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Study of Environmental Radiation on Sand and Soil Samples from Kuakata Sea Beach of Patuakhali

Khondaker Mohammed Nazrul Islam[1], Debasish Paul[2], Md. Mahbubur Rahman Bhuiyan[3*], Amina Akter[1], Budrun Neher[3], Sheikh Mohammad Azharul Islam[1]

[1]Department of Physics, Jahangirnagar University, Savar, Bangladesh; [2]Health Physics & Radioactive Waste Management Unit (HP & RWMU), Institute of Nuclear Science & Technology (INST), Atomic Energy Research Establishment (AERE), Savar, Bangladesh; [3]Department of Physics, Comilla University, Comilla, Bangladesh.
Email: *rahmanmahbubur@ymail.com

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ABSTRACT

The activity concentrations of radionuclides in the sand and soil samples collected from Kuakata seabeach of Patuakhali district in Bangladesh have measured using a high resolution high purity germanium (HPGe) detector of relative efficiency 40%. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were found in the sand samples of Kuakata seabeach varied from 2.82 ± 4.89 to 87.96 ± 4.45 Bq·Kg^{-1}, 21.72 ± 16.27 to 290.93 ± 18.15 Bq·Kg^{-1} and 26.24 ± 0.35 to 852.05 ± 142.15 Bq·Kg^{-1} respectively. For soil samples the activity concentrations of corresponding radionuclides were found to be 20.98 ± 3.96 to 42.92 ± 4.76 Bq·Kg^{-1}, 59.25 ± 15.62 to 144.34 ± 18.52 Bq·Kg^{-1} and 570.43 ± 100.3 to 1165 ± 166.27 Bq·Kg^{-1} respectively. The average absorbed dose rate due to radionuclides in sand was estimated to range from 51.84 to 246.55 nGy·h^{-1} with an average of 98.33 nGy·h^{-1}. Also the average absorbed dose rate due to radionuclides in soil was estimated to range from 76.63 nGy·h^{-1} to 142.36 nGy·h^{-1} with an average of 110.04 nGy·h^{-1}. Radium equivalent activities were calculated for the analyzed samples to assess the radiation hazards arising due to the presence of this radionuclide in the samples. Most of the calculated radium equivalent activities are lower than the limit set in the OECD report (370 Bq·kg^{-1}). The measured representative level index values for the investigated samples varied in the range 0.8 to 3.75.

Keywords: Radionuclide; Activity Concentration; HPGe detector; Kuakata Seabeach; ^{226}Ra; ^{232}Th; ^{40}K and ^{137}Cs

1. Introduction

Radiation is present in every environment of the Earth's surface, beneath the Earth and in the atmosphere. According to UNSCEAR (1993), about 87% of the radiation dose received by mankind is due to natural radiation sources and the remaining is due to anthropogenic radiation [1]. It is observed that most of natural radioactive elements present in soil are primordial radionuclides from the uranium series, thorium series, and ^{40}K [2]. The man and the animal kingdom however make adjustment to the natural radiation sources. But the advent of artificial or man-made radiation sources, when man succeeded in fissioning of the uranium atomic nucleus, their widespread application and accidental uncontrolled release of radioactivity in the environment have altered the balance. Nuclear weapons test release radioactive fissions products into the atmosphere and its depositions over the earth's surface are termed "fallout". The distribution of this fallout in the environment takes place in various ways depending on the strength of the nuclear device, mode of burst and climate conditions. Significant amounts of man-made radionuclides, ^{137}Cs and ^{90}Sr, are also present in the environment as a result of nuclear weapon tests and nuclear accidents [1].

Radionuclides can be deposited to the sand and soil in various ways. The uranium, thorium series and potassium-40 are the most common radionuclides present in most material. All radionuclides release ionizing radiation. Ionizing radiation may cause cancer. Any amount of radiation dose may cause stochastic effect (e.g. cancer etc.). Uncontrolled radiation from any source is harmful to the occupational workers, public and environment.

Assessment of any release of radioactivity to the environment is important for the protection of public health; especially if the released radioactivity is a matter of direct population exposure and can enter into the food chain [3].

