

# Study of Natural Radioactivity and Radiological Hazard of Sand, Sediment, and Soil Samples from Inani Beach, Cox's Bazar, Bangladesh

M. M. Ahmed<sup>1,\*</sup>, S. K. Das<sup>1</sup>, M. A. Haydar<sup>2</sup>, M. M. H. Bhuiyan<sup>2</sup>, M. I. Ali<sup>2</sup>, D. Paul<sup>2</sup>

<sup>1</sup>Department of Physics, Jagannath University, Dhaka, Bangladesh

<sup>2</sup>Health Physics & Radioactive Waste Management Unit, INST, BAEC, Savar, Dhaka, Bangladesh

**Abstract** The radionuclide contents and their activity concentrations in beach sand, sediment and adjacent soil samples collected from Inani sea beach, Cox's Bazar, Bangladesh were determined by using a high resolution germanium detector (HPGe) of 20% relative efficiency. A total of eighteen samples of three categories were collected and analysed. The activity concentrations of <sup>226</sup>Ra, <sup>232</sup>Th and <sup>40</sup>K in the sand samples of the beach were found to be varied from  $15.14 \pm 2.62$  to  $28.67 \pm 3.09$  Bqkg<sup>-1</sup>,  $24.39 \pm 2.50$  to  $49.46 \pm 3.58$  Bqkg<sup>-1</sup> and  $362.00 \pm 79.61$  to  $560.87 \pm 81.40$  Bqkg<sup>-1</sup> respectively. For sediment samples the activity concentrations of the corresponding radionuclides ranged between  $18.09 \pm 2.66$  to  $53.32 \pm 4.01$  Bqkg<sup>-1</sup>,  $31.01 \pm 2.73$  to  $78.37 \pm 4.35$  Bqkg<sup>-1</sup>,  $390.26 \pm 76.37$  to  $733.61 \pm 85.80$  Bqkg<sup>-1</sup>, respectively where as for soil samples the values were  $26.11 \pm 2.99$  to  $61.66 \pm 5.88$  Bqkg<sup>-1</sup>,  $41.93 \pm 4.18$  to  $89.39 \pm 6.15$  Bqkg<sup>-1</sup> and  $467.16 \pm 77.62$  to  $1304.11 \pm 147.07$  Bqkg<sup>-1</sup> respectively. The calculated average absorbed dose rates due to these radionuclides in the three types of samples were found as  $52.24$  nGyh<sup>-1</sup>,  $62.96$  nGyh<sup>-1</sup>, and  $104.97$  nGyh<sup>-1</sup>, respectively. The estimated outdoor annual effective dose ranged from  $0.05$  to  $0.08$  mSvy<sup>-1</sup>,  $0.05$  to  $0.11$  mSvy<sup>-1</sup> and  $0.07$  to  $0.17$  mSvy<sup>-1</sup> with the mean values of  $0.06$  mSvy<sup>-1</sup>,  $0.08$  mSvy<sup>-1</sup>, and  $0.13$  mSvy<sup>-1</sup> for sand, sediment, and soil samples, respectively. The values of radium equivalent activity in almost all the samples were less than  $370$  Bq.kg<sup>-1</sup>. On the other hand, the values of external hazard index for sand, sediment, and soil samples varied between  $0.22$  to  $0.37$ ,  $0.25$  to  $0.54$ , and  $0.33$  to  $0.78$  with the average values of  $0.30$ ,  $0.37$ , and  $0.59$ , respectively. The values are less than unity in all the samples that indicate the non-hazardous nature of the samples.

**Keywords** Natural Radionuclides, Radioactivity Concentration, Gamma Spectroscopy, Radium Equivalent Activity, Radiation Hazard Index, Absorbed Dose, Annual Effective Dose

## 1. Introduction

Natural radioactivity is present in the human environment due to the presence of cosmogenic and primordial radionuclides in the earth's crust [1]. Cosmogenic radionuclides are produced by the interaction of cosmic-rays with atomic nuclei in the atmosphere, while primordial ones (terrestrial background radiation) were formed by the process of nucleosynthesis. Human activities like mining and milling of mineral ores, ore processing and enrichment etc. cause the redistribution of the activity concentration on the earth crust. Most of the radioactivity deposited on surface sediment is washed by rains and drained through rivers to the oceans. The naturally occurring radionuclides are relatively and uniformly distributed in the seas and oceans. Radionuclides on reaching the oceans become part of the

marine ecosystem (water, sediments, sands and biota) and may transfer- through seawater-sediments-biota interface to human beings [2]. Accumulation of such substances in the marine coastal environment raises many problems concerning the safety of biotic life, food chain and ultimately human. Due to the fact that radionuclides can have harmful effects on the habitat and can also pose health hazard problems for human, the assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population [3, 4].

