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Measurement of Natural and Artificial Radioactivity in Soil at Some Selected Thanas around the TRIGA Mark-II Research Reactor at AERE, Savar, Dhaka

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ABSTRACT

The activity concentration of natural and fallout radionuclides in the soil at some selected Thanas around the TRIGA Mark-II Research Reactor at Atomic Energy Research Establishment (*AERE*), *Savar, Dhaka were measured by using a high purity germanium detector* (*HPGe*). *The study revealed that only natural radionuclides were present in the samples and no trace of any artificial radionuclide was found. The average activity concentration of* ^{238}U, ^{232}Th *and* ^{40}K *were found to be* 37.8 ± 5.6 $Bq{\cdot}kg^{-1}$, 58.2 ± 11.0 $Bq{\cdot}kg^{-1}$ *and* 790.8 ± 153.4 $Bq{\cdot}kg^{-1}$ *respectively. The radium equivalent activity* (R_{eq}), *absorbed dose rate* (*D*), *external radiation hazard index* (H_{ex}) *and internal radiation hazard index* (H_{in}) *were also calculated to find out the probable radiological hazard of the natural radioactivity.*

Keywords: *Natural Radionuclide, Artificial Radionuclide, HPGe Detector, TRIGA Mark-II Research Reactor, Activity Concentration*

1. Introduction

Radioactivity may be natural and artificial. Natural radioactivity occurs due to extraterrestrial sources as well as from radioactive elements in the earth's crust. Significant amount of artificial (man-made) radioactivity is emitted by nuclear power plant, industrial plant and research facilities. A large amount of radiation releases due to accident of nuclear reactor.

Most widely spread natural radionuclides are from the family of Uranium (^{238}U), Thorium (^{232}Th), Actinium (^{235}Ac) and Kalium (^{40}K). Significant amount of man-made radionuclides ^{137}Cs and ^{90}Sr may also present in soil as a result of nuclear weapon testing in the atmosphere, accidents (such as the Chernobyl power plant accident) and the routine discharge of radionuclides from nuclear installations [1]. ^{137}Cs dominates among durable artificial gamma radiators. It takes 300 year for it to fragment completely. Due to that it migrates in various geospheres and biological links. The biggest part of ^{137}Cs is accumulated in the upper layer of the soil and forest floor [2].

The TRIGA Mark-II Research Reactor of AERE is located at Savar of Dhaka District is a light-water-cooled graphite reflected reactor designed for continuous operation at a steady-state power level of 3 MW. A significant amount of low-level of solid, liquid and gaseous radioactive wastes are being generated from operation and maintenance of 3 MW TRIGA Mark-II Research Reactor. Radiation may release from these waste. These radioactive substance precipitated on the earth surface are either lifted again by the wind or penetrate into the ground. The radioactive substances are absorbed by plant through their roots and finally reach human body [2].

The aim of this study is to detect the natural (^{238}U, ^{232}Th and ^{40}K) and probable artificial radionuclide (^{137}Cs) and to determine their activity level in the soil at Some Selected Thanas around the TRIGA Mark-II Research Reactor at AERE, Savar, Dhaka.

2. Methods and Analysis

2.1. Sample Collections and Preparation

Eighteen soil samples were collected from the four Thanas (Dhamrai, Ashulia, Savar and Singair) around the TRIGA Mark -II Research Reactor, AERE, Savar, Dhaka. Each sample was collected maintaining a distance of about 1 km to 5 km from each other. The soil samples were collected at the depth of 5 cm with respect to the surface. About 1 kg of sample was collected from each location and each of the samples was placed in plastic packet and transported to the laboratory. All the samples were collected during the period of 25 October to 16 December in 2008. Each sample was segregated for stone and grass and then dried at about 110˚C in an oven for 24 hours. The samples were then ground into fine powder with a grinder and collected after passing through a 10-mesh screen. Thus, homogenized sample was transferred to sealable cylindrical plastic container of 7 cm height and 5.5 cm in diameter, marked individually with identification parameters. The net weights of all the samples were noted. All the sample containers were then sealed tightly with cap and wrapped with Teflon and thick vinyl tapes around their screw necks and finally air tightened with polythene pack and stored for minimum four weeks prior to counting, allowing establishment of secular equilibrium between the long lived ^{238}U, ^{232}Th and their decay products. **Figures 1**, **2** and **3** show the sampling loca-

