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Measurement of Radioactivity for the Assessment of Radiological Risk in Sand Sample Collected From Kuakata and Cox's Bazar Sea Beach Located in Bangladesh

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ABSTRACT

Radiation can cause harm to the health of the public who stay with various coastlines as sand can contain various types of harmful radionuclides. In this current study, activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th & ^{40}K in fourteen sand samples gathered from Kuakata (eight samples) sea beach and Cox's Bazar (six samples) sea beach are measured through gamma-ray spectroscopy system by means of HPGe detector. The range of activity concentration of ^{226}Ra, ^{232}Th & ^{40}K of sand samples from Kuakata sea beach are varied from 24.48 ± 2.17 to 76.14 ± 3.25, from 9.22 ± 2.15 to 46.80 ± 2.17 & from 76.23 ± 12.34 to 458.65 ± 17.04 Bqkg^{-1} respectively; and from Cox's Bazar sea beach are from 14.12 ± 2.75 to 75.54 ± 3.15, from 10.28 ± 1.95 to 53.37 ± 2.75 & from 56.42 ± 10.16 to 341.22 ± 14.64 Bqkg^{-1} respectively. Radium equivalent activity associated with sand samples from Kuakata sea beach is found to be from 61.02 to 163.14 Bqkg^{-1}, and from Cox's Bazar sea beach is found to be from 49.17 to 153.1 Bqkg^{-1} respectively. Internal & External hazard indices associated with the sand samples from Kuakata sea beach are from 0.23 to 0.65 & from 0.16 to 0.44 respectively; and from Cox's Bazar sea beach to be varied from 0.17 to 0.62 and 0.13 to 0.41 respectively. The annual effective dose associated with these sand samples from Kuakata sea beach is found to be varied from 0.20 to 0.53 mSvy^{-1}and from Cox's Bazar sea beach is found to be varied from 0.17 to 0.49 mSvy^{-1}. Artificial radionuclide is not observed in the collected samples. The findings are quite comparable with other countries' similar studies. The findings obtained in this current investigation can be considered baseline database in Kuakata and Cox's Bazar sea beach for the radiological protection of people.

Keywords: Terrestrial radiation, HPGe detector, External & Internal Hazard Index, Effective dose.

1. Introduction

Radiation means rapid transfer of energy through waves or particles. The typical value of radioactivity present in the residue (soil) and sand is a significant reason for outside gamma-ray openness. There are a couple of spots that exhibit a significant level of radiation due to the geographical and geochemical impacts. The recorded past radiation degree is extreme inside the seashore sands because of the presence of Thorium (Th) and Uranium (U) bearing minerals which incorporates monazite and zircons. It is very important to measure gamma-ray activity concentrations for the naturally occurring radionuclides ^{232}Th, ^{226}Ra, and ^{40}K in the sand samples collected from the popular sea-beaches of Bay of Bengal in Bangladesh [1]. Sand is sourced from surface wash disintegration of hill slopes, ravine disintegration, and ocean seashore disintegration. Bangladesh has three widely acclaimed seashores as the sightseers' resort, one is the longest and quite possibly the most famous travel industry focus in the world is the Cox's Bazar seashore, and the other is the Kuakata seashore, Potuakhali in Bangladesh. Each of these seashores is positioned on the bank of Bay of Bengal. Usual amount of radioactivity present in sediment and sand is one of the vital causes of outside gamma-ray contact. Natural radionuclides present in beach sand samples are the main resources of both internal and external radiation contact of the citizens existing in coastal areas. Measurement of radioactivity in soil, sand, and sediment sample was evaluated in Kuakata and Cox's Bazar sea beach in Bangladesh long ago between 2012-2014 [2-4] and some soil, sand, and sediment sample from Kuakata and Cox's Bazar sea beach showed high levels of radium equivalent activity, absorbed dose rate, external & internal hazard index and annual effective dose which exceeded the recommended safety limit. As tourists visit these places consistently because of its beauty-continuous assessment of radioactivity in sand, soil, and sediment samples is required for the protection of the tourist and inhabitants living nearby. Current study aims to provide baseline database on natural (^{226}Ra, ^{232}Th, and ^{40}K) and artificial radioactive isotopes and assessment of environmental pollution associated with fourteen sand samples collected from Kuakata (eight samples) and Cox's Bazar (six samples) sea beaches in Bangladesh using gamma spectroscopy system consist of high purity germanium detector.

