Bq Kg^{-1}, BDL to 2.53 ± 4.32 Bq Kg^{-1} and 426.91 ± 107.23 to 1280.71 ± 133.89, average 758.298 ± 109.66 Bq Kg^{-1}. The annual effective dose of Arum samples has been found that intake high effective dose of ^{40}K of 454.90 µSv y^{-1}. The natural radioactivity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for all samples are higher than the worldwide average values. These values of doses are much below the permissible level, and, therefore, there is no immediate health risk on general public due to natural radioactivity present in the samples of the study area.

Keywords: Natural radionuclides, Arum, Activity concentrations, HPGe.

Introduction

Radiation is a part and parcel of our environment. There is no place or element in the universe without radiation. At the very beginning when there were no sign of lives in the universe, still was full of radiation [1]. Radiation and radioactivity are presence all the constituents of our environment such as soil, water, air, plants, wood, vegetables, food, fruits etc. all living and non living components [2]. Radiation is everywhere, but high level of radiation definitely harmful to human being [3]. Studies on radiation levels and radionuclide distribution in the environment provide vital radiological baseline information. Such information is essential in

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understanding human exposure from different sources of radiation. The present study is to determine the probable radionuclides, radioactivity concentration and annual effective dose in the agricultural crops i. e., Arum vegetables. The present work helps the determination of radiation dose received by the people from these crops to human food-chain.

Methodology

Arum samples have been collected from different parts on the Bank of Rupsha River at Rupsha Upazilla in Khulna City, Bangladesh. Using a GPS device geographical coordinates of sampling sites were recorded. The coordinates of the sampling sites of Rupsha river is in between 22°46′4.17′′N to 22°50′31.86′′N and 89°33′11.39′′E to 89°36′5.85′′E. A total of 8 Arum samples have been collected from in and around the Rupsha river located at Rupsha area, Khulna during the period of 30/04/2015 to 02/05/2015. Samples have been collected from equidistant locations with a distance of about 1 km from each other. The radionuclide contents and their activity levels of the each sample were measured using a calibrated HPGe detector of energy resolution of 2.0 KeV at 1.33 MeV of Cobalt-60 for a period of 10,000s at Health Physics, Atomic Energy Commission Saver, Dhaka. An error analysis of the data has also been performed. Moreover, based on the activity level and the annual intake of radionuclides through the consumption of these samples, the annual effective doses due to these radionuclides has also been estimated. The activity concentrations of each radionuclide in the sample was determined by using the count per second (cps) after subtracting the background counts from the gross counts for the same counting time under the selected photo peaks, weight of the sample, the photo-peak efficiency and the gamma intensity at a specific energy as [4].

$$A = \frac{cps}{E \times I \times W} \tag{1}$$

Where, A = Activity concentrations of the sample in Bq kg^{-1}

cps = The net counts per second = cps for the sample - cps for the background value

E = The counting efficiency of the gamma energy, I = Absolute intensity of the gamma ray and

W = Net weight of the sample (in kilogram).

The errors in the measurements were expressed in terms of standard deviation (± σ), where σ is expressed as [3]**:**

$$\sigma = \left[\frac{N_s}{T_s^2} + \frac{N_b}{T_b^2} \right]^{1/2} \tag{2}$$

Where, N_s is the sample counts measured in time T_s, and N_b is the background counts measured in time T_b. The standard deviation ± 2σ in cps was converted into activity in Bq kg^{-1} according to equation (01).

Annual Effective Dose (AED): The annual effective dose due to the intake of radionuclides from food and vegetables samples was calculated using the following equation (Ajayi and Owolabi, 2008):

$$\text{AED } (\mu\text{sv}) = \text{C} \times \text{I} \times \text{E} \times 10^6 \tag{3}$$

Where, C is the activity concentration of radionuclides in the collected samples (Bq kg^{-1}), I is the annual intake of food and vegetables, E is the ingested dose conversion factor for radionuclides (Sv Bq^{-1}) (ICRP, 1977).

The absorbed dose rate was converted into annual effective dose equivalent by using a conversion factor of 0.7 Sv Gy^{-1} recommended by the UNSCEAR 2000 and 0.2 for the outdoor occupancy factor by considering that the people on the average, spent 20% of their time in outdoors. The effective dose due to natural activity in the Arum samples was calculated by:

$$E\ (mSvyr^{-1}) = D \times 24 \times 365.25 \times 0.2 \times 0.7 \times 10^{-6} \tag{4}$$

The detector efficiency calibration curve as a function of energy for solid matrixes is shown in Figure 1. The energy calibration of the detector was performed by ^{137}Cs and Cobalt-60 point sources. Table 1 shows daughter radionuclides for Radiun and Thorium with their energy.