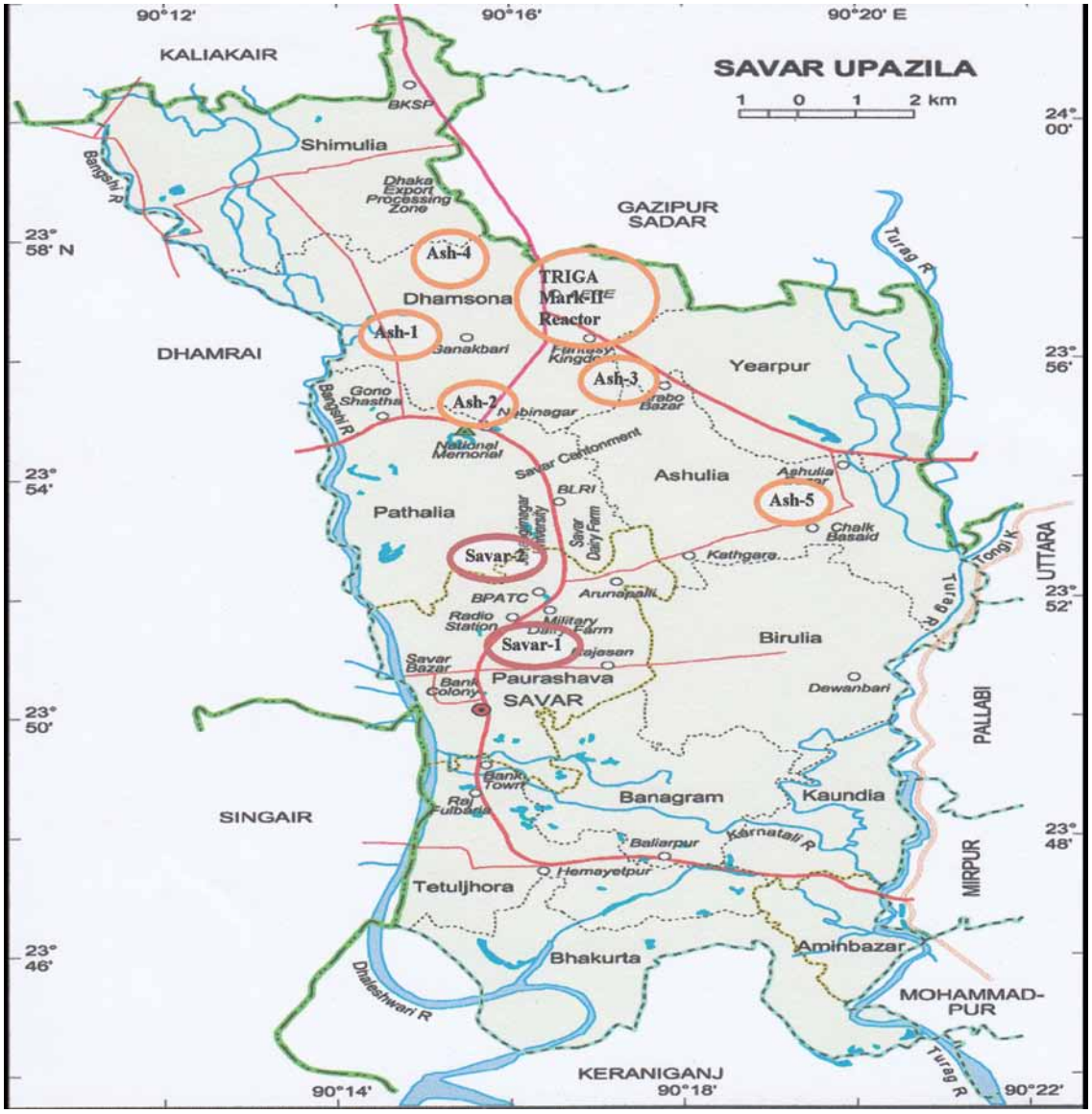

Figure 1. Map showing the different locations of sample collection in Savar and Ashulia Thana.