2. Materials and Methodology

2.1 Description of the study area

To evaluate radioactivity concentration in the beach sands, fourteen sand samples are collected from various locations. The first eight samples are collected from Kuakata sea beach which is named K1, K2, etc (Latitude**:** 21°48'49"-21°48'5 North and Longitude**:** 90°7'25"-90°10'39" East). Among them, the first four samples are collected

maintaining a 500-meter distance from each & the last four samples are collected keeping one-kilometer distance from each other. Six samples are collected maintain one-kilometer distance from Cox's Bazar sea beach named C9, C10, etc (Latitude: 21°25'40-21°24'23" North and Longitude: 91°58'14"-91°59'20" East).

2.2 Sample Preparation and Measurement

Upon collection, the sand samples are heated (by the sunlight) for the removal of moisture. Then the packaging of all collected samples is done appropriately and marked with respective code. Then the collected samples are securely transported, properly processed, and stored in sample preparation and storage facility of Health Physics Division in Atomic Energy Centre Dhaka (AECD). After the collection of samples, unexpected substance like organic debris, stones roots and vegetation, are separated from the samples. Then sand samples are dried carefully approximately at 105˚C-110˚C. After drying, the samples are crashed with the help of mortar and pestle, then homogenized, then screened with the help of test sieve having aperture 425 micrometer, and then weighted. Then samples are kept in cylindrical size plastic containers having height 7 cm & diameter 5.5 cm and by means of an electrical balance, the weights of the samples are measured. These containers were closed firmly by using cap and covered by thick vinyl tape round their necks; individually spotted with associated number and date of sample preparation & net weight and kept in storage facility for approximately thirty days in order to obtain secular equilibrium among ^{238}U and ^{232}Th series and their respective daughter progenies [5, 6]. The processed sand samples are then measured by using a HPGe detector coupled by a digital spectrum analyzer (DSPEC jr 2.0). The following Fig.1 represents the block diagram of the high-purity germanium (HPGe) detector system.

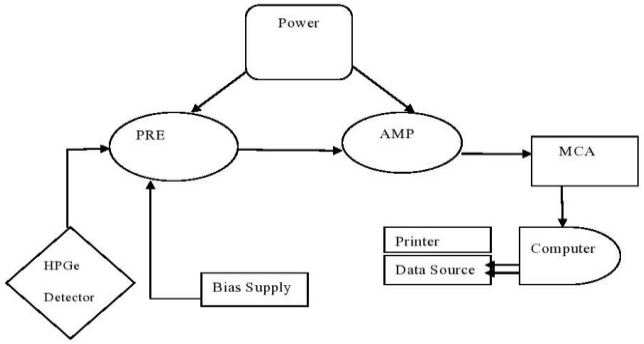

Fig. 1: Block diagram of the HPGe detecting system.

The volume of used detector was found to be 83.47 cm^3 and the energy resolution by 1.33 MeV energy peak of ^{60}Co is found to be 1.69 keV obtained on full width half maximum value having 19.6% relative efficiency. All the collected samples and background were measured for same duration 5000s.

In this research, the gamma reference sources like ^{137}Cs (monoenergetic gamma source), ^{60}Co, and ^{40}K are carefully used aimed for energy calibration owing to the broad-ranging of energies of gamma-ray emitted through whole relevant energy series. For determination of counting efficiency, a standard source is properly prepared by adding Eu^{152} of known activity with the Al_2O_3 matrix. By using this standard source, the associated efficiency [7] graph of the HPGe detector was drawn.

$$\text{Efficiency} = \frac{\text{CPS}}{\text{DPS}\times I_\gamma} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, CPS represents the counts per unit second for radionuclides present in the standard sample, DPS is the disintegration per second and I_γ is the γ-ray Emission probability