Beach sand or soil is mineral deposits formed through the weathering and erosion of rocks. These deposits found at different levels within the sand contain natural

*Corresponding author.

radionuclides that contribute to ionizing radiation exposure on earth [4]. Kuakata Seabeach of Patuakhali is one of the attractive tourist places in Bangladesh. An attempt has made in this study to determine the concentration of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in beach sand and soil samples collected from Kuakata Seabeach of Patuakhali using HPGe gamma ray spectrometer and to compute the total absorbed gamma dose rate in air due to the presence of ^{238}U, ^{232}Th and ^{40}K in the samples.

2. Materials and Method

2.1. The Study Area

Kuakata Seabeach is the area of interest in the present study, which is located at Patuakhali district in Bangladesh. The study area is situated at about 65 kilometer away and to the north of Patuakhali. The locations of sample collection are shown in **Figure 1**. The sand samples were collected from the beach area while the soil samples were collected from adjacent locality around the beach.

2.2. Collection and Preparation of Samples

For the measurement of natural radionuclides at the study area, a total of 15 sand samples and 7 soil samples were collected from in and around the seabeach areas. Each sample was taken maintaining a distance of about 1 km from each other. About 0.75 - 1.00 kg of sample was collected from each location and each of the samples was placed in plastic packet and transported to the laboratory. Each of the collected sand and soil samples was first weighed, then dried at about 110˚C in an oven for 24 hours and there after ground into a 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. All the sample containers were 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.

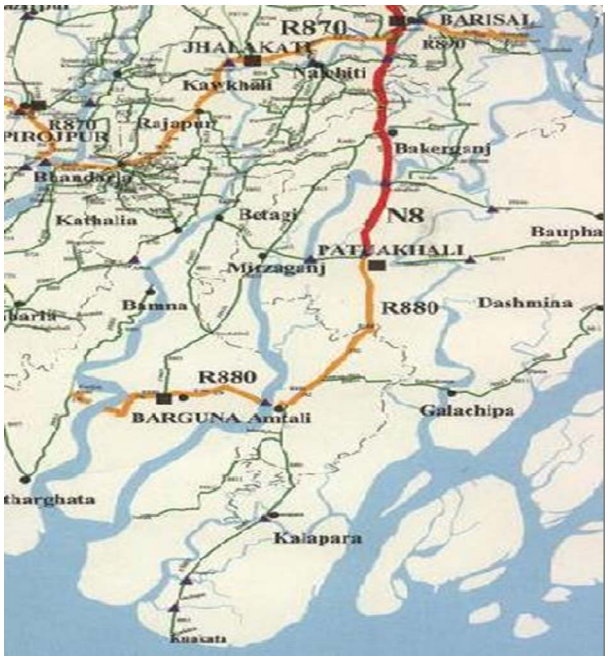

Figure 1. Geographical location of SAMPLING area.

2.3. Data Collection and Analysis

After adjustment of necessary parameters such as resolution, peak to Compton ratio etc. and measurement of minimum detectable activity of the detectors, each of the collected samples was placed on the top of the HPGe detector within the shielding arrangement and counted for above 10,000 seconds. 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

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

where, A is the activity concentration in Bq·kg^{-1}, CPS is the net peak counts per second of the samples, W is the weight of the sample in gm, $\varepsilon(abs)$ is the absolute gamma peak detection efficiency, $I_r(abs)$ is the absolute gamma intensity of the corresponding gamma ray energy. Gamma rays intensities were taken from the literature [5]. 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 2**. 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).

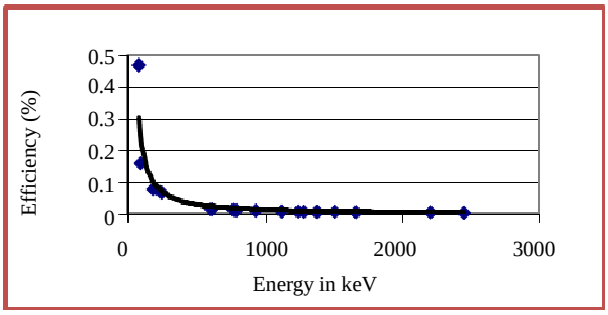

Figure 2. Efficiency curve of HPGe detector.

Most prominent gamma energy peaks of 351.92 keV (due to ^{214}Pb) and 609.31 keV (due to ^{214}Bi) were used to determine ^{226}Ra; 911.07 keV (due to ^{228}Ac) and 969.11 keV (due to ^{228}Ac) were used to determine ^{232}Th; 1460.75 keV was used to determine ^{40}K and 661.66 keV was used to determine ^{137}Cs.