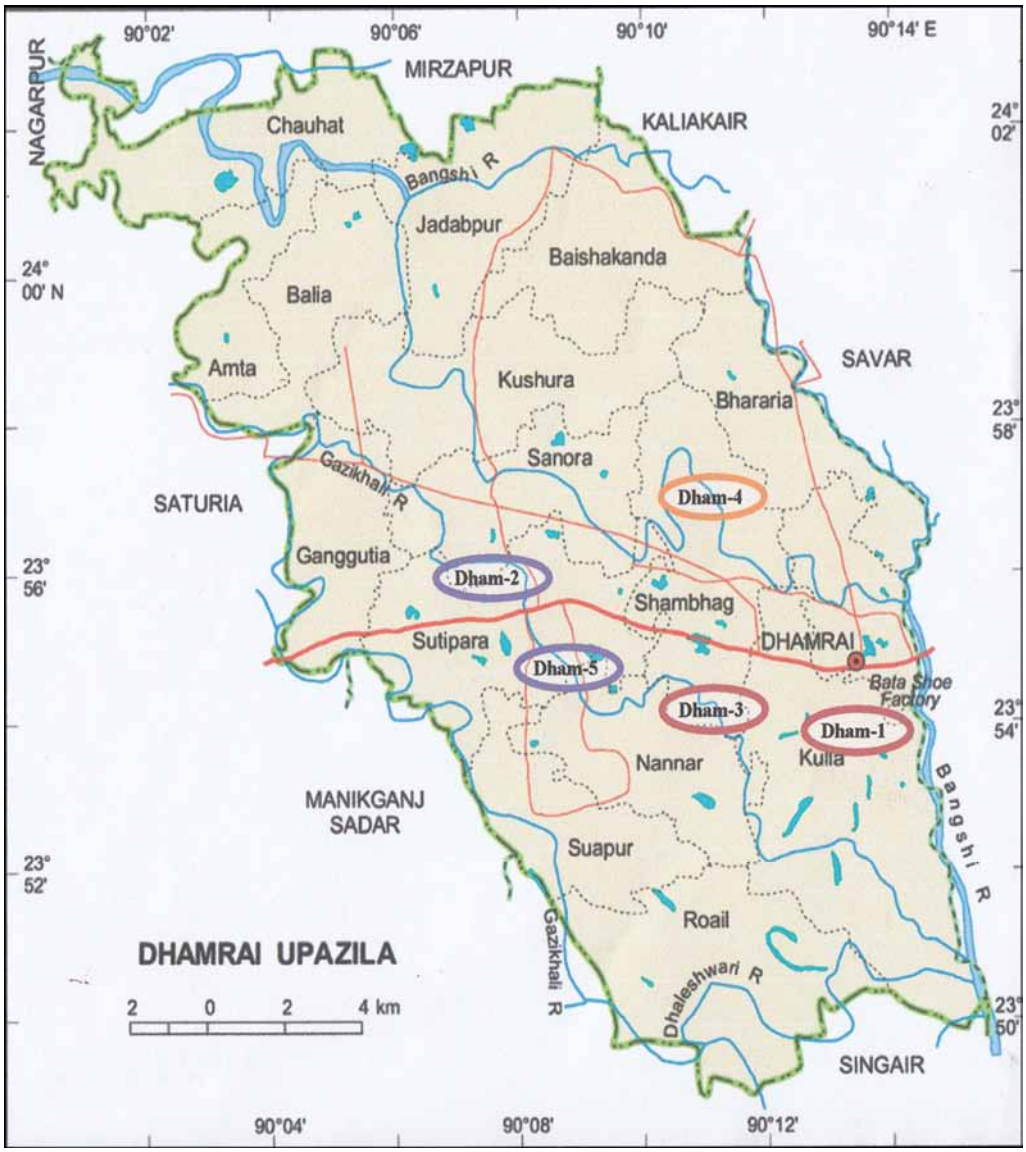

Figure 2. Map showing the different locations of sample collection in Dhamrai Thana.

tions.