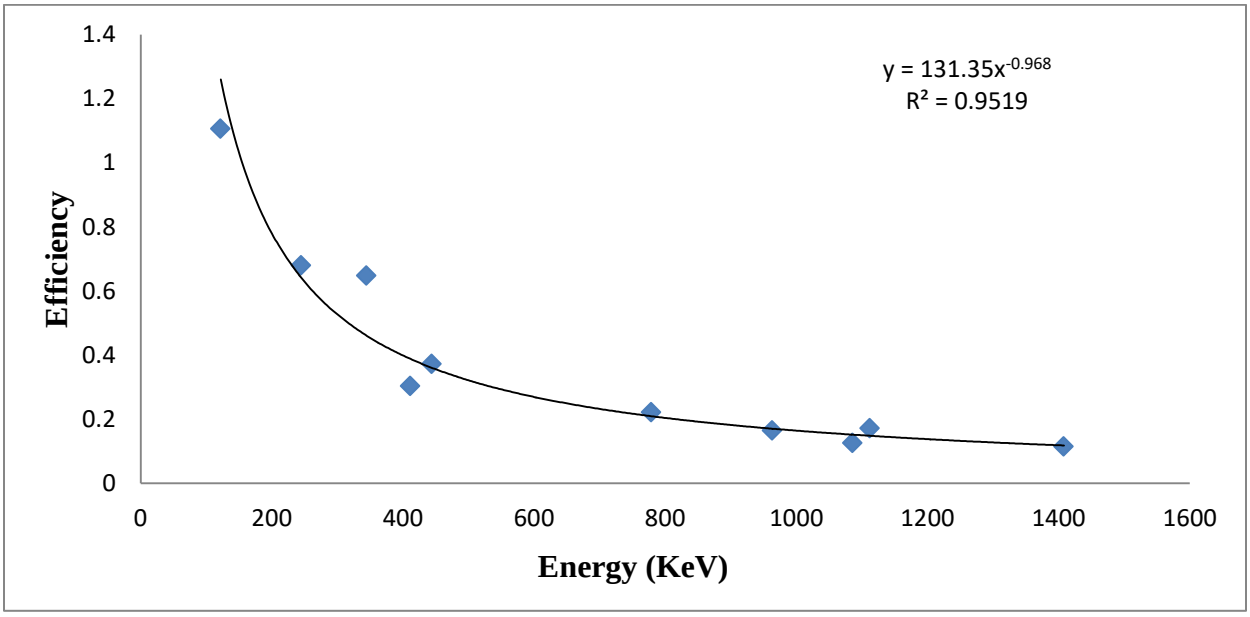

Fig. 2 Efficiency graph of HPGe Detector for solid samples

2.3 Activity Calculation and error calculation

Activity concentration of ^{226}Ra, ^{232}Th has been calculated from daughter nuclides [^{214}Pb (295.21 keV), ^{214}Pb (351.92 keV), ^{214}Bi (609.31 keV), ^{214}Bi (1120.29 keV), ^{214}Bi (1764.49 keV)] for ^{226}Ra and [^{212}Pb (238.63 keV), ^{208}Tl (583 keV), ^{228}Ac (911.07 keV), ^{228}Ac (969.11 keV)] for ^{232}Th respectively [5].

Activity concentration of individual radionuclides in sand samples is calculated using:

$$A = \frac{cps}{\varepsilon \times P\gamma \times w} \text{ .... (2)}$$

Where

A is the activity in collected sample in $BqKg^{-1}$

CPS is net counts per unit second

=CPS for the collected sample – CPS the measured background value

ε is counting efficiency of respective gamma energy

Pγ is the absolute intensity of gamma-ray and

w is the net weight (sample weight) (in gm)

Disintegration of radionuclide is a nonstop and random process; true activity of sample may be estimated only. The percentage of sample counting error [7] is found by means of the following relation:

$$\sigma = \sqrt{\frac{N_t}{{T_t}^2} + \frac{N_b}{{T_b}^2}} \text{ .... (3)}$$

Where σ represents the standard deviation; N_t represents the counts for collected samples; N_b represents counts of background; T_t represents counting time of N_t and T_b is counting time of N_b.

