Distribution and Comparison of Natural and Anthropogenic Radionuclides in Sediment Below and at Surface level in Charfassion Island, Bhola, Bangladesh

Q. M. R. Nizam[1]*, G .M.Ginnah[1], M M Rahman[1], N. M. Eman[1], M Kamal[2] and M I Chowdhury[2]

[1]*Lecturer*
Department of Physics
University of Chittagong
Chittagong-4331, Bangladesh

[2]*Chief Scientific Officer*
Radioactivity Testing and Monitoring Laboratory
Bangladesh Atomic Energy Commission
CMCH Campus, Chittagong, Bangladesh

ABSTRACT- ***In order to assess the activity concentration of natural and anthropogenic radionuclides in the Charfassion Island, Bhola, Bangladesh, the lower level sediment samples were analyzed by using Broad Energy Germanium (BEGe) detector. Average activity concentrations of ^{238}U, ^{232}Th and ^{40}K were found 19.34±4.37 BqKg^{-1}, 31.14±5.58 BqKg^{-1} and 767.96±27.71 BqKg^{-1}. These results were used to calculate the radiation hazard parameters like radium equivalent activities (Raeq), representative level index (Iγr) and compare mobility of natural radionuclides through the sediment. It has been found that ^{238}U and ^{40}K has a little bit higher mobility than the ^{232}Th. Due to natural radionuclides in sediment, the effective annual outdoor dose in the study area is 0.07 mSv; which is within the accepted range 0.07 mSv and representative level index (Iγr) is also found to be 0.95 BqKg^{-1}. The findings from this research work would be useful to evaluate the population exposure from radionuclides in this island.***

Keywords: Charfassion island, natural radioactivity, gamma spectrometry, BEGe detector, absorbed dose rate, effective annual dose rate.

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1. INTRODUCTION

The present trend of environmental radioactivity study has come forward to save human life from the effects of nuclear radiation originating from naturally occurring radionuclides and anthropogenic radionuclides. Natural radioactivity is mainly due to the presence of primordial radionuclides such as ^{232}Th , ^{235}U, ^{238}U, ^{40}K, and ^{87}Rb [1]. The anthropogenic radionuclides are mainly from nuclear activities. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different levels in the soils of each region in the world [2-4]. It is important to make studies on distribution of various radionuclides present in the sediment and the different factors that distribute the various radionuclides from soil to food chain and their subsequent transfer to the human body. Since these natural radioisotopes are not uniformly distributed, the knowledge of their distribution in soils and rocks play an important role in radiation protection [5]. Higher concentration and higher radiation levels are associated with igneous rocks, such as granite, and lower levels with sedimentary rocks. There are exceptions, however, as some shale and phosphate rocks have relatively high content of radionuclides [1]. So, for the assessment of radiation hazard it is essential to determine the concentration of terrestrial radionuclides throughout the country. The study area was Charfassion island, Bhola Bangladesh, which is located at 22.1847°N 90.7625°E. This is one of the dense island in Bangladesh with density 309/km2 (800/sq mi) [6]. This is a small island with area 1,106.31 km2 (427.15 sq mi) surrounded by Bay of Bengal. The sediments from 25cm depth were analyzed by using broad energy germanium (BEGe) detector so that measured values can be compared with the upper level sediment samples values of concentration of natural and anthropogenic radionuclides and radiational hazard parameters. This work will be valuable in the development of rules and regulation for the health and environmental safety in this area.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Total nine samples were collected from the study area (shown in figure-1) with a soil iron corer having diameter 6 cm. This sediment samples were collected from 20-25 cm depth from the surface level. The lower level samples were collected to compare with the upper level sediment samples values. All the solid and powdered samples were air dried under laboratory temperature. All solid samples were cleaned and dried at about 120oC in an oven for about 24 hours to remove added moisture and thereafter crushed to fine powder with mortar and pestle. Each of the samples was transferred to sealed cylindrical plastic container of diameter 7 cm and 3.5 cm in height, marked individually with identification parameter such as name and the location of the sample, date of preparation and net weight. All the samples containers were sealed tightly with cap and wrapped with Teflon and thick vinyl tapes inside and outside around their screw necks and finally air tightened with polythene pack and stored for minimum four weeks to allow secular equilibrium between the long lived ^{238}U and ^{232}Th and their short lived progeny.

