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Radiological risk analysis of sediment from Kutubdia island, Bangladesh due to natural and anthropogenic radionuclides

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► ***Short report***

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ABSTRACT

To assess the environmental radioactivity levels and hence to determine the population exposure in Kutubdia Island, Bangladesh the sediment samples were analyzed by using gamma ray spectrometry. In those sediment samples the average activity concentration of natural radionuclides ^{238}U, ^{232}Th and ^{40}K were found 15.39±1.67, 38.35±0.76 and 475.51±21.15 Bq/kg respectively. The activity concentration of ^{238}U and ^{232}Th were less than the world average. But the activity concentration of ^{40}K was higher than the world average values. These results were used to calculate the radiological hazard parameters like radium equivalent activities (Ra_{eq}), representative level index ($I_{\gamma r}$). Due to natural radionuclides in sediment, the effective annual outdoor dose in the study area was 0.07 mSv; which is within the accepted range of 0.07 mSv. The average value of radium equivalent activities (Ra_{eq}) and representative level index (Igr) were found to be 128.03±12.08 Bq/Kg and 0.96±0.09 Bq/Kg which were greater than the world average. The anthropogenic radionuclide ^{137}Cs was also found in few samples. The average activity concentration of ^{137}Cs was 1.64±0.20 Bq/kg which is lower than the world average. The obtained experimental data of this research work would be useful to assess the population exposure from radionuclides in sediment as well as base line data of natural radioactivity in this island.

Keywords: *Natural radionuclides, HPGe gamma-spectrometry, radium equivalent activity, representative level index, annual effective dose.*

INTRODUCTION

The geographical position of Kutubdia island is 21° 50' 06" N and 91° 50' 16" E. The area of this island is 215.8 square km (83.3 sq mi) with total population of 95,055. This is one of the very dense island with the density 440/km^2 (1,100/sq mi) [(1)]. Also it is one of the probable island near which a deep sea port may be built in near future. So it is necessary to find out the radiological threat due to naturally occurring radioactive materials of this area. The decay of these radionuclides in soil produces a β-γ radiation field that crosses the soil-air interfaces and produces exposure to humans [(2)]. Again natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical positions, and appear at different levels in the soils of each region in the world [(3-6)]. Due to these reasons our study was carried out in this island. The objective of this

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study was to assess the radiological risk due to the natural and anthropogenic radionuclides and to find out the distribution of various radionuclides present in the sediment samples and the different factors that distribute the various radionuclides from soil to food chain and their subsequent transfer to the human body. So this work will provide the background data on natural and anthropogenic radioactive isotope and environmental pollution by technologically enhanced natural radionuclides as well as accidental radionuclides which are useful in the assessment of human radiation exposure from the environment. The data would be useful as a base line data for further use in this area. The accumulation of information on natural radiation is of great value for radiation protection.

MATERIALS AND METHODS

Sample collection and preparation

In order to determine the radioactivity of naturally occurring and anthropogenic radionuclides in the sediment, a total number of 10 sediment samples were collected from Kutubdia island. The location of this island is shown in figure 1. All the solid and powdered samples were air dried under laboratory temperature. All solid samples were cleaned and dried at about 120°C 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. These sealed containers were then stored for a period of four weeks to allow for the attainment of secular equilibrium between the long lived ^{238}U and ^{232}Th and their short lived progeny [7, 8].

Measurement system

A high purity germanium (HPGe) detector, model CPVDS30-30185 made by Canberra Industries Inc, USA was used to record the gamma emission from the sediment samples. The measured resolution of the detector was 1.85 keV (FWHM) at gamma energy of 1332 keV and the relative efficiency was 35%. This gamma detector was coupled with a digital spectrum analyzer, DSA-1000, which provided a full featured multichannel analyzer of 16K channel based on digital signal processing techniques. Canberra's Genie-2000* spectroscopy software was used to record and analyze the gamma ray spectra of sediment samples. Determination of counting efficiency and calibration were done by using the standard samples provided by the International Atomic Energy Agency (IAEA);