2.4 Radium Equivalent Activity

Natural radionuclides for example ^{226}Ra, ^{40}K and ^{232}Th always do not consistently circulated in sand. Non homogeneous circulation of the radionuclides is because of disequilibrium among ^{226}Ra & its associated decay creations. For the determination of the radiological consequences due to ^{226}Ra, ^{232}Th & ^{40}K by a distinct parameter, a specific indicator called radium equivalent activity (Ra_{eq}) [7] is used as:

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \text{......... (4)}$$

Here A_{Ra}, A_{Th} & A_K represents specific activities of ^{226}Ra, ^{232}Th & ^{40}K, individually in the unit $Bqkg^{-1}$.

2.5 Absorbed dose rate

Impacts of the gamma radiation often indicated as absorbed dose rate situated in air, which comes from the radioactive nuclides from sand. Absorbed dose rate ($nGyh^{-1}$)on air at one meter above ground exterior because of radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the soil is estimated by means of the following method described in UNSCEAR 2000 [8] as:

$$D_{out} = 0.462A_{Ra} + 0.604A_{Th} + 0.042\,A_K. \text{......(5)}$$

The indoor contribution is usually 1.2 times larger than relevant outdoor dose; indoor absorbed dose rate [8] is calculated by using the formula:

$$D_{in} = D_{out} \times 1.2(nGyh^{-1}) \text{ .... (6)}$$

2.6 External and Internal Hazard Indices

Sand can contribute to outdoor gamma dose rates for public. External hazard index (H_{ex}) [7] is obtained by the external exposure to gamma radiation and is calculated through:

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \text{...... (7)}$$

Internal hazard index (H_{in}) [7] gives rise to internal exposure due to carcinogenic radon &associated short-lived offspring and is obtained by following formula:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \text{ .... (8)}$$

Calculated values of H_{ex} and H_{in} must be lower than unity in order to retain radiation threat unimportant [8].

2.7 (Outdoor and indoor) Annual effective dose

Outdoor annual effective dose & the associated indoor annual effective dose ($mSvy^{-1}$)[8] can be considered using the formula:

$$E_{out} = D \times 8760 \times 0.2 \times 0.7 \times 10^{-6} \text{ .... (9)}$$

$$E_{in} = D \times 8760 \times 0.8 \times 0.7 \times 10^{-6} \text{........ (10)}$$

3. Results and Discussion

The calculated activity concentrations of the radionuclides in the collected sand samples are represented in the following Table-1. The table shows that, the activity concentration of ^{226}Ra, ^{232}Th & ^{40}K nuclide varies from a minimum of 14.12 ± 2.75 to a maximum of 76.14 ± 3.25 $Bqkg^{-1}$, 9.22 ± 2.15 to 53.37 ± 2.75 $Bqkg^{-1}$ and 56.42 ± 10.16 to 458.65 ± 17.04 $Bqkg^{-1}$ respectively. The minimum and maximum external & internal hazard indices are 0.13 and 0.44, 0.17 and 0.65 respectively which are lower than the permissible limit in the world of Hazard Index which is unity [8].

In the Table 1, the calculated minimum & maximum values of outdoor and indoor absorbed dose rates are to be from 24.3 to 74.8 $nGyh^{-1}$ and 29.1 to 89.7 $nGyh^{-1}$ respectively. The recommended value of annual effective dose is 1.0 $mSvy^{-1}$ to allow radiation threat insignificant [8]. The measured external and internal effective dose revealed in Table 1 is from 0.01 to 0.09 $mSvy^{-1}$, 0.14 to 0.44 $mSvy^{-1}$, which shows the non-dangerous nature of the sand samples.

Radium equivalent activity & total annual effective doses related with the samples are given in Fig. 3 and Fig. 4. From Fig. 3, the minimum and maximum radium equivalent activity of sand samples are from 46.45 to 163.14 $Bqkg^{-1}$.It is under the world allowable limit of 370 $Bqkg^{-1}$ as recommended by the UNECEAR 2000 [8, 9]. From Fig. 4, annual effective dose is obtained from 0.17 to 0.53 $mSvy^{-1}$. These obtained results show that the radiation danger in the considered area is insignificant.

