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Assessment of Activity Concentrations of Radionuclides from Upper Level Sediment in Charfassion Island, Bhola, Bangladesh

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Abstract In order to assess the activity concentration of natural and anthropogenic radionuclides in the Charfassion Island, Bhola, Bangladesh, the upper 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 16.82±2.18 $BqKg^{-1}$, 32.84±2.56 $BqKg^{-1}$ and 743.52±22.07 $BqKg^{-1}$. These results were used to calculate the radiation hazard parameters like radium equivalent activities (Ra_{eq}), representative level index ($I_{\gamma r}$). Representative level index is used to estimate the level of gamma radiation hazard associated with the natural radionuclides. 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 0.94 Bq/Kg. The findings from this research work would be useful to evaluate the population exposure from radionuclides in this island.

Keywords Natural Radioactivity, Gamma Spectrometry, Bege Detector, Absorbed Dose Rate, Effective Annual Dose

1. Introduction

Environmental radioactivity measurements are necessary for determining the background radiation level due to natural radioactivity sources of terrestrial and cosmic origin. The terrestrial component is due to the radioactive nuclides that are present in air, sediments, rocks, water and building materials in amount that vary significantly depending on the geological and geographical features of a region and appear at different levels in the soils of each region in the world[1, 2, 3]. The cosmic radiation originates from spaces as cosmic rays whose contribution to background changes mainly with elevation and latitude. In addition to the natural sources, the level of background radiation region is affected from man-made sources such as those from nuclear sources and accidents[4]. Besides the radiological threat is increasing day by day due to increasing the nuclear activities. Such types of activities are frequently occurred in our neighbouring country. The aim of the present study is the assessment of the radioactivity contamination level in the cyclones "Sidr" and "Aila" affected areas. Most of the affected areas with above mentioned cyclones are situated in southern side of Bangladesh. This is why the present study was carried out in Bhola island. For this, nine different points were selected which are under area $22^0$7'35.63" N to $90^0$48'26.41" E. From the selected area coastal riverbed sediment were collected with soil iron corer having diameter 6 cm. Many areas of this country were surveyed for radiological risk assessments except this island. So, for the assessment of radiation hazard in Bangladesh, it is essential to determine the concentration of terrestrial radionuclides in this island. This research work will find out the distribution of different radionuclides in upper (surface) level sediments of this area and thereby assessed the radiation hazard. So, this work will be valuable in the development of rules and regulation for the health and environmental safety.

2. Materials and Methods

All collected solid and powdered samples were air dried under laboratory temperature. Then the samples were cleaned and dried at 120^0 C in an electric oven for 24 hours to remove moisture. After drying in oven the samples were crushed to fine powder with mortal and pastel. These samples were transferred to cylindrical plastic containers which are with height 3.5 cm and dia. 6.5 cm. these containers were marked individually with identification number, name and location of the sample, date of preparation and net weight. Then containers were sealed tightly with cap and wrapped with Teflon and thick vinyl tapes inside and outside with their screw necks and finally air tightened with polythene pack and stored for four weeks to allow secular equilibrium between the long lived U-238, Th-232 with their short lived progeny respectively. The sampling site

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Charfasion island, Bhola is shown in Fig-1 below:

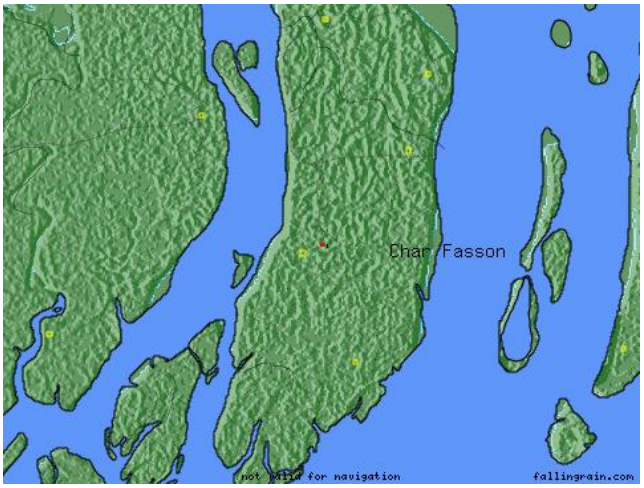

Figure 1. Sampling site Charfassion island, Bhola, Bangladesh

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 soil 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.

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. Activity of ^{238}U 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. The net events were obtained after subtracting the background. These net activities were calculated by using the formula:

$$Activity\ (Bq/kg) = \frac{c}{e\ i\ m} \quad (1)$$

Where, e is the counting efficiency (in fraction) of the detector at the measured gamma energy, i is the intensity of the measured gamma from the radio-nuclide and m is the mass of soil sample in kg.