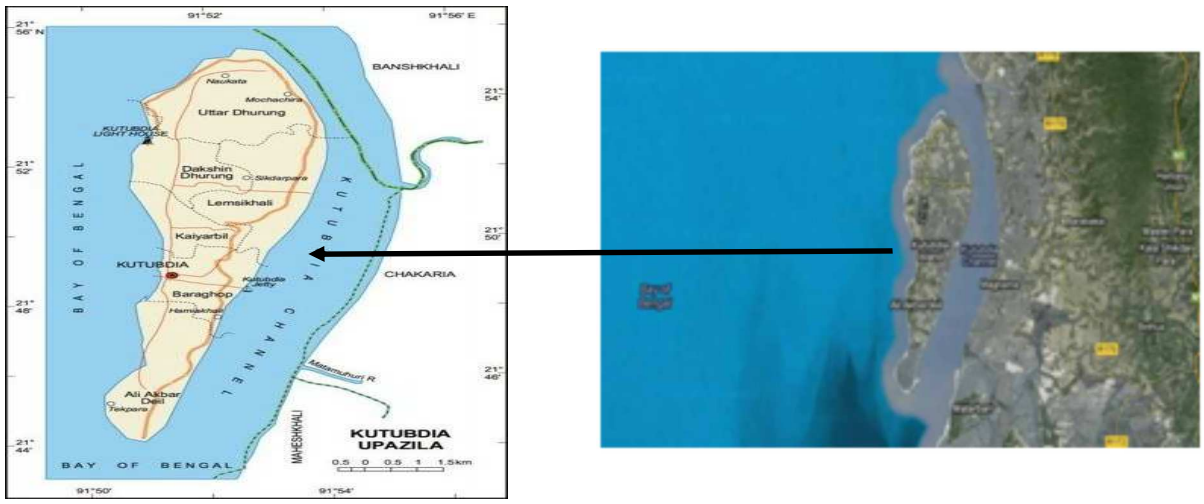

Figure 1. The Kutubdia Island.

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these reference samples were RGU-1 for ^{238}U series, RGTh-1 for ^{232}Th series, RGK-1 for ^{40}K and IAEA-152 for ^{137}Cs. The detector was placed inside a massive lead shield in order to reduce the background radiation. After adjustment of the necessary parameters such as resolution, peak to Compton ratio etc, and measurement of minimum detectable activity of the detector, each of the collected samples were placed on the end cap of the detector within the shielding arrangement [9]. Moreover, a background spectrum was recorded for 20,000 seconds for a blank sample container of the same geometry of the detector. This background reading was subtracted from the sample reading to determine the net count originated from the sample. Gamma spectrum for each sediment and reference sample was also recorded for 20,000 seconds. 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 KeV of ^{208}Tl were used. Gamma peaks at energies 1460.75 keV and 661.66 keV were used for the determination of activities of ^{40}K and ^{137}Cs respectively. Then the activities were calculated by using the equation 1 [10]:

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

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

RESULTS AND DISCUSSION

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 ^{238}U was found to be 4.87±0.65 to 31.57±3.22 Bq/kg with an average activity of 15.39±1.67 Bq/kg. The activity of ^{232}Th was found 28.26±3.09 to 65.04±6.35 Bq/kg with an average activity of 38.35±0.76 Bq/kg. The average activity of ^{40}K was found 475.51±21.12 Bq/kg with the range 309.72±25.51 to 872.74±61.58 Bq/kg. The anthropogenic radionuclide ^{137}Cs was found in few samples with an average activity of 1.64±0.20 Bq/kg which is within very low level. Figure 2 shows the comparison of activity concentrations of ^{238}U, ^{232}Th and ^{40}K with world average.

Radiological hazard parameters

1. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K measured in each of the studied samples indicate the quantity of the radioactivity present but do not provide a measure of radiation risk in the form of absorbed dose rate. The absorbed dose rate D (nGy/h) in air at 1m above the ground level due to presence

Table 1. The concentrations of natural and anthropogenic radionuclides in sediment samples.

Sample ID	Activity concentrations in Bq/Kg			
	U-238	Th-232	K-40	Cs-137
KSD-01	12.06±1.66	28.26±3.09	309.72±33.31	1.64±0.17
KSD-02	31.57±3.22	65.04±6.07	721.56±47.83	ND*
KSD-03	24.65±2.67	38.36±4.23	371.35±25.51	ND
KSD-04	4.87±0.65	30.27±3.32	360.64±34.04	0.07±0.03
KSD-05	15.37±1.64	31.22±3.49	418.29±35.31	1.14±0.14
KSD-06	24.47±2.29	59.30±6.35	603.53±54.10	ND
KSD-07	30.05±3.01	59.31±6.05	812.96±56.88	8.66±0.50
KSD-08	24.98±2.29	52.74±5.21	772.35±61.58	1.55±0.21
KSD-09	21.08±2.12	50.72±4.97	872.74±59.04	2.47±0.27
KSD-10	9.86±1.15	33.26±3.3	485.42±38.46	0.14±0.05
Average	15.39±1.67	38.35±0.76	475.51±21.12	1.64±0.20