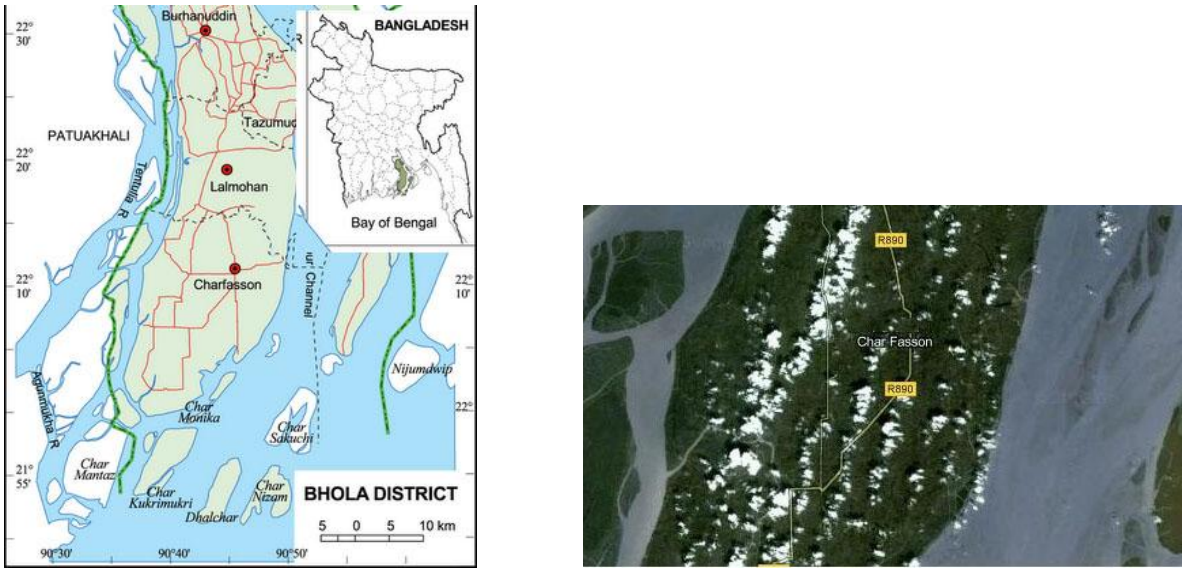

Figure-1: Charfassion upazila, Bhola, Bangladesh

2.2 Setup of Detection System

Since most of the radio-nuclides are gamma emitter, gamma spectroscopy can reveal dominant sources of radioactivity. A broad energy germanium (BEGe) detector BE3820 made by Canberra Industries Inc, USA was used to record the gamma emission from the sediment samples. This detector can efficiently measure gamma in the energy region from 3 keV to 3 MeV (Canberra, USA). The measured resolution of the detector was 1.9 keV (FWHM) at gamma energy 1332 keV. Efficiency and calibration of the detection system were done against the standard sources provided by International Atomic Energy Agency (IAEA). The efficiency of a particular detector varied with the distance between the source and detector and its geometry. By placing the standard source at the top of window of the detector, the peaks were accumulated for 20,000 seconds, and the peak area for each radionuclide was calculated by using the specialized computer program Windows based Genie-2000 software for quantitative analysis of nuclear spectroscopy available in Radioactivity Testing and Monitoring Laboratory (RTML), Chittagong.

2.3 Activity Calculation

Each of the collected and prepared samples was placed on the top of the BEGe detector within the shielding arrangement and counted for 20,000 seconds, after adjustment of the necessary parameters such as resolution, peak to Compton ratio etc, and measurement of minimum detectable activity of the detectors. The net events were obtained after subtracting the background. Activity of 238U radionuclide was determined from the observed counts at gamma energies 241.98 keV, 295.21 keV and 351.92 keV emitted by the daughter nuclide ^{214}Pb and also at energies 609.31 keV, 1120.29 keV and 1764.49 keV emitted by the another daughter ^{214}Bi. For the radionuclide ^{232}Th, counts at energies 238.63 keV of ^{212}Pb, 338.40 keV, 911.07 keV and 969.11 keV of ^{228}Ac and 583.19 of ^{208}Tl were used. Gamma peaks at energies 1460.75 keV and 661.66 keV, respectively, were used for the determination of activities of ^{40}K and ^{137}Cs. Then the activities were calculated by using the formula [7]:

$$\text{Activity (BqKg}^{-1}) = \frac{CPS \times 100 \times 1000}{E \times I \times w(gm)}$$

Where, CPS = Net counts per second
E = Efficiency of the gamma energy.
I = Intensity of the gamma ray.