Results and Discussion

The activity concentration of all the daughter nuclides of ^{226}Ra & ^{232}Th series in Arum samples has been given in Table 2. It is seen that the concentration of ^{214}Pb, ^{214}B, ^{212}Pb, ^{208}Tl and ^{228}Ac has been found to be varied between BDL to11.12 ± 2.55 Bq kg^{-1}, BDL to 6.44 ± 3.6 Bq kg,$^{-1}$ BDL to 4.53 ± 1.21 Bq kg^{-1}, BDL to 5.19 ± 3.57 Bq kg^{-1} and BDL to 1.84 ± 8.36 Bq kg,$^{-1}$ respectively. On the other hand, the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in Arum samples has been found to be varied between BDL. to 8.78 ± 3.08 Bqkg^{-1}, BDL to 2.53 ± 4.32 Bqkg^{-1}, and 426.91 ± 107.23 Bq kg^{-1} to 1280.71 ± 133.89 Bq kg^{-1} respectively, with an average of 5.77 ± 2.97 Bq kg^{-1} of ^{226}Ra, maximum Arum samples have been found BDL for ^{232}Th and 758.298 ± 109.66 Bq kg^{-1} of ^{40}K The highest activity concentration of 1280.71 ± 133.89 Bq kg^{-1} for ^{40}K was found in Arum sample (sample ID Arum 2) collected from Khan Mohammadpur. The values of activity concentration in Arum samples are shown in Table 3. Annual intake of radionuclides in the Arum samples and estimated annual effective dose has been calculated (Table 4). Comparison of the present study with different parts of Bangladesh and the world for radionuclides in vegetables samples (Bq Kg^{-1}) have also been given in Table 5.

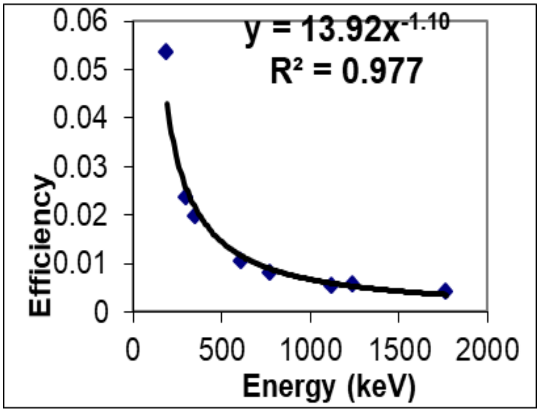


Figure 1: Efficiency curve

Table 1: Daughter radionuclides for ^{226}Ra and ^{232}Th with their energy

Principal radionuclide	Daughter product	Energy (KeV)	Intensity (yields)
^{226}Ra	^{214}Pb	295.18	0.1815
	^{214}Pb	351.92	0.351
	^{214}Bi	609.35	0.446
	^{214}Bi	1120.5	0.147
	^{214}Bi	1764.5	0.151
^{232}Th	^{214}Pb	238.76	0.435
	^{208}Tl	583.24	0.307
	^{228}Ac	911.32	0.266
	^{228}Ac	969.19	0.1623
	^{208}Tl	2613.2	0.356
^{40}K		1460.9	0.107

(a) (b) (c)

Picture 1: (a) Sampling Locations, (b) Arum sample grown on the Bank of Rupsha River and (c) Arum sample dry in sun shine

Picture 1 shows (a) Arum samples grown on the bank of Rupsha River, (b) drying process of Arum sample in sun shine and (c) Prepared samples. Figure 2 shows (a) Activity concentrations of daughters (^{214}Pb; ^{214}Bi) of ^{226}Ra, (b) Activity concentrations of daughters (^{212}Pb.^{208}Tl, ^{228}Ac) of ^{232}Th, (c) Activity concentrations of parents' nuclei ^{226}Ra, ^{232}Th and ^{40}K, (d) Variation of estimated Annual Effective Dose respectively. The activity concentration of ^{226} Ra in all sample of this area is higher than the other part of Bangladesh. According to a report by (UNSCER,2000) the total exposure per person resulting from ingestion of terrestrial radioisotopes should be 0.29 msv, of which 0.17 mSv is from ^{40}K and 0.12mSv is from thorium and uranium series. In the present study it shows that people intake high effective Dose of ^{40}K of 454.90 μSvy^{-1} by Arum samples. The effective dose of ^{40}K (0.45 mSv) is high than world safe value (0.29 msv) in Arum and and ^{232}Th (0.24 msv) is low World safe value. The natural radioactivity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for all samples is higher than the worldwide average values. So further study should be needed with more samples as well as radioactivity in soil and water of this area should also be analyzed.