*ND= Not detected

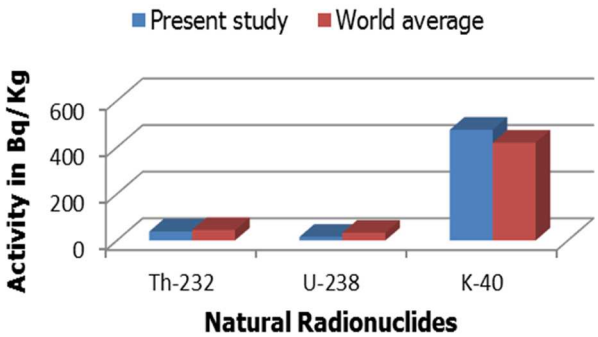

Figure 2. Comparison of natural radionuclides concentrations in sediment samples with world average.

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of ^{238}U, ^{232}Th and ^{40}K in studied samples was calculated using the equation (2) [11]:

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

Where, A_U, A_{Th}, and A_K are the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in units of Bq/kg. The values of the absorbed dose rate ranges from 35.56±3.73 to 90.26±7.89 $nGyh^{-1}$ with an average of 60.17±5.60 $nGyh^{-1}$ which was greater than the world average value 59 $nGyh^{-1}$ [12].

2. To estimate the annual effective dose rates (H), 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 equation (3) [13]:

$$=D_{air} \times 0.7 \times 0.2 \times 24 \times 365 \times 10^{-6} \quad (3)$$

The resulting average of annual effective dose is 0.07±0.01 mSv/a with ranges from 0.04±0 to 0.11±0.01 mSv/a while the average annual effective dose was 0.07 mSv/a [11].

3. The radiation hazard index of radium equivalent activity (Ra_{eq} in Bq/kg) and representative level index ($I_{\gamma r}$) was calculated according to the following formula [14]. Representative level index is used to estimate the level of gamma radiation hazard associated with the natural radionuclides.

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

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) respectively.

The resulting average of radium equivalent activity (Ra_{eq}) is 128.03±12.08 Bq/kg with ranges from 75.85±8.01 to 191.61±17.03 Bq/kg. The resulting average of representative level index ($I_{\gamma r}$) was 0.96±0.09 Bq/kg with ranges from 0.57±0.06 to 1.44±0.13 Bq/kg which is lower than the world average value 0.66 Bq/kg [15]. Figure 3 shows the comparison of average values of radiological hazard parameters with world average.

CONCLUSION

The following conclusion can be presented:

A. In the present study the average activity concentrations of ^{238}U, ^{232}Th were less than the value of the world averages wherein ^{40}K was greater than that. The increasing trend of ^{40}K might be due to the presence of loamy and clay sediments [16] and due to the high content of monazite [17]. From the previous work on coastal area [18-20] we can conclude that the concentrations of natural radionuclides in these samples are lower than the any other coastal area of the country.

B. There were no nuclear activities in this island. But the presence of anthropogenic radionuclides ^{137}Cs was detected in few samples which is due to atmospheric fallout. Though the average activity concentrations of this radionuclides was very low.

C. The estimated dose rate, annual effective

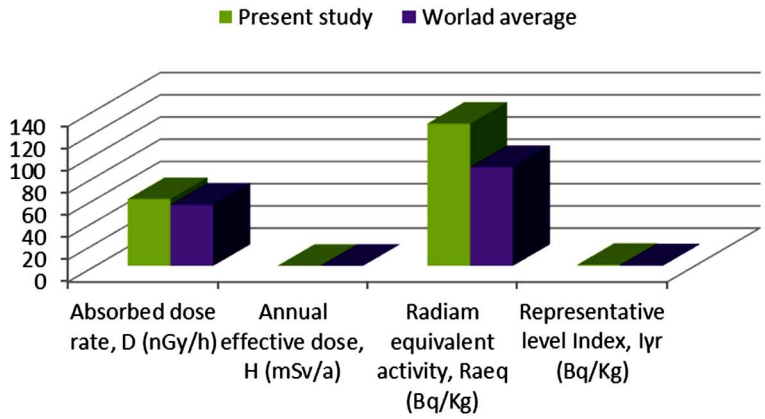

Figure 3. Comparison of average value of present study with world average.

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dose, radium equivalent activities and representative level index in the studied area are greater than the recommended values.

The mean concentrations of the radionuclides ^{238}U, ^{232}Th, ^{137}Cs, and ^{40}K in sediment samples determined in this study compare suitably with literature values. But the ^{137}Cs activity concentrations of all places were below the detectable range. This study can be used as a baseline data for future investigations and the data obtained in this study may be useful for natural radioactivity mapping.

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Conflict of interest: *Declared none.*

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