3. RESULT AND DISCUSSION

3.1. Activity Concentrations

The measured activity concentrations of natural radionuclides ^{238}U, ^{232}Th and ^{40}K in the sediment samples are given in Table-1. The study shows that the activity concentration of 238U was found to be 25.67±2.42 Bq.kg^{-1} to 14.74±2.60 Bq.kg^{-1} with an average activity of 19.34±4.37 Bq.kg^{-1}. The activity of ^{232}Th was found 34.11±2.47 Bq.kg^{-1} to 27.04±2.00 Bq.kg^{-1} with an average activity of 31.14±5.58 Bq.kg-^{1}. The highest activity of 40K was found 767.96±27.71 Bq.kg^{-1} with the range 850.16±22.47 Bq.kg^{-1} to 690±22.47 Bq.kg^{-1}. The anthropogenic radionuclide ^{137}Cs was not found in any Figure-1 represents the comparative activity concentration of ^{238}U and ^{232}Th in different sediment samples whereas figure-2 represents the same for ^{40}K. And figure-3 shows the comparison of activity concentrations of ^{238}U, ^{232}Th and ^{40}K with world average.

Table-1: Measured activity concentrations of natural radionuclides ^{238}U, ^{232}Th and ^{40}K in the sediment samples

Sample ID	Activity concentrations of natural radionuclides in Bq/Kg		
	U-238	Th-232	K-40
BS-01	16.15±1.89	29.61±2.33	830.5±22.06
BS-02	25.67±2.42	28.04±2.31	750.15±22.18
BS-03	14.74±2.60	31.89±2.43	850.16±22.47
BS-04	23.96±2.50	29.21±2.31	760.14±22.47
BS-05	17.36±2.26	34.11±2.47	720.3±22.68
BS-06	22.41±2.81	32.40±2.43	790.12±22.51
BS-07	22.39±3.32	33.99±2.50	770.1±22.72
BS-08	16.61±1.02	33.96±2.53	750.2±22.51
BS-09	14.80±1.84	27.04±2.00	690±22.47
Average	**19.34±4.37**	**31.14±5.58**	**767.96±27.71**

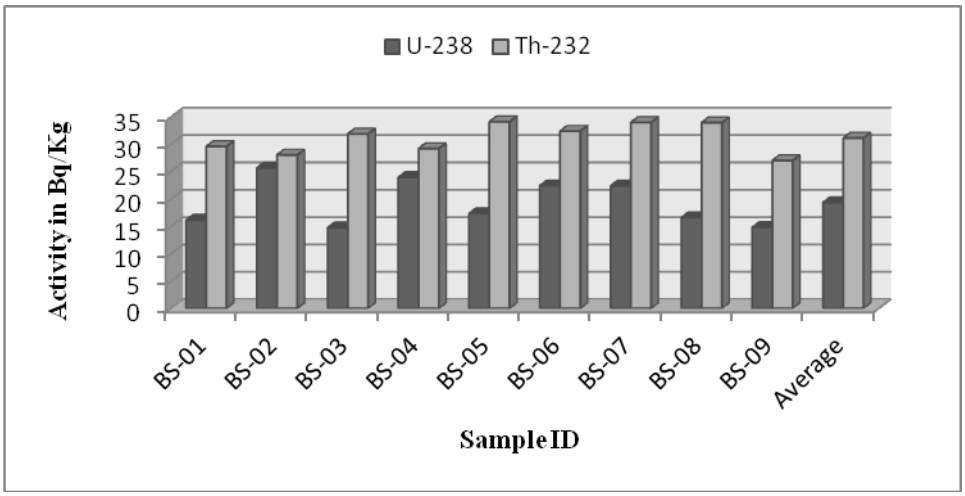

Figure-1: The comparative activity concentration of ^{238}U and ^{232}Th in different sediment samples