Table 2: Activity concentrations of radioactive daughter elements of ^{226}Ra and ^{232}Th radioactive series in Arum samples under study. *BDL: Below Detection Level

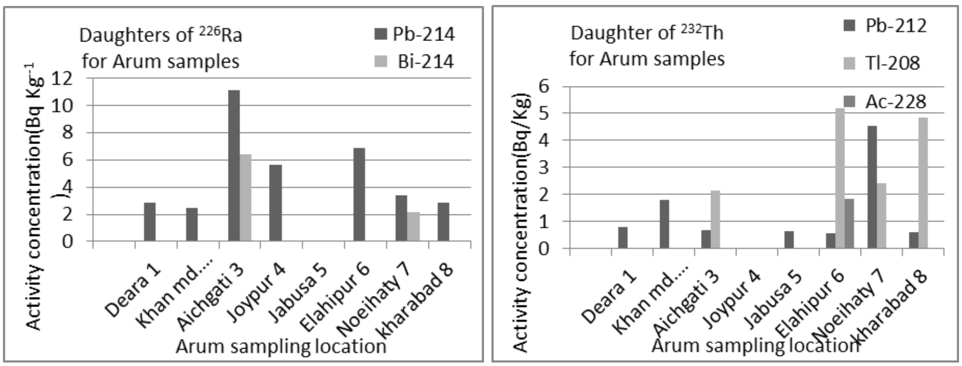
Sl No	**Sampling Location**	**Sample ID**	**Activity concentration (Bq kg^{-1})**				
			^{214}Pb	**^{214}Bi**	**^{212}Pb**	**^{208}Tl**	**^{228}Ac**
1	Deara	Arum 1	2.88 ± 2.95	BDL	0.79 ± 1.04	BDL	BDL
2	Khanmd.pur	Arum 2	2.47 ± 2.38	BDL	1.79 ± 1.2	BDL	BDL
3	Aichgati	Arum 3	11.12 ± 2.55	6.44 ± 3.6	0.69 ± .99	2.15 ± 1.25	BDL
4	Joypur	Arum 4	5.662.21	BDL	BDL	BDL	BDL
5	Jabusa	Arum 5	BDL	BDL	0.66 ± .96	BDL	BDL
6	Elahipur	Arum 6	6.84 ± 2.4	BDL	0.56 ± 1.03	5.19 ± 3.57	1.84 ± 8.36
7	Noeihati	Arum 7	3.37 ± 2.17	2.15 ± 3.56	4.53 ± 1.21	2.43 ± 3.39	BDL
8	Kharabad	Arum 8	2.85 ± 1.92	BDL	0.62 ± .9	4.85 ± 3.11	BDL
Maximum			**11.12 ± 2.55**	**6.44 ± 3.6**	**4.53 ± 1.21**	**5.19 ± 3.57**	**1.84 ± 8.36**
Minimum			**BDL**	**BDL**	**BDL**	**BDL**	**BDL**
Average			**5.03 ± 2.26**	**4.29 ± 3.58**	**1.38 ± 1.05**	**3.66 ± 2.83**	**1.84 ± 8.36**

Table 3: Activity concentration of radionuclei ^{226}Ra, ^{232}Th and $^{-40}$K in Arum Samples

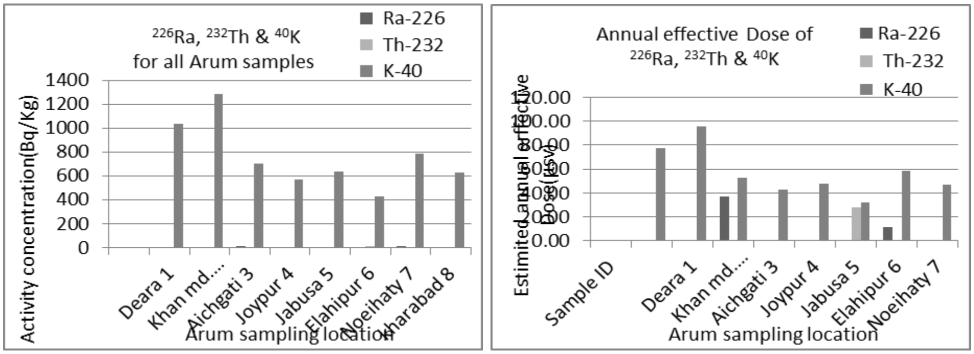
SI NO.	Sampling Location	Sample ID	Activity concentration (Bq kg^{-1})		
			^{226}Ra,	**^{232}Th**	**^{40}K**
1	Deara	Arum 1	BDL	BDL	1034.32 ± 115.53
2	Khan md.pur	Arum 2	BDL	BDL	1280.71 ± 133.89
3	Aichgati	Arum 3	8.78 ± 3.08	BDL	701.79 ± 106.97
4	Joypur	Arum 4	BDL	BDL	571.75 ± 102.71
5	Jabusa	Arum 5	BDL	BDL	638.94 ± 102.52
6	Elahipur	Arum 6	BDL	2.53 ± 4.32	426.91 ± 107.23
7	Noeihati	Arum 7	2.76 ± 2.9	BDL	783.99 ± 111.77
8	Kharabad	Arum 8	BDL	BDL	627.97 ± 96.68
Maximum			**8.78 ± 3.08**	**2.53 ± 4.32**	**1280.71 ± 133.89**
Minimum			**BDL**	**BDL**	**426.91 ± 107.23**
Average			**5.77 ± 2.97**	**-**	**758.298 ± 109.66**