2.2. Data Collection and Analysis

Each of the prepared samples and standard (Al_2O_3 based ^{226}Ra) were placed on the top of the HPGe detector within the shielding arrangement and counted for 10,000 seconds. The software of the HPGe detecting system provides the corresponding gamma spectra collected for both samples and standards. Gamma ray spectrometry can be used to identify gamma ray energies and consequently the radioactive species which are producing them. The area under the peak in a gamma ray spectrum represents the number of counts collected for only that gamma ray energy. These peak areas were used for determination of radioactivity concentration of the radionuclides present in the sample. The net count of the sample is obtained by subtracting a linear background distribution of the pulse height spectra from the corresponding peak energy area. From the net counts of the samples activity concentration of the radionuclides were calculated using the formula

$$A = \frac{CPS \times 1000}{\varepsilon(abs) \times I_r(abs) \times W} \quad (1)$$

where, A is the activity concentration in $Bq \cdot kg^{-1}$, CPS is the net peak counts per second of the samples, W is the weight of the sample in gm, ε(abs) is the absolute gamma peak detection efficiency, $I_r(abs)$ is the absolute gam-

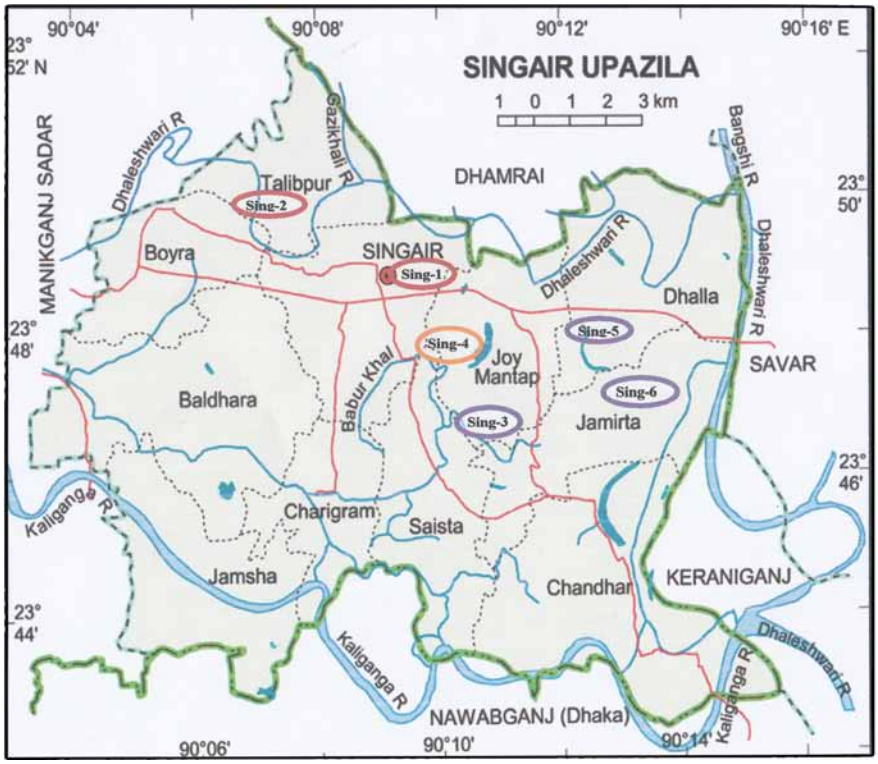

Figure 3. Map showing the different locations of sample collection in Singair Thana.

ma intensity of the corresponding gamma ray energy. Gamma rays intensities were taken from the literature [3]. The peak detection efficiencies were calculated from the full energy peak detection efficiency curve plotted using Al_2O_3 based ^{226}Ra standard as shown **Figure 4**. The error in the measurement have been expressed in terms of standard deviation ($\pm 2\sigma$), where σ is expressed as,

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

where N_s is the counts measured in time T_s and N_b is the background counts measured in time T_b. The standard deviation $\pm 2\sigma$ in CPS was converted into activity concentration in Bq·kg^{-1} according to Equation (1).

To determine the activity concentration, the γ-ray line

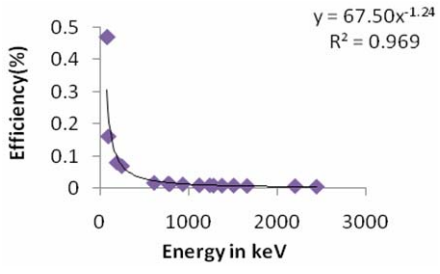

Figure 4. Efficiency curve of HPGe detector.

of 351.92 keV (^{214}Pb) and 609.31 keV (^{214}Bi) were used to determine ^{238}U. The γ-ray line of 911.07 keV (^{228}Ac) and 583.19 keV (^{208}Tl) were used to determine ^{232}Th. The γ-ray line of 1460.75 keV was used to determine ^{40}K and 661.31 keV were used to determine ^{137}Cs.