2.4. Radiological Hazard Assessment

2.4.1. Radium Equivalent Activities

The radium equivalent activity is an index that represents the specific activities of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity which takes into account the radiation hazards associated with them. This can be calculated using the equation below [4] as

$$\mathrm{Ra}_{eq} = C_{\mathrm{Ra}} + 1.43C_{\mathrm{Th}} + 0.077C_{\mathrm{K}} \quad (3)$$

where C_{Ra}, C_{Th} and C_{K} are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq·Kg^{-1} respectively. The maximum value of Ra_{eq} in building materials must be <370 Bq·Kg^{-1} for safe use [4].

2.4.2. Representative Level Index Values

Another radiation hazard index called the representative level index, used to estimate the level of gamma radiation associated with different concentrations of some specific radionuclides, can be defined as follows [6]

$$I_{\gamma r} = \frac{C_{\mathrm{Ra}}}{150} + \frac{C_{\mathrm{Th}}}{100} + \frac{C_{\mathrm{K}}}{1500} \quad (4)$$

where C_{Ra} ,C_{Th} ,C_{K} are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq·Kg^{-1} were calculated for the samples under investigation to indicate different levels of external γ-radiation due to different combination of specific natural activities in other materials. This index can be used to estimate the level of γ-radiation hazard associated with the natural radionuclide in the materials.

2.4.3. Dose Rate Calculation

The formula given in the UNSCEAR (1998) report was used to estimate the absorbed gamma dose rate in outdoor air due to natural radionuclides from the beach sand and soil one metre above the surface [1] as

$$D = 0.427C_{\mathrm{Ra}} + 0.662C_{\mathrm{Th}} + 0.0432C_{\mathrm{K}} \quad (5)$$

where C_{Ra} C_{Th} and C_{K} are specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq·Kg^{-1}. The total absorbed dose rate for the present studied samples from a height of one meter above the ground surface as shown in **Table 3**.

3. Results and Discussions

The natural radioactivity level of sand and soil samples collected from Kuakata sea beach of Patuakhali district in Bangladesh were measured using high purity germanium (HPGe) detector. The activity concentration of ^{226}Ra in sand samples ranged from 2.82 ± 4.89 to 87.96 ± 4.45 Bq·Kg^{-1} with an average value of 29.48 ± 3.85 Bq·Kg^{-1}. The concentration of ^{232}Th in sand samples ranged from 21.72 ± 16.27 to 290.93 ± 18.15 Bq·Kg^{-1} with an average value of 93.72 ± 15.62 Bq·Kg^{-1} and the concentration of ^{40}K in sand samples ranged from 26.24 ± 0.35 to 852.05 ± 142.15 Bq·Kg^{-1} with an average value of 551.24 ± 109.95 Bq·Kg^{-1}.

The activity concentration of ^{226}Ra in soil samples ranged from 20.98 ± 3.96 to 42.92 ± 4.76 Bq·Kg^{-1} with an average value of 29.19 ± 4.88 Bq·Kg^{-1}. The activity concentration of ^{232}Th in soil samples ranged from 59.25 ± 15.62 to 144.34 ± 18.52 Bq·Kg^{-1} with an average value of 90.56 ± 17.94 Bq·Kg^{-1} and the concentration of ^{40}K in soil samples ranged from 570.43 ± 100.3 to 1165 ± 166.27 Bq·Kg^{-1} with an average value of 874.89 ± 119.96 Bq·Kg^{-1}.

The mean activity concentration of ^{226}Ra, ^{232}Th and ^{40}K Bq·Kg^{-1}; range and mean values of activity concentrations; radium equivalent activities (Ra_{eq}) in Bq·Kg^{-1}, representative level index values ($I_{\gamma r}$), dose rate (D) in nGy·h^{-1} are shown in the **Tables 1-3** respectively. The mean activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in sand and soil samples are shown graphically in **Figures 3** and **4** respectively. Since no ^{137}Cs radionuclide was detected in any of the sand and soil samples, it indicates that there is no fission product present in the sand and soil samples of Kuakata seabeach.