Table 4: Annual intake of radionuclides and estimated annual effective Dose

Sl No	Sampling Location	Sample ID	Annual Intake (usv)			Annual effective dose (usv)		
			^{226}Ra	**^{232}Th**	**^{40}K**	**^{226}Ra**	**^{232}Th**	**^{40}K**
1	Deara	Arum 1	-	-	15514.80	-	-	77.57
2	Khan d.pur	Arum 2	-	-	19210.65	-	-	96.05
3	Aichgati	Arum 3	131.70	-	10526.85	36.88	-	52.63
4	Joypur	Arum 4	-	-	8576.25	-	-	42.88
5	Jabusa	Arum 5	-	-	9584.10	-	-	47.92
6	Elahipur	Arum 6	-	37.95	6403.65	-	28.08	32.02
7	Noeihati	Arum 7	41.40	-	11759.85	11.59	-	58.80
8	Kharabad	Arum 8	-	-	9419.55	-	-	47.10



(a) (b)



(c) (d)

Figure. 2: (a) Activity concentrations of daughters (^{214}Pb; ^{214}Bi) of ^{226}Ra, (b) Activity concentrations of daughters (^{212}Pb. ^{208}Ti, ^{228}Ac) of ^{232}Th, (c) Activity concentrations of parents' nuclei ^{226}Ra, ^{232}Th and ^{40}K (d) Variation of estimated annual effective dose

Table 5: Comparison of the present study with different parts of Bangladesh and the world for radio nuclides in vegetables samples (Bq Kg^{-1}).

Region	**Samples name**	**Radio-nuclides (Bq Kg^{-1})**			**References**
		^{226}Ra	**^{232}Th**	**^{40}K**	
Jamalpur, Bangladesh	Ladies finger	_	8 - 248	1274 - 4860	[6]
Kustia, Bangladesh	Redamaranth	_	5.5 - 23	870 - 1231	
Tangail, Bangladesh	Redamaranth	_	9 – 23.6	1109 - 1383	
Jessore, Bangladesh	Redamaranth	_	4 - 19	204 - 366	
Savar, Bangladesh	Rice	2.86 – 26.61	1.93 – 42.63	307 - 498	[7]
Bangladesh, Cox's Bazar	vegetables	80.95	83.53	1691.45	[8]
Malaysia	vegetables	17.5	65.2	446	[9]
Nigeria	vegetables	83.5	-	684.5	[10]
Iran	vegetables	67	0.5	91.73	[11]
China	vegetables	0.32	-	111	[12]
World average value	Vegetables/ Fruits	0.03	0.0005	-	[5]
Khulna Bangladesh	Papaya	13.29-77.96	0 -26.2	1112.65-1712.47	[13]
Khulna Bangladesh	Arum	O – 8.78	0 – 2.53	426.91-1280.71	Present study

Conclusions

The results have been indicated that only the natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) are present in the samples and no artificial radionuclide has been detected in the samples. The natural radioactivity concentrations and annul effective dose of ^{226}Ra, ^{232}Th and ^{40}K for all sample are higher than the worldwide average values. The estimated annual effective dose found in this study for an adult individual in Bangladesh is relatively higher than that of the world average value. However, these values of doses are much below the permissible level set by International Commission Radiological Protection [14], and, therefore, there is no immediate health risk on general public due to natural radioactivity present in the samples of the study area. The investigation conducted under the current study is very important concerning the radiological safety of the public and the environment in these areas. This study also provides current exposure level and base-line database for the development of future guidelines in the country.

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