The radium equivalent activity (R_{eq}) in Bq·kg^{-1} was calculated to compare the specific activity of the material containing different amount ^{238}U, ^{232}Th and ^{40}K using the following relation given in [4]:

$$Ra_{eq} = \left[C_{Ra} + 1.43C_{Th} + 0.07C_k\right] Bq \cdot kg^{-1} \quad (3)$$

where C_{Ra}, C_{Th} and C_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively.

The γ-ray absorbed dose rate (D) in nGyh^{-1} in air due to the natural radionuclides ^{238}U, ^{232}Th and ^{40}K was calculated using the formula as reported in [1]:

$$D = \left[0.42C_{Ra} + 0.662C_{Th} + 0.0432C_K\right] \quad (4)$$

where C_{Ra}, C_{Th} and C_K have the same meaning as Equation (3).

The soil is used for making earthen huts and bricks have the external radiation hazard index (H_{ex}) and internal radiation hazard index (H_{in}). The H_{ex} and H_{in} were calculated using the formula as given in [1].

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \le 1 \quad (5)$$

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (6)$$

where C_{Ra}, C_{Th} and C_K have the same meaning as Equation (3).

3. Results and Discussion

The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K were measured by using a HPGe detector. The activity concentration of ^{238}U ranged from 25.5 ± 5.4 to 64.4 ± 6 with an average value of 37.8 ± 5.6 Bq·kg^{-1}. The activity concentration of ^{232}Th ranged from 40.8 ± 10.1 to 77.4 ± 11.2 with an average value of 58.2 ± 11.0 Bq·kg^{-1}. The activity concentration of ^{40}K ranged from 425.1 ± 156.1 to 974.8 ± 156.4 with an average value of 790.8 ± 153.4 Bq·kg^{-1}. Mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K, Radium equivalent activity (R_{eq}), dose rate (D), external radiation hazard (H_{ex}), internal radiation hazard (H_{in}) and range and mean values of activity concentration are shown in the **Table 1** and **Table 2**, respectively. The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K are shown graphically in the **Figures 5-7**, respectively.

The results of the present study showed that the activity concentration of thorium is 1.5 times higher than that of uranium. It is also observed that the activity concentration of ^{40}K is 13.5 times higher than that of thorium and 20.9 times higher than that of uranium. The excessive usage of Potassium containing fertilizers (NPKS, MOP etc.) in the area adjacent to the sampling sites may contribute to the higher value of ^{40}K activity [1].

A comparative study was also performed for the activity concentrations in the present work with the other studies performed in home and aboard and is shown in the **Table 3**.

The activity concentrations of the radionuclides in the soil samples of four Thanas around the TRIGA Mark-II research reactor in Bangladesh are within the range of values reported in the other work performed in home and abroad.

Since no ^{137}Cs radionuclide was detected in any of the soil samples, it indicates that there is no fission product

Table 1. Mean activity concentration of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in Bq·kg^{-1}, the radium equivalent activity (R_{eq}), absorbed dose rate (D), external hazard index (H_{ex}) and internal hazard index (H_{in}) in soil samples