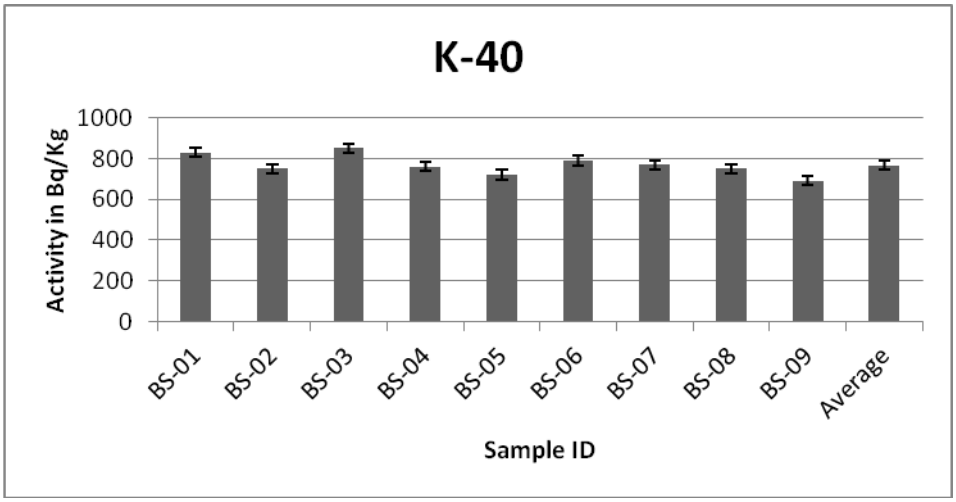

Figure-2: The activity concentration of ^{40}K in different sediment samples

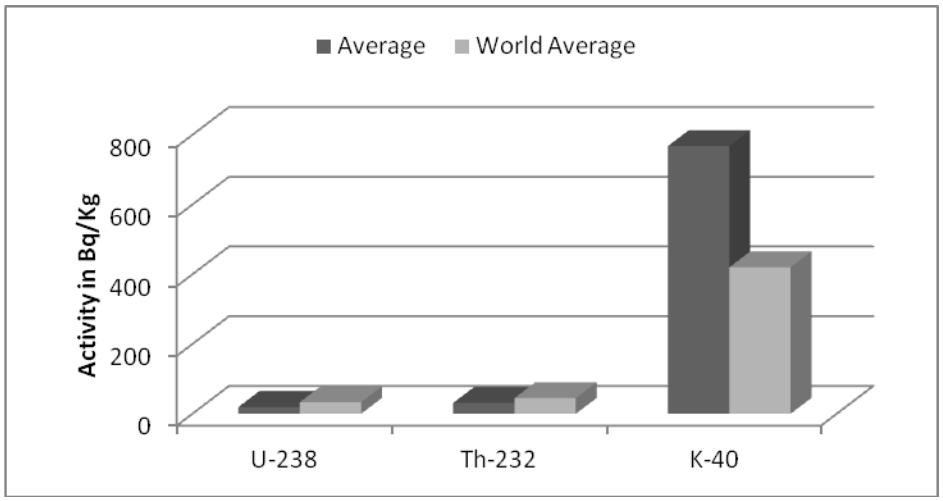

Figure-3: The comparison of activity concentrations of ^{238}U, ^{232}Th and ^{40}K with world average

3.2. Radiological Impact on Environment

3.2.1. The absorbed dose rate D (nGy/h) in air at 1m above the ground level due to presence of ^{238}U, ^{232}Th and ^{40}K in studied samples was calculated using the following equation [8]:

$$D\ (nGyh\text{-}1) = 0.462A_U + 0.604A_{Th} + 0.0417A_K$$

Where, A_U, A_{Th}, and A_K are the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in the units of $BqKg^{-1}$. The table-2 given below reveals the absorbed dose rate with an average of 59.77±3.43 $nGyh^{-1}$ which is greater than the world value 59 $nGyh^{-1}$ [1].

3.2.2 To estimate the annual effective dose rates, the conversion coefficient from absorbed dose rate in air to effective dose (0.7) and outdoor occupancy factor (0.2) proposed by UNSCEAR (2008) were used. The effective dose rate (mSv/a) was calculated using the formula [9]:

$$=Dair \times 0.7 \times 0.2 \times 24 \times 365 \times 10\text{-}6$$

The resulting average of annual effective dose is 0.07±0.01 mSv/a with ranges from 0.04±0 mSv/a to 0.07 mSv/a while the average annual effective dose is 0.07 mSv/a [8].

3.2.3 The radiation hazard index radium equivalent activity (Raeq in $Bq.kg^{-1}$) and representative level index (Iγr) was calculated according to the following formula [10].

$$Raeq = (10/10)\ A_U + (10/7)\ A_{Th} + (10/130)\ A_K$$

and $$I\gamma r = (1/150)\ A_U + (1/100)\ A_{Th} + (1/1500)\ A_K$$

Where A_U, A_{Th}, and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K (in $Bq.kg^{-1}$) respectively. The resulting average of radium equivalent activity (Raeq) is 122.89±7.40 $BqKg^{-1}$. And the resulting average of representative level index (Iγr) is 0.95 $BqKg^{-1}$. The table-2 given below shows the average, maximum, minimum and world average values [1, 11] of absorbed dose rate, annual effective dose rate, radium equivalent activity and representative level index. Figure-4 shows the comparison of average value of radiological hazard parameters with world average.