From the activities given in **Table 1**, activity ratios of ^{232}Th and ^{226}Ra were computed for all the sand and soil samples. These ratios (^{232}Th/^{226}Ra) varied from 1.68 to 8.57 (mean: 4.45) for all the sand samples and 2.14 to 4.57 (mean: 3.17) for all the soil samples indicating that the concentration of ^{232}Th is greater than that of ^{226}Ra.

From **Table 1**, it has observed that the mean activity of ^{226}Ra (29.48) in sand is about 1.18 times higher than that of the world average (25 Bq·Kg^{-1}) [7] and the mean activity of ^{226}Ra (29.19) in soil is about 1.17 times higher than that of the world average (25 Bq·Kg^{-1}) [7], whereas the mean activity of ^{232}Th (93.72) in sand is about 3.75 times higher than that of the world average (25 Bq·Kg^{-1}) [7] and the mean activity of ^{232}Th (90.56) in soil is about

Table 1. The mean activity concentration of the measured radionuclides in sand and soil samples in Kuakata seabeach of Patuakhali.

Name of sample	Specific activity of radionuclides in Bq·Kg^{-1} ± 2 σ			
	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
	Sand Sample of Kuakata			
K.S-1	42.39 ± 4.33	150.68 ± 13.8	26.24 ± 0.35	**ND**
K.S-2	13.29 ± 3.28	48.195 ± 13.64	516.16 ± 122.92	**ND**
K.S-3	16.70 ± 0.29	143.22 ± 15.71	540.74 ± 118.00	**ND**
K.S-4	18.62 ± 3.33	58.53 ± 16.81	669 ± 129.96	**ND**
K.S-5	10.42 ± 2.01	61.23 ± 7.97	479 ± 63.94	**ND**
K.S-6	87.96 ± 4.45	81.32 ± 17.16	545.32 ± 126.22	**ND**
K.S-7	17.35 ± 4.09	61.22 ± 10.05	515.66 ± 115.63	**ND**
K.S-8	2.82 ± 4.89	21.72 ± 16.27	843.28 ± 129.6	**ND**
K.S-9	85.26 ± 4.60	290.93 ± 18.15	408.02 ± 104.22	**ND**
K.S-10	39.89 ± 4.24	139.53 ± 16.6	412.41 ± 104.26	**ND**
K.S-11	22.09 ± 4.66	80.59 ± 17.4	562.57 ± 125.52	**ND**
K.S-12	11.28 ± 4.6	72.39 ± 18.42	766.86 ± 135.9	**ND**
K.S-13	54.20 ± 4.10	91.50 ± 16.92	542.05 ± 119.85	**ND**
K.S-14	6.60 ± 4.70	44.55 ± 18.58	852.05 ± 142.15	**ND**
K.S-15	13.33 ± 4.23	60.17 ± 16.80	589.26 ± 124.76	**ND**
	Soil sample of Kuakata			
K.M-1	32.28 ± 5.46	69.24 ± 12.7	1073 ± 154.85	**ND**
K.M-2	42.92 ± 4.76	144.34 ± 18.52	662.27 ± 115.11	**ND**
K.M-3	20.98 ± 3.96	59.25 ± 15.62	661.67 ± 11.1	**ND**
K.M-4	31.53 ± 5.39	88.26 ± 20.24	1052.71 ± 151.91	**ND**
K.M-5	30.12 ± 4.49	66.33 ± 18.61	939.186 ± 140.23	**ND**
K.M-6	24.17 ± 4.39	110.54 ± 17.57	570.43 ± 100.3	**ND**
K.M-7	22.37 ± 5.69	96.00 ± 22.36	1165 ± 166.27	**ND**

Table 2. Range and mean value of activity concentrations of ^{226}Ra, ^{232}Th & ^{40}K in Bq·Kg^{-1} of the samples.

Radionuclides	Sample type	Minimum	Maximum	Mean
^{226}Ra	Sand	2.82 ± 4.89	87.96 ± 4.45	29.48 ± 3.85
	Soil	20.98 ± 3.96	42.92 ± 4.76	29.19 ± 4.88
^{232}Th	Sand	21.72 ± 16.27	290.93 ± 18.15	93.72 ± 15.62
	Soil	59.25 ± 15.62	144.34 ± 18.52	90.56 ± 17.94
^{40}K	Sand	26.24 ± 0.35	852.05 ± 142.15	551.24 ± 109.95
	Soil	570.43 ± 100.3	1165 ± 166.27	874.89 ± 119.96

Table 3. Radium equivalent activities (Ra_{eq}) in Bq·Kg^{-1}, Representative level index values ($I_{\gamma r}$) in Bq·Kg^{-1}, Dose rate (D) in nGy·h^{-1} in Sand and Soil samples in Kuakata seabeach of Patuakhali.