Sam. ID	Activity concentration in Bq·kg^{-1}				R_{eq} in Bq·kg^{-1}	Dose rate in nGy·h^{-1}	H_{ex}	H_{in}
	^{238}U	^{232}Th	^{40}K	^{137}Cs				
Soil of Dhamrai Thana								
Dham-1	64.4 ± 6.0	67.3 ± 10.8	974.8 ± 156.4	ND	228.8 ± 32.3	114 ± 16.3	0.62 ± .08	0.8 ± 0.10
Dham-2	40.4 ± 5.8	62.7 ± 10.8	950.6 ± 157.5	ND	196.5 ± 32.2	99.7 ± 16.3	0.54 ± 0.08	0.65 ± 0.10
Dham-3	48.9 ± 5.7	72.7 ± 10.7	934.6 ± 153.9	ND	218.2 ± 31.7	109.2 ± 16	**0.47 ± 0.08**	0.73 ± 0.10
Dham-4	40.4 ± 5.2	49.0 ± 9.6	880.0 ± 143.0	ND	172.0 ± 28.9	87.6 ± 14.6	0.48 ± 0.08	0.58 ± 0.07
Dham-5	38.8 ± 5.9	49.3 ± 10.9	863.5 ± 162.2	ND	169.6 ± 32.7	86.4 ± 16.7	0.47 ± 0.09	**0.37 ± 0.10**
Soil of Ashulia Thana								
Ash-1	39.8 ± 5.4	68.5 ± 10.4	610.8 ± 146.9	ND	**180.51 ± 30**4	88.5 ± 15.4	0.49 ± 0.08	0.6 ± 0.09
Ash-2	31.1 ± 5.5	60.8 ± 10.7	646.6 ± 154.0	ND	163.2 ± 31.5	81.3 ± 15.9	0.45 ± 0.08	0.53 ± 0.1
Ash-3	27.4 ± 5.4	58.0 ± 9.9	694.5 ± 143.4	ND	158.9 ± 29.5	79.9 ± 14.9	0.44 ± 0.08	0.51 ± 0.09
Ash-4	29.7 ± 5.0	47.5 ± 18.5	639.7 ± 138.8	ND	142.3 ± 41.1	71.6 ± 20.2	0.395 ± 0.1	0.47 ± 0.12
Ash-5	41.4 ± 5.9	66.7 ± 11.2	586.6 ± 159.8	ND	177.7 ± 33	87.0 ± 16.8	**0.38 ± 0.09**	0.59 ± 0.1
Soil of Savar Thana								
Savar-1	45.3 ± 5.7	73.4 ± 10.7	579.4 ± 151.1	ND	190.7 ± 31.5	92.8 ± 15.9	0.52 ± 0.08	0.64 ± 0.1
Savar-2	39.3 ± 5.8	77.4 ± 11.2	425.1 ± 156.1	ND	179.6 ± 32.7	86.2 ± 20.3	0.49 ± 0.09	0.59 ± 0.1
Soil of Singair Thana								
Sing-1	39.2 ± 6.1	57.6 ± 11.5	966.6 ± 169.1	ND	189.1 ± 34.3	96.5 ± 17.5	0.52 ± 0.09	0.63 ± 0.11
Sing-2	33.4 ± 5.4	41.9 ± 10.0	958.0 ± 150.0	ND	160.3 ± 30.2	83.2 ± 15.3	0.45 ± 0.08	0.53 ± 0.09
Sing-3	28.1 ± 5.3	41.0 ± 10.0	856.4 ± 150.8	ND	146.6 ± 30.1	75.9 ± 15.3	0.41 ± 0.08	0.48 ± 0.09
Sing-4	34.6 ± 5.3	53.0 ± 10.0	844.9 ± 146.7	ND	169.4 ± 29.8	86.1 ± 15.1	0.47 ± 0.08	0.56 ± 0.09
Sing-5	33.3 ± 5.9	61.3 ± 11.5	972.8 ± 167.8	ND	188.9 ± 34	96.7 ± 17.3	0.52 ± 0.09	0.61 ± 0.10
Sing-6	25.5 ± 5.4	40.8 ± 10.1	849.4 ± 154.9	ND	143.2 ± 30.6	74.4 ± 15.6	0.40 ± 0.08	0.47 ± 0.09

ND: Not Detected.

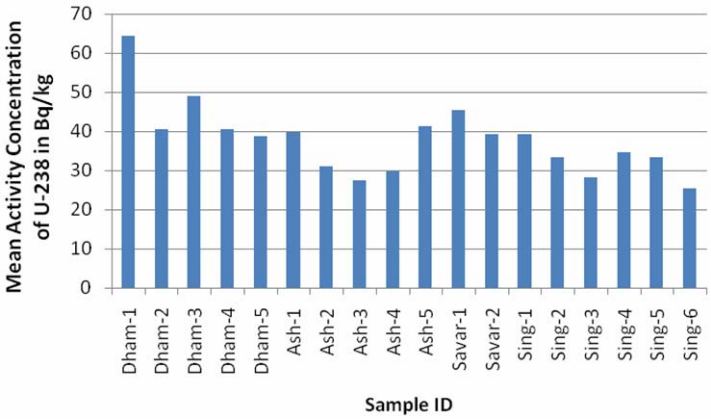

Figure 5. Mean activity concentration of ^{238}U in Bq·kg^{-1} in the collected soil samples.