Table 1: Activity concentration of radionuclides, hazard index, absorbed dose rate, external & effective dose associated with the sand samples.

Sample ID	Ra-226 $Bqkg^{-1}$	Th-232 $Bqkg^{-1}$	K-40 $Bqkg^{-1}$	External Hazard Index	Internal Hazard Index	Absorbed Dose Rate ($nGyh^{-1}$) D_{out}	D_{in}	External Effective Dose ($mSvy^{-1}$)	Internal Effective Dose ($mSvy^{-1}$)
K1	38.74±3.15	9.22±2.15	359.10±15.69	0.21	0.32	38.1	45.8	0.05	0.22
K2	33.44±2.37	24.81±207	458.65±17.04	0.19	0.37	50.6	60.8	0.06	0.30
K3	27.49±2.19	17.20±2.23	225.99±13.94	0.19	0.26	32.9	39.5	0.04	0.19
K4	43.44±3.25	17.70±2.29	76.23±12.34	0.20	0.32	33.6	40.3	0.04	0.20
K5	42.32±2.31	25.24±1.75	134.47±12.29	0.24	0.35	40.6	48.7	0.05	0.24
K6	24.48±2.17	18.64±1.57	128.32±13.06	0.16	0.23	28.3	34	0.03	0.17
K7	76.14±3.25	46.80±2.17	260.65±13.20	0.44	0.65	74.8	89.7	0.09	0.44
K8	43.71±2.19	14.65±2.91	103.88±11.47	0.20	0.31	32.9	39.4	0.04	0.19
C9	75.54±3.15	51.20±2.29	56.42±10.16	0.41	0.62	68.6	82.3	0.08	0.40
C10	55.69±2.19	27.47±2.39	341.22±14.64	0.33	0.48	56.7	68.1	0.07	0.33
C11	66.18±2.51	53.37±2.75	121.60±11.49	0.41	0.59	68.8	82.6	0.08	0.41
C12	61.48±2.37	43.36±2.85	228.17±13.36	0.38	0.55	64.8	77.8	0.08	0.38
C13	14.12±2.75	10.28±1.95	264.25±13.89	0.13	0.17	24.3	29.1	0.03	0.14
C14	51.02±2.95	31.27±2.89	191.40±12.90	0.30	0.44	50.8	60.9	0.01	0.30
Min	14.12±2.75	9.22±2.15	56.42±10.16	0.13	0.17	24.3	29.1	0.01	0.14
Max	76.14±3.25	53.37±2.75	458.65±17.04	0.44	0.65	74.8	89.7	0.09	0.44