Sample ID.	Ra_{eq} in Bq·Kg^{-1}	$I_{\gamma r}$ in Bq·Kg^{-1}	Dose rate in nGy·h^{-1}
	Sand sample of Kuakata		
K.S-1	259.88	1.81	118.98
K.S-2	121.95	0.92	59.78
K.S-3	263.14	1.91	125.19
K.S-4	153.83	1.15	75.47
K.S-5	134.86	1.00	65.58
K.S-6	246.24	1.77	114.84
K.S-7	144.60	1.07	70.11
K.S- 8	98.81	0.80	51.84
K.S-9	532.71	3.75	246.55
K.S-10	271.17	1.94	127.14
K.S-11	180.65	1.33	86.97
K.S-12	173.85	1.31	85.71
K.S-13	226.78	1.64	107.02
K.S-14	135.91	1.06	68.95
K.S-15	144.75	1.08	70.86
	Soil sample of Kuakata		
K.M-1	213.91	1.63	105.76
K.M-2	300.32	2.17	142.36
K.M-3	156.66	1.17	76.63
K.M-4	238.80	1.79	117.16
K.M-5	197.29	1.49	97.16
K.M-6	226.17	1.64	108.03
K.M-7	249.35	1.89	123.19

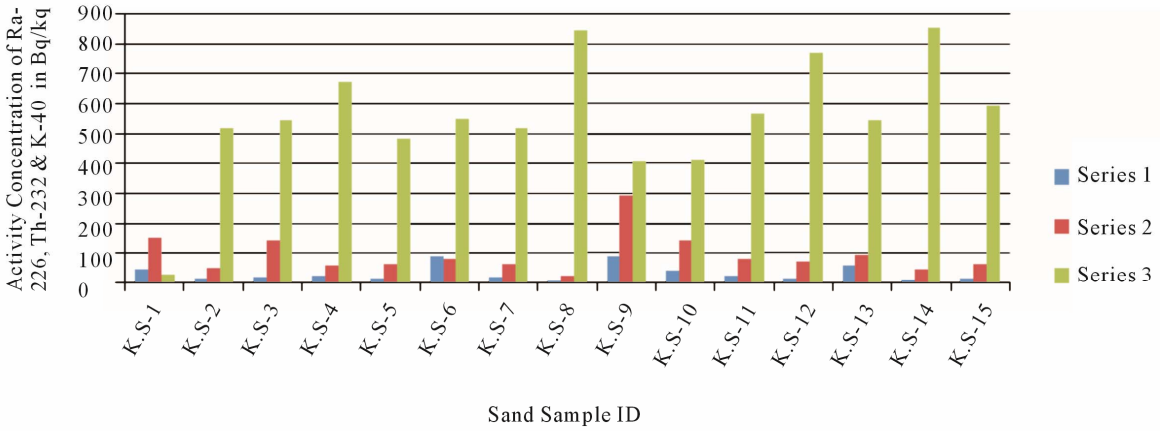

Figure 3. Mean activity concentration of ^{226}Ra, ^{232}Th & ^{40}K in Bq·Kg^{-1} in the sand samples.