The outdoor dose rates and annual effective dose rate were calculated by using the following formula[5]

$$D\ (nGyh^{-1}) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \quad (2)$$

And $H = (D_{outdoor} * 0.7 * 0.2 * 24 * 365 * 10^{-6})$

Where, A_U, A_{Th}, *and* A_K are the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in sediment in units of Bq/kg.

Radiological hazard index the radium equivalent activity concentration (Ra_{eq}) and representative level index ($I_{\gamma r}$) was calculated according to[6]:

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \quad (3)$$

$$\text{and } I_{\gamma r} = 0.0067\ A_U + 0.01\ A_{Th} + 0.000067\ A_K \quad (4)$$

Where, A_U, A_{Th}, *and* A_K are the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in sediment in units of Bq/kg.

3. Results and Discussion

3.1. Activity Concentrations

Table 1. The measured activity concentrations of natural and anthropogenic radionuclides ^{238}U, ^{232}Th ,^{40}K and ^{137}Cs in the sediment samples

Sample ID	Activity concentration in Bq/Kg			
	U-238	Th-232	K-40	Cs-137
BS-01	15.13±1.67	28.77±2.60	700.10±22.10	ND
BS-02	24.35±1.84	33.86±2.21	900.20±22.31	ND
BS-03	18.14±2.82	30.54±2.62	770.25±22.18	ND
BS-04	17.03±3.55	38.11±2.73	810.11±22.23	ND
BS-05	17.58±5.56	32.82±2.54	700.20±21.42	ND
BS-06	15.52±0.92	24.86±2.38	650.00±22.27	ND
BS-07	16.18±0.85	38.31±2.71	700.00±21.45	ND
BS-08	16.61±1.02	33.96±2.53	750.20±22.51	ND
BS-09	10.86±1.36	34.34±2.73	710.60±22.18	ND
Average	16.82±2.18	32.84±2.56	743.52±22.07	ND

The measured activity concentrations of natural and anthropogenic radionuclides ^{238}U, ^{232}Th and ^{40}K in the sediment samples are given in Table-1. The study shows the range of activity of ^{238}U was found in 24.35±5.56 BqKg^{-1} to 10.86±0.85 BqKg^{-1} with an average value of 16.82±2.18 BqKg^{-1}. The activity of ^{232}Th was found in the range of 38.31±2.73 BqKg^{-1} to 24.86±2.21 BqKg^{-1} with an average value of 32.84±2.56 BqKg^{-1}. The highest activity of ^{40}K was found 900.20±22.51 Bq.kg^{-1} and the lowest was 650.0±21.20 Bq.kg^{-1} with an average activity of 743.52±22.07 Bq.kg^{-1}. Fig-2 represents comparison between the activity concentration of ^{238}U and ^{232}Th in different sediment samples whereas Fig-3 represents the same for ^{40}K. Figure-6 represents these measured values of natural radionuclide

concentrations with world average values.

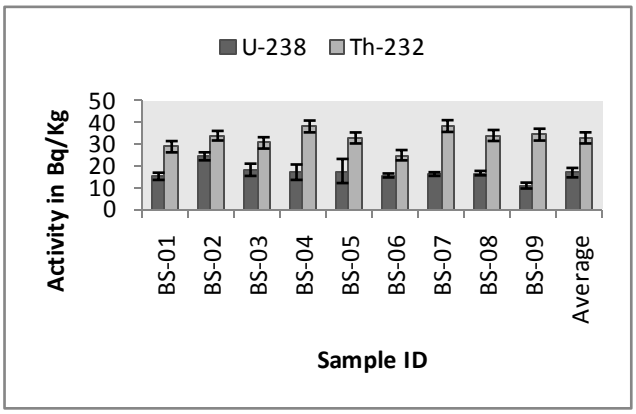

Figure 2. Comparison between concentrations of U-238 and Th-232 in different sediment samples