Beaches are deposition landforms, and are the result of wave action by which waves or currents move sand or other loose sediments of which the beach is made of as these particles are held in suspension. Beach materials come from erosion of rocks offshore, as well as from headland erosion and slumping producing deposits of scree. These deposits found at different levels within the sand contain natural radionuclides that contribute to ionizing radiation exposure on earth [5].

Inani beach, recently recognized as one of the most

\* Corresponding author:

murad.ahmed.bd@gmail.com (M. M. Ahmed)

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popular tourist spots in Bangladesh, is located at a distance of 35 km to the south of Cox's Bazar sea beach, the longest sea beach in the world. The beach composed of light gray to gray sands [6] has become an attractive spot for tourist due to its fine sands and calm and quiet natural environment. The beach sand is fine to medium in size and its gray color indicates the presence of considerable quantity of fine material mixed with the sand. Since the sand, sediment and the soil adjacent to the beach may contain elevated level of natural radioactivity, therefore, the aim of the present study is to investigate the presence of probable natural radionuclides ( $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ ) and their activity concentration levels in the collected samples and finally determine the radiological effect on the tourist, public and the environment due to these radionuclides [7].

## 2. Methods and Materials

### 2.1. Study Area

Inani beach is the area of interest in the present study, which is located in Ukhia Thana under Cox's Bazar district of Chittagong division. The locations of sample collection under current study are shown in Figure 1 and 2.

### 2.2. Sampling Locations

A total of 18 samples (5-sand, 6-soil and 7-sediment) were collected from the beach area during the period of 11/04/2013 to 13/04/2013. In the present work the soil samples were collected from the adjacent area of the beach, most of which is the cultivated land, whereas sand and sediment samples were collected from the beach area and shore line of the sea, respectively. The coordinates of the sampling area of Inani beach is in between  $21^{\circ}8'55.52''\text{N}$  to  $21^{\circ}9'49.79''\text{N}$  and  $92^{\circ}4'19.11''\text{E}$  to  $92^{\circ}3'21.33''\text{E}$ .



Figure 1. Location map the Inani Beach, Cox's Bazar, Bangladesh



**Figure 2.** Location map of sampling (using Google map) at the Inani Beach, Cox's Bazar, Bangladesh

### 2.3. Sample Collection and Processing

About 1 to 1.25 kg of sample was collected from each sampling location. The samples were collected from equidistant locations with a distance of 100 m from each other and at a depth of 10-15 cm from the surface. Upon collection, all the samples were properly packed and marked for their identification code. The samples were then transported, stored and processed at the sample preparation laboratory of Health Physics and Radioactive Waste management Unit (HPRWMU), Bangladesh Atomic Energy Commission (BAEC), Savar, Dhaka. The samples were cleaned for stones, gravels, grass-roots, vegetation etc. and then dried in the sun for several days. The samples were then crushed and ground to fine grains using a grinding machine. The samples were mixed homogeneously and passed through a sieve of 200  $\mu\text{m}$  mesh size. The samples were dried again in a temperature controlled oven at 104  $^{\circ}\text{C}$  temperature for 24 hours in order to eliminate any traces of water. Upon drying the samples were transferred to sealable cylindrical plastic containers of 7 cm height and 5.5 cm in diameter and the weights (after grinding) of the samples were recorded using an electrical balance. The sample-filled plastic containers were sealed tightly with cap and wrapped with thick vinyl tape around their necks; marked individually

with identification number, sample location, date of preparation and net weight and then stored for about 30 days to assume secular equilibrium between  $^{238}\text{U}$  and  $^{232}\text{Th}$  series and their daughter progenies.

### 2.4. Experimental Procedure

The detection and measurement of radionuclides in the samples were carried out by gamma spectrometry system using a p-type co-axial HPGe detector of 93  $\text{cm}^3$  active volume and 20% relative efficiency supplied by CANBERRA (*Model GC-2018 and serial No. 0408941*). The co-axial geometry with electrical contacts in the form of concentric cylinders closed at the end makes it possible to produce very large volume detector elements with excellent efficiencies for high-energy photons.