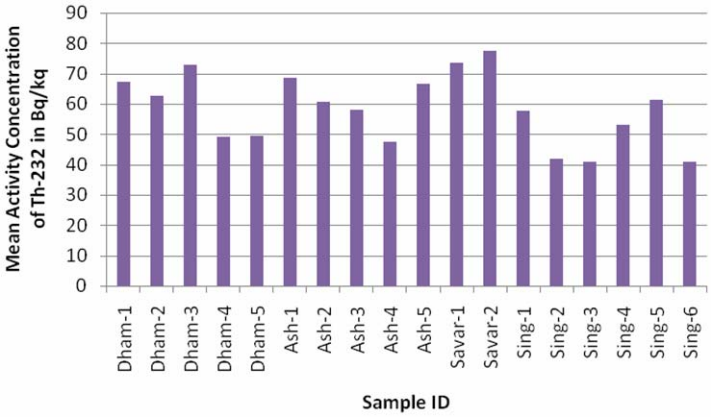

Figure 6. Mean activity concentration of ^{232}Th in Bq·kg^{-1} in the collected soil samples.

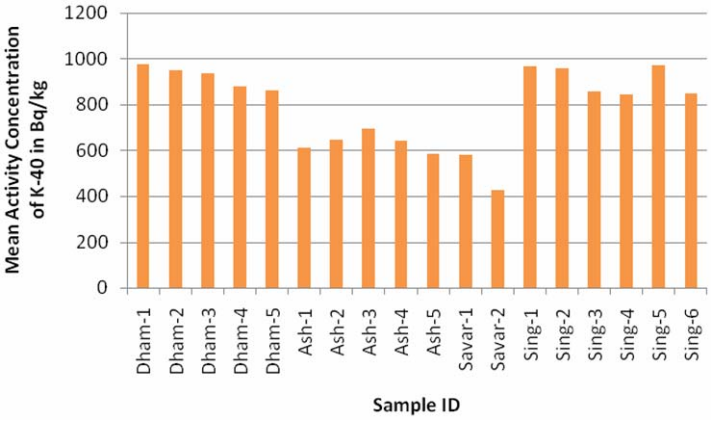

Figure 7. Mean activity concentration of ^{40}K in Bq·kg^{-1} in the collected soil samples.

spread due to the operation of the TRIGA Mark-II research reactor or due to any other nuclear sources elsewhere.

4. Conclusions

The Savar region is one of the most populated regions in the country and socio-economic condition of this area is improving day by day due to industrial development. The country's only Research Reactor is established in this area. The use of the reactor and the accidental release of radionuclide may greatly modify the natural radiation environment. The activity concentrations of the radionu-

Table 2. Range and mean value of activity concentrations of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in Bq·kg^{-1} of the samples.

Radionuclide	Minimum	Maximum	Mean
^{238}U	25.5 ± 5.4	64.4 ± 6	37.8 ± 5.6
^{232}Th	40.8 ± 10.1	77.4 ± 11.2	58.2 ± 11.0
^{40}K	425.1 ± 156.1	974.8 ± 156.4	790.8 ± 153.4
^{137}Cs	ND	ND	ND

Table 3. Comparison of the present study with other work.

Location	^{226}Ra	^{232}Th	^{40}K	References
Around TRIGA Mark-II (Bangladesh)	**37.8 ± 5.6**	**58.2 ± 11.0**	**790.8 ± 153.4**	**Present Study**
Louisiana (Soil), USA	43 - 95	50 - 190	43 - 729	[5]
Irakia (sand), Greece	212 (24 - 765)	43 (18 - 66)	1130 (464 - 2464)	[6]
Nile Delta, Egypt	17	-	316	[7]
Jessore, Bangladesh	48 ± 9	53 ± 9	481 ± 78	[1]
Nigeria	8.3 ± 2.6	34.3 ± 3.4	684 ± 7.3	[8]
Chittagong, Bangladesh	34.6	60	438	[9]
Peshwar, Pakistan	65	84	646	[10]

clides in the soil samples are in the range of the values reported in other countries, but the activity levels are slightly higher than the permissible activity levels which are in general 41.0, 52.2 and 230 Bq·kg^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively [11]. Further, the results of the present study would be useful as a base line data of the regions under study and also help as a guideline for the competent authority (Bangladesh Atomic Energy Commission) to go forward to fix up the dose limit for the radiation protection activities of the country and in the academic activities of the health physics, geophysics and environmental science.

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