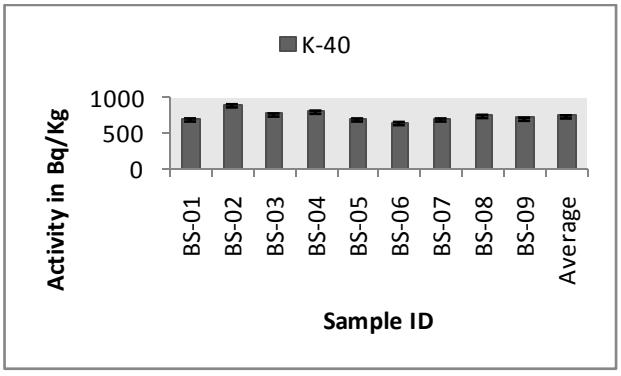

Figure 3. Activity concentration of K-40 in different sediment samples

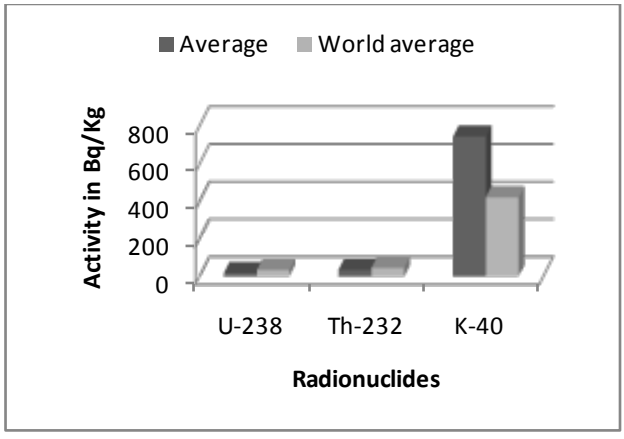

Figure 4. Comparison of measured activity concentration with world average

3.2. Radiational Hazard Parameters

i. The outdoor gamma ray exposure rate in air at one meter height above the ground due to natural radionuclides in sediment was found with an average of 58.61±3.47 nGyh-1 which is lower than the world value 59 nGyh-1[4].

ii. 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 resulting average of annual effective dose is 0.07 mSv/a while the world average annual effective dose is 0.07 mSv/a[4].

iii. For the estimation of radiation hazards due to natural radio-nuclides it is now common practice to calculate the radium equivalent activity (Ra_{eq}) and representative level index ($I_{\gamma r}$). The resulting average of radium equivalent activity (Ra_{eq}) is 120.79±7.62 $BqKg^{-1}$ and the resulting average of representative level index ($I_{\gamma r}$) is 0.94±0.05 $BqKg^{-1}$.

The above values are shown in the table-2 given below. And comparisons of these values with world average are shown in table-3.

Table 2. The average values of outdoor dose rate, annual effective dose, radium equivalent activities 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)
BS-01	53.56±3.2	0.07±0	110.09±7.09	0.86±0.05
BS-02	69.24±3.1	0.08±0	141.96±6.72	1.10±0.05
BS-03	58.94±3.8	0.07±0	121.01±8.27	0.94±0.06
BS-04	64.67±4.2	0.08±0	133.79±9.16	1.03±0.07
BS-05	57.14±5.0	0.07±0	118.33±10.84	0.91±0.08
BS-06	49.29±2.7	0.06±0	101.04±6.03	0.79±0.04
BS-07	59.80±2.9	0.07±0	124.75±6.37	0.96±0.05
BS-08	59.46±2.9	0.07±0	122.82±6.37	0.95±0.05
BS-09	55.39±3.2	0.07±0	114.59±6.96	0.89±0.05
Average	58.61±3.4	0.07±0	120.93±7.53	0.94±0.05

Table 3. Comparison of results of the present study with corresponding world average values worldwide value and regional study

Radiological Parameters	Present Study	Regional study[7]	World average[4, 5]
U-238 in Bq/Kg	18.26±2.28	37.9±20	33
Th-232 in Bq/kg	31.18±2.54	65.9±12.2	45
K-40 in Bq/kg	753.74±22.26	272±35	420
Radium equivalent activity, Ra_{eq} (Bq/Kg)	120.79±7.53	151±39	89
Representative level index, ($I_{\gamma r}$) (Bq/Kg)	0.94±0.06	1.08±0.27	0.66
Outdoor dose rate, D (nGy/h)	58.61±3.47	70.78±18.26	59
Annual effective dose rate, H (mSv/a)	0.07	------	0.07

4. Conclusions

In the present study the activity concentrations of ^{238}U, ^{232}Th are lower than the value of the world averages (33 $Bq.kg^{-1}$ for ^{238}U, 45 $Bq.kg^{-1}$ for ^{232}Th)[8] but the activity concentration of ^{40}K is greater than the world average value (420 $Bq.kg^{-1}$ for ^{40}K)[8]. The increasing trend of ^{40}K is due to the presence of loamy and clay sediments[9] and may be due to the high content of monazite[10]. The value of outdoor dose rate is lower than the world average value whereas radium equivalent activities and representative level index are greater than the world average value. But the average

value of annual effective dose is same as world average value. And there were no detection of anthropogenic radionuclides ^{137}Cs.

This study may provide scientific information on contamination of this important region. In spite of the randomness in the choice of the samples and the choice of locations from where the samples were collected for the study of the natural environment radiation, it is interesting indeed to observe that all samples exhibit the presence of ^{40}K radionuclides and daughter product of ^{238}U and ^{232}Th radionuclides. The results may be used as a reference data for monitoring possible radioactivity pollutions in future.

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