The HPGe had a resolution of 2 keV at 1332 keV of Cobalt-60 gamma-ray line. The detector was coupled to a 16 k-channel analyser. The spectra of all samples were perfectly analysed using Genie-2000 spectra analysis software (which matched various gamma energy peaks to a library of all possible radionuclides) to calculate the concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ . The detector was enclosed in a cylindrical shielding container made of lead and iron and having a moving cover to reduce the external gamma-ray

background. All the samples were counted for 10 ks. Prior to the measurement of the samples, the environmental gamma background at the laboratory site was determined with an identical empty plastic container used in the sample measurement. The energy regions selected for the corresponding radionuclides were 295 keV and 352 keV of  $^{214}\text{Pb}$  and 609 keV, 1120 keV and 1764 keV for  $^{214}\text{Bi}$  for  $^{226}\text{Ra}$ , 583 keV and 2614 keV of  $^{208}\text{Tl}$ , 911 keV and 969 keV of  $^{228}\text{Ac}$  for  $^{232}\text{Th}$ , and 1460 keV for  $^{40}\text{K}$  [8]. These are shown in Figure 3(a).

#### 2.4.1. Calibration of the Detector

The efficiency calibration of the detector was carried out by standard source of solid matrix prepared using  $^{226}\text{Ra}$  standard solution. The standard source was prepared using identical container used for the measurement of the samples. The preparation process of standard sources had been reported elsewhere [9]. The efficiency calibration curve as a function of energy for solid matrix is shown in Figure 3(b). The energy calibration of the detector was performed by  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  point sources.