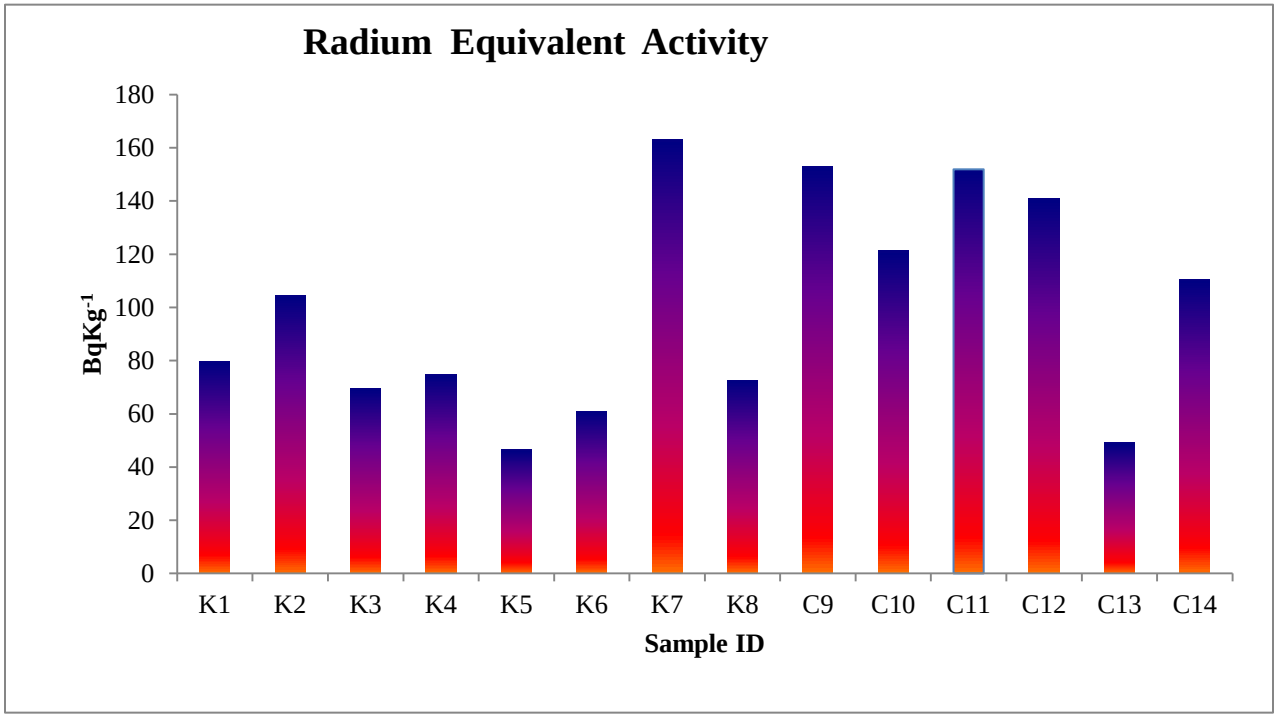

Fig. 3: Graphical representation of radium equivalent activity

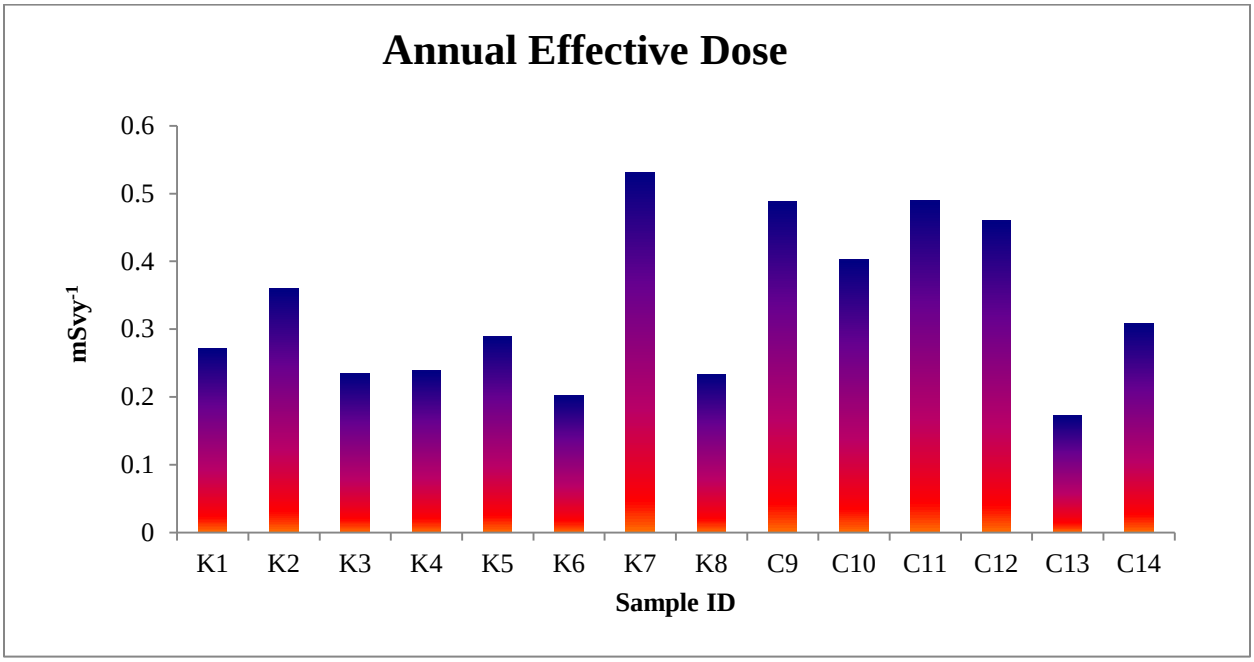

Fig. 4. Graphical representation of annual effective dose

Table 2. Assessment of measured concentration of radionuclides of collected sand samples with home & around the world