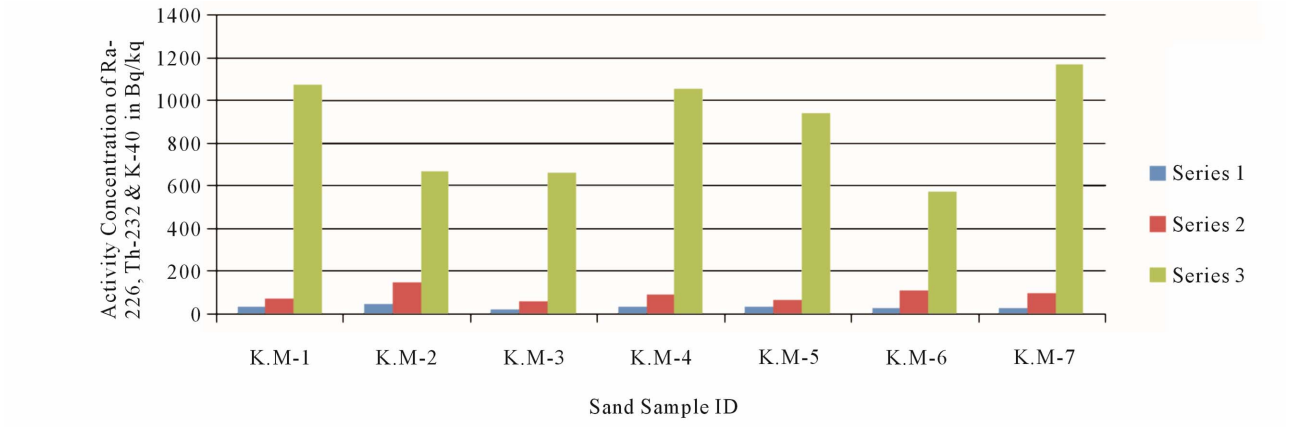

Figure 4. Mean activity concentration of ^{226}Ra, ^{232}Th & ^{40}K in Bq·Kg^{-1} in the soil samples.

Table 4. Activity concentration of radionuclides in sand or soil samples from different parts of the world.

Location	^{226}Ra	^{232}Th	^{40}K	Reference
USA	4 - 140	4 - 130	100 - 700	[10]
Louisiana (USA) (soil)	43 - 95	50 - 190	43 - 729	[11]
Nile Delta (Egypt) (soil)	17	19	316	[12]
Lake Nasser, Egypt	4 - 41	9 - 50	16 - 487	[13]
Dhaka City, Bangladesh	21 - 43	9 - 22	402 - 705	[14]
Chittagong, Bangladesh	15 - 18	7 - 39	128 - 610	[15]
Kalpakkam, Tamilnadu (soil)	5 - 71	15 - 776	200 - 854	[1]
Kalpakkam, Tamilnadu (sand)	36 - 258	352 - 3872	324 - 405	[1]
Peshwar, Pakistan	65	84	646	[16]
Northeast Coast, Spain (sand)	5 - 19	5 - 44	136 - 1087	[17]
Kuwait	36	6	227	[18]
Zircon, Bangladesh	6439	1324	472	[19]
World average	25	25	370	[7]
Sand of Kuakata seabeach	**29.48 ± 3.85**	**93.72 ± 15.62**	**551.24 ± 109.95**	**Present study**
Soil of Kuakata seabeach	**29.19 ± 4.88**	**90.56 ± 17.94**	**874.89 ± 119.96**	**Present study**

3.62 times higher than that of the world average (25 Bq·Kg^{-1}) [7]. ^{40}K mean activity (551.24) in sand is 1.48 times higher than that of the world average (370 Bq·Kg^{-11}) [7] and mean activity (874.89) in soil samples is 2.36 times higher than that of the world average (370 Bq·Kg^{-1}) [7].

It can be observed from **Table 3** that the calculated total dose rate due to the presence of ^{226}Ra, ^{232}Th and ^{40}K in sand varied from 51.84 to 246.55 nGy·h^{-1} with an average of 98.33 nGy·h^{-1}, which is 1.78 times higher than the world average value (55 nGy·h^{-1}) [8] and in soil varied from 76.63 to 142.36 with an average value of 110.04 nGy·h^{-1}, which is 2 times higher than the world average value (55 nGy·h^{-1}) [8].

The experimental results of radium equivalent activity (**Table 3**) which indicate radiation hazards arising from the various beach samples (sand and soil) studies show that the average Ra_{eq} values are below the internationally acceptable value of 370 Bq·Kg^{-1} [9].

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 4**.

The activity concentrations of the radionuclides in the sand and soil samples collected from Kuakata seabeach are within the range of values reported in the other work

performed in home and abroad.

4. Conclusion

The present environmental radiation level on the sand and soil of Kuakata seabeach at Patuakhali district in Bangladesh has been carried out by using gamma spectrometry system. The mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in beach sand and soil, dose rate and other calculated hazard indices are comparable with the world average. The study also reflects that there is no fallout ^{137}Cs in the sand and soil samples of the area under investigation. Finally it can be concluded that no harmful radiation effects are pose to the public and tourists going to the beaches for recreation or to the sailors and fishermen involved in their activities in the area as a results of the activity of beach sand and soil.

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