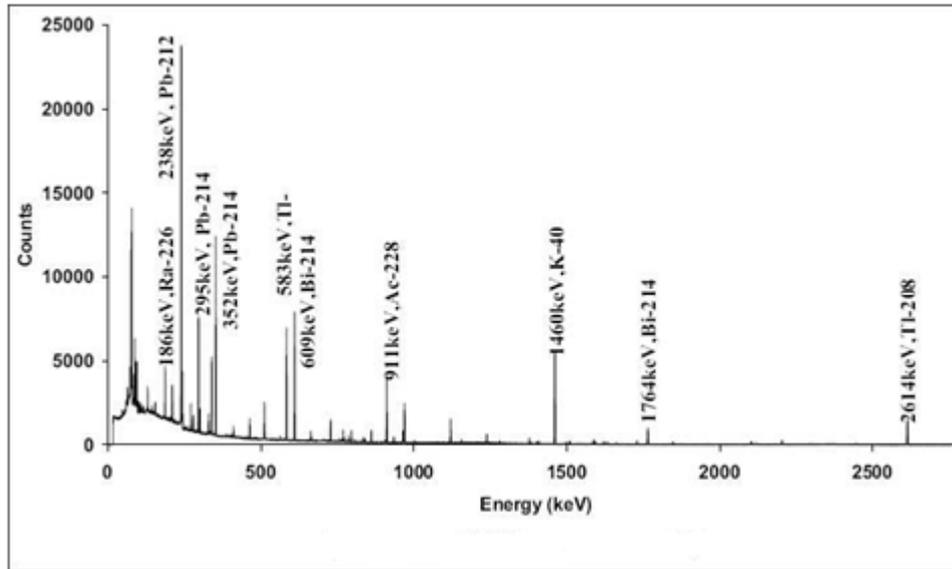


Figure 3(a). Energy diagram of the sample in HPGe detector with 20% efficiency

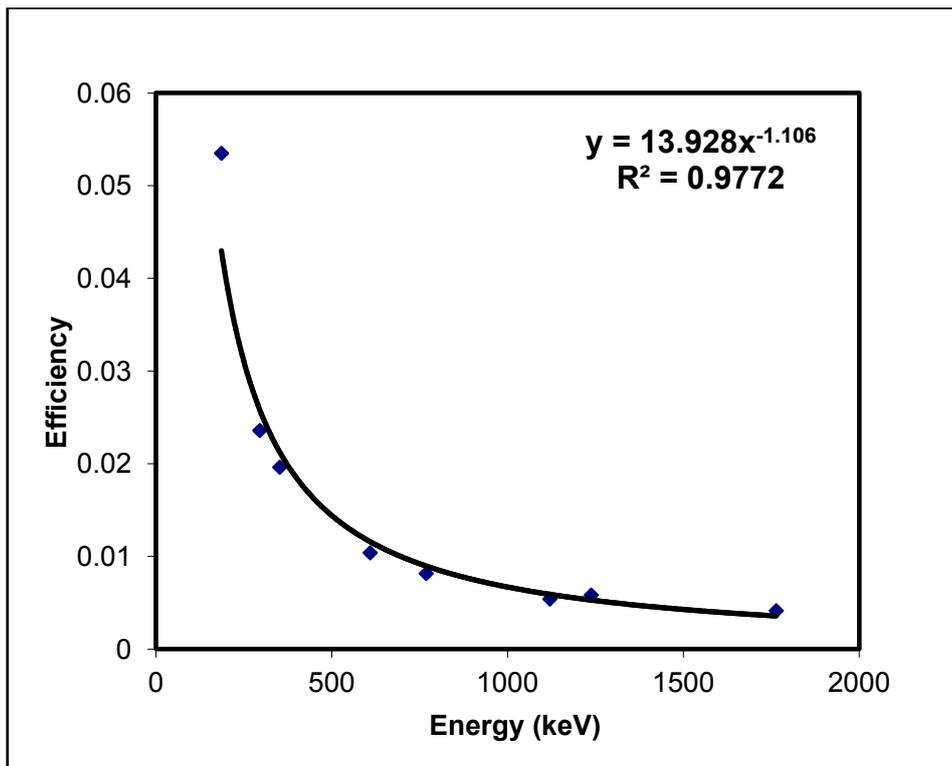


Figure 3(b). Efficiency curve of the HPGe detector for Solid matrix

#### 2.4.2. Calculation of Elemental Concentrations

The activity concentration ( $A$ ) of each radionuclide in the samples was determined by using the net count ( $cps$ ) (found by subtracting the background counts from the gross counts with same counting time under the selected photo peaks), weight of the sample, the photo-peak efficiency and the gamma intensity at a specific energy as [10]:

$$A = \frac{cps \times 1000}{E \times I \times W} \quad (1)$$

Where,  $A$  = activity of the sample in  $Bqkg^{-1}$

$cps$  = the net counts per second = cps for the sample – cps for the background value.

$E$  = the counting efficiency of the gamma energy

$I$  = absolute intensity of the gamma ray and

$W$  = samples net weight (in kg).

The errors in the measurement have been expressed in terms of standard deviation ( $\pm 2\sigma$ ), where  $\sigma$  is expressed as [11]:

$$\sigma = \left[ \frac{N_s}{T_s^2} + \frac{N_b}{T_b^2} \right]^{\frac{1}{2}} \quad (2)$$

Where,  $N_s$  is the counts measured in time  $T_s$  and  $N_b$  is the background counts measured in the  $T_b$ . The standard deviation ( $\pm 2\sigma$ ), in cps was converted into activity in  $Bqkg^{-1}$  according to equation (1).

#### 2.4.3. Calculation of Radiological Hazard

Radiological impacts of the radionuclides found in the samples were calculated on the basis of calculation of radium equivalent activity, dose rate calculation, and effective dose rate and hazard indexes as following:

The radionuclides  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$  are not homogeneously distributed in soil, sand and sediments samples. The inhomogeneous distribution from naturally occurring radionuclides is due to disequilibrium between  $^{226}Ra$  and its decay products. For uniformity in exposure estimates, the radionuclide concentrations are defined in terms of 'Radium equivalent activity' ( $Ra_{eq}$ ) in  $Bqkg^{-1}$ . This allows comparison of the specific activity of materials containing different amounts of  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$  according to Beretka and Mathew as follows [12]:

$$Ra_{eq} (Bqkg^{-1}) = C_{Ra} + 1.43 C_{Th} + 0.077 C_K \quad (3)$$

Where,  $C_{Ra}$ ,  $C_{Th}$  and  $C_K$  are the specific activities of  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$ , respectively in  $Bqkg^{-1}$ .

The absorbed dose rate was calculated from the measured activities of  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$  in the surface soil, sand, and sediment samples using the formula given below [13]:

$$D (nGyh^{-1}) = 0.462C_{Ra} + 0.604C_{Th} + 0.042C_K \quad (4)$$

Where,  $D$  is absorbed dose rate ( $nGyh^{-1}$ ). In natural environmental radioactivity situations, the effective dose is calculated from the absorbed dose by applying the factor is  $0.7 Sv/Gy$  [14].