Country (Region)	^{226}Ra (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	^{40}K (Bqkg^{-1})
Kuakata beach, Bangladesh [Present study]	24.48-76.14	9.22-46.80	76.23-458.65
Cox's Bazar beach, Bangladesh [Present study]	14.12-75.54	10.28-53.37	56.42-341.22
Kuakata beach, Bangladesh [2]	22.83-100.21	68.76-297.37	75.87-161.81
Kuakata beach, Bangladesh [3]	2.82- 87.96	21.72- 290.93	26.24 - 852.05
Cox's Bazar beach, Bangladesh [4]	12.77-845.32	24.07-1537.93	243.49-453.72
Rosetta beach, Egypt [10]	36.5–177.4	50–397.5	56.1-168.9
Gran Canaria, Spain [11]	8.1-26.7	7.4-41.9	130-1055
Bahia, Brazil [12]	8.4-8300	21-18450	3.4-3110
Sithonia Peninsula [13]	5-767	5-1750	185-875
Montenegro [14]	2.09-15.5	1.4-16.6	7.1-304.9
North-East beach, Madagaskar [15]	91-3199	1574-15391	91-3199
Akkuyu Mersin, Turkey [16]	15.82-39.48	3.96-17.18	133.54-287.06
Adriatic, Albania [17]	8 – 67	5 – 91	43 – 458
Andaman beach, Thailand [18]	1.6-52.5	0.3-73.9	2.8-1111.9

Measured activity concentration of radionuclides found in the collected sand samples shown in this present study is compared with the researches performed in home and outside the country and is represented in the Table 2. Comparison shows the radioactivity level of the collected sand samples in different beaches of Bangladesh and foreign countries is comparable with the current study except for Bahia, Brazil [12] & North-East beach, Madagaskar [15].

4. Conclusion

Overall fourteen sand samples (eight samples from the Kuakata seashoreand six examples collected from Cox's Bazar seashore) have been examined by utilizing HPGe detector having relative efficiency 19.6%. There are no artificial radionuclides found during this study. The obtained average activity concentration of the natural radionuclides ^{226}Ra, ^{232}Th, and ^{40}K of sand samples collected from Kuakata seashore is 41.22 ± 2.56, 21.78 ± 2.27 & 218.41 ± 13.63 Bqkg^{-1}; from Cox's Bazar are from 54.01 ± 2.65, 36.16 ± 2.42 & 200.51 ± 12.74 Bqkg^{-1} respectively. Activity concentrations of collected sand samples are comparable with Bangladesh [2-4] and foreign countries [10-18].The average radium equivalent activity of sand samples from Kuakata seashore is 83.94 ± 35.99 Bqkg^{-1}; from Cox's Bazar is 121.15 ± 39.13 Bqkg^{-1}. All

samples have lower radium equivalent activity than the suggested estimation of 370 $Bqkg^{-1}$[8]. Average internal & external hazard index from Kuakata seashore are 0.35 ± 0.13 & 0.23 ± 0.09; from Cox's Bazar sea beach are 0.48 ± 0.16 & 0.33 ± 0.11 respectively. All values are less than unity which is the recommended limit. The average annual effective dose of these samples from Kuakata is 0.29 ± 0.11 $mSvy^{-1}$; from Cox's Bazar sea beach is 0.39 ± 0.13 $mSvy^{-1}$. Calculated annual effective dose of all the collected sand samples is beneath the admissible limit of 1 $mSvy^{-1}$[8]. In addition, all the radiological hazard parameters studied in sand samples collected from the current study area are inside the suggested safety boundary. This demonstrates that radiation level of the collected sand samples in this current study doesn't cause a health risk. Therefore the sand samples investigated in the study area are viewed as safe for the individuals living in that locality. Further examination should be done on that area on sands as well as on other ecological samples like soil, water, vegetables, and so on. The outcomes from that review focuses on widening baseline information in Bangladesh for radiological safety of individuals living in beachfront zones.

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