Table-2: Average, maximum, minimum and world average values [1, 11] of absorbed dose rate, annual effective dose rate, radium equivalent activity and representative level index

Sample ID	Absorbed dose rate, D (nGy/h)	Annual effective dose rate, H (mSv/a)	Radium equivalent activities, Raeq (Bq/kg)	Representative level index, Iγr (Bq/kg)
Average	59.77±3.43	0.07	122.89±7.40	0.95
Maximum	62.99±3.99	0.08	130.18±8.64	1.0
Minimum	51.94±2.99	0.06	106.50±6.42	0.08
World Average	**55**	**0.07**	**89**	**0.06**

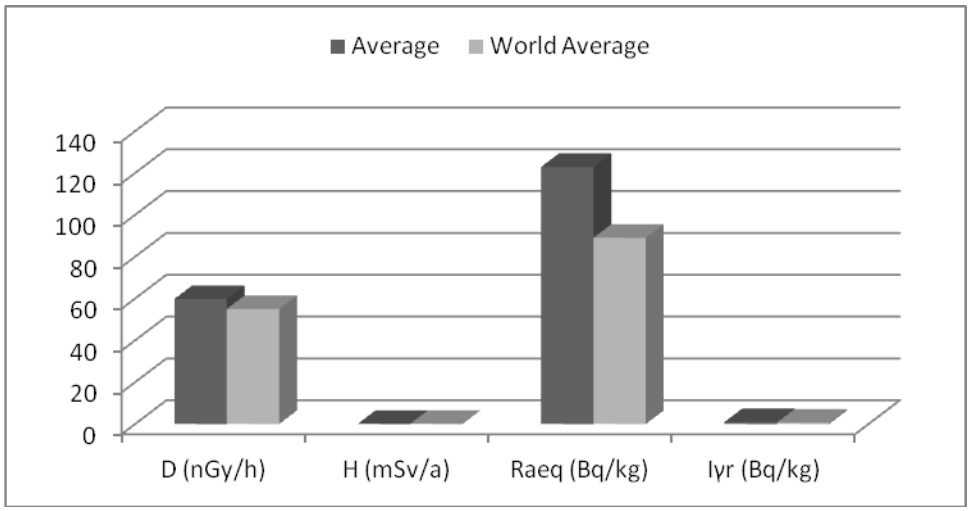

Figure-4: Comparison of average values of radiological hazard parameters with world average.

3.2.4. The ratio of concentrations of radionuclides 238U, ^{232}Th and 40K of upper level [12] to the lower level are shown in table-3. These ratios provide the information that the upper level concentrations of ^{238}U and ^{40}K are higher than the lower level. But the upper level concentration of ^{232}Th is lower than the upper level.

Table-3: The ratio of concentrations of radionuclides ^{238}U, ^{232}Th and ^{40}K of upper level [12] to the lower level are shown

Sample ID	**Ratio of upper level to lower level concentrations of natural radionuclides**		
	U-238	**Th-232**	**K-40**
BS-01	1.06	1.01	1.09
BS-02	1.04	0.9	0.91
BS-03	0.92	0.98	1.05
BS-04	1.22	0.87	0.96
BS-05	0.99	0.93	1.01
BS-06	1.21	1.12	1.11
BS-07	1.17	0.91	1.04
BS-08	1	1	1
BS-09	1.25	0.89	0.99
Average	**1.09**	**0.95**	**1.01**

4. CONCLUSION

The following conclusions can be presented.

(1) In the present study the activity concentrations of ^{238}U and ^{232}Th are within the value of the world average. But the average concentration of ^{40}K is greater than the world average. The increasing trend of ^{40}K is due to the presence of loamy and clay sediments [13] and may be due to the high content of monazite [14].

(2) There are no presence of fallout isotope ^{137}Cs which indicate that there are no nuclear activities in this island.

(3) The estimated dose rate, annual effective dose and representative level index in the studied area are higher than the recommended values because of higher concentration of ^{40}K.

(4) From table-3 we can conclude that ^{238}U and ^{40}K has the a little bit higher mobility than the ^{232}Th.

5. ACKNOWLEDGEMENT

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