To estimate the annual effective dose rate, the conversion

co-efficient from absorbed dose,  $0.7 SvGy^{-1}$  and outdoor occupancy factor 0.2 proposed by UNSCEAR, 2000 were used by considering that the people on the average, spent 20% of their time outdoors [15]. The effective dose rate in units of  $mSvy^{-1}$  was calculated by the following formula:

$$E (mSvy^{-1}) = D \times 365.25 \times 0.2 \times 0.7 S \times 10^{-6} \quad (5)$$

The external hazard index,  $H_{ex}$ , is defined as [16]:

$$H_{ex} = (C_{Ra}/370 + C_{Th}/259 + C_K/4810) \leq 1 \quad (6)$$

The value of this index must be less than unity in order to keep the radiation hazard insignificant.

### 3. Results and Discussions

The results of the present study on the three types (Sand, Sediment and Soil) of samples are summarized in following sections.

#### 3.1. Activity Concentrations in Sand, Sediment and Soil Samples

The activity concentrations of  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$  of all the samples were calculated in  $Bqkg^{-1}$  with a counting error of two sigma ( $\pm 2\sigma$ ) and are shown in the Table 1, 2 & 3. The bar diagrams (Figure 4, 5 & 6) show the distribution of the concentrations of all the radionuclides present in the collected samples.

The activity concentrations of  $^{226}Ra$ ,  $^{232}Th$ , and  $^{40}K$  in sand samples were found to be varied from  $15.14 \pm 2.62 Bqkg^{-1}$  to  $25.16 \pm 3.05 Bqkg^{-1}$ ,  $24.39 \pm 2.50 Bqkg^{-1}$  to  $49.46 \pm 3.58 Bqkg^{-1}$ , and  $362.00 \pm 79.61 Bqkg^{-1}$  to  $560.87 \pm 81.40 Bqkg^{-1}$  with the average values of  $21.26 \pm 2.87 Bqkg^{-1}$ ,  $36.64 \pm 3.20 Bqkg^{-1}$ , and  $477.57 \pm 79.80 Bqkg^{-1}$ , respectively. The average values are almost same as measured by K. M. N. Islam et al at Kuakata Sea-Beach of Bangladesh [17].

The activity concentrations of  $^{226}Ra$ ,  $^{232}Th$ , and  $^{40}K$  in sediment samples were ranged from  $18.09 \pm 2.66 Bq.Kg^{-1}$  to  $53.32 \pm 4.01 Bq.Kg^{-1}$ ,  $31.01 \pm 2.73$  to  $78.37 \pm 4.35 Bq.Kg^{-1}$  and  $390.26 \pm 76.37$  to  $733.61 \pm 85.80 Bq.Kg^{-1}$  with an average of  $28.17 \pm 3.12 Bqkg^{-1}$ ,  $48.57 \pm 3.43 Bqkg^{-1}$ , and  $490.59 \pm 81.04 Bqkg^{-1}$ , respectively. These average values are almost similar the values found in another study on the sediment samples collected from a tourist spot in Bangladesh [18].

The activity concentrations of  $^{226}Ra$ ,  $^{232}Th$ , and  $^{40}K$  in soil samples ranged from  $26.11 \pm 2.99 Bqkg^{-1}$  to  $61.66 \pm 5.88 Bqkg^{-1}$ ,  $41.93 \pm 4.18 Bqkg^{-1}$  to  $89.39 \pm 6.15 Bqkg^{-1}$ , and  $467.16 \pm 77.62 Bqkg^{-1}$  to  $1304.11 \pm 147.07 Bqkg^{-1}$  with the average values of  $44.39 \pm 4.91 Bqkg^{-1}$ ,  $69.79 \pm 5.52 Bqkg^{-1}$ , and  $1007.25 \pm 130.85 Bqkg^{-1}$ , respectively. The results found in the current study show that the activity levels in sea-beach soil are almost same as the main land soil as per other report [19].

The correlation of naturally occurring radionuclides has been shown in Figures 7, 8 and 9.  $^{226}Ra$  and  $^{232}Th$  were strongly correlated with correlation coefficient  $R^2$  value of 0.945. This strong correlation might be due to they have

some similarity in their environmental origin [23]. A good correlation between  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  is shown in Figure. 7. The relationship between  $^{226}\text{Ra}$  and  $^{40}\text{K}$ , were weak with correlation coefficient of 0.613. The weak correlation (0.613) between Radium and potassium might be explained due to high potassium solubility [23]. The weak correlation existed between  $^{232}\text{Th}$  and  $^{40}\text{K}$  in the samples ( $R^2 = 0.585$ ) shown in Figure. 9, which indicated  $^{40}\text{K}$  concentrations might not be related to the presence of  $^{232}\text{Th}$  [24].

Moreover, the values of activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  found in the current study for few samples were higher than the worldwide average value of 35, 30 and 400  $\text{Bqkg}^{-1}$ , successively [20].

**Table 1.** Activity Concentration ( $\text{Bqkg}^{-1}$ ) in Different Sand Samples of Inani Beach

Sample code	Activity concentration in $\text{Bqkg}^{-1}$		
	Ra-226	Th-232	K-40
IN SAND 01	15.14 ± 2.62	26.70 ± 2.65	362.00 ± 79.61
IN SAND 02	25.16 ± 3.05	49.46 ± 3.58	534.21 ± 82.70
IN SAND 03	28.67 ± 3.09	48.42 ± 4.32	516.34 ± 78.87
IN SAND 04	22.18 ± 2.87	34.23 ± 2.95	560.87 ± 81.40
IN SAND 05	17.68 ± 2.70	24.39 ± 2.50	414.43 ± 76.81
<b>Average</b>	<b>21.76 ± 2.87</b>	<b>36.64 ± 3.20</b>	<b>477.57 ± 79.88</b>
<b>World AVG</b>	<b>35</b>	<b>30</b>	<b>400</b>

**Table 2.** Activity Concentration ( $\text{Bqkg}^{-1}$ ) in Different Sediment Samples of Inani Beach

Sample code	Activity concentration in $\text{Bqkg}^{-1}$		
	Ra-226	Th-232	K-40
IN SEDI 01	24.61 ± 2.84	43.60 ± 3.20	475.50 ± 75.66
IN SEDI 02	53.32 ± 4.01	78.37 ± 4.35	450.48 ± 79.60
IN SEDI 03	29.95 ± 3.34	58.85 ± 3.96	412.10 ± 83.69
IN SEDI 04	18.19 ± 2.83	32.86 ± 2.97	481.60 ± 85.80
IN SEDI 05	18.09 ± 2.66	31.01 ± 2.73	390.26 ± 76.37
IN SEDI 06	25.29 ± 3.02	46.73 ± 3.39	733.61 ± 85.80
<b>Average</b>	<b>28.17 ± 3.12</b>	<b>48.57 ± 3.43</b>	<b>490.59 ± 81.04</b>
<b>World AVG</b>	<b>35</b>	<b>30</b>	<b>400</b>

**Table 3.** Activity Concentration in  $\text{Bqkg}^{-1}$  in Different Soil Samples of Inani Beach

Sample code	Activity concentration in $\text{Bqkg}^{-1}$		
	Ra-226	Th-232	K-40
IN SOIL 01	38.86 ± 4.30	64.81 ± 4.65	919.32 ± 115.16
IN SOIL 02	44.05 ± 5.66	66.84 ± 5.68	1229.75 ± 162.46
IN SOIL 03	61.66 ± 5.88	89.39 ± 6.15	1304.11 ± 147.02
IN SOIL 04	49.10 ± 5.54	73.30 ± 5.65	1006.96 ± 146.09
IN SOIL 05	48.86 ± 5.35	77.37 ± 5.68	1214.30 ± 143.36
IN SOIL 06	42.09 ± 4.68	74.92 ± 6.65	909.09 ± 124.22
IN SOIL 07	26.11 ± 2.99	41.93 ± 4.18	467.16 ± 77.62
<b>Average</b>	<b>44.39 ± 4.91</b>	<b>69.79 ± 5.52</b>	<b>1007.25 ± 130.85</b>
<b>World AVG</b>	<b>35</b>	<b>30</b>	<b>400</b>

### 3.2. Radiological Indices

The radiological parameters such as indices of radium equivalent activity ( $R_{\text{eq}}$ ), absorbed dose rate (D), outdoor annual effective dose (E), and external hazard index ( $H_{\text{ex}}$ ) were calculated to estimate the radiological risk due to the presence of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in the samples. Table 4 depicts the values of  $R_{\text{eq}}$ , D, E, and  $H_{\text{ex}}$ .

**Table 4.** Absorbed dose rate (D), outdoor annual effective dose (E), radium equivalent activity ( $R_{\text{eq}}$ ) and external hazard index ( $H_{\text{ex}}$ ) of the samples collected from Inani Beach Cox's Bazar

Sample ID	Radium equivalent activity, $R_{\text{eq}}$ ( $\text{Bqkg}^{-1}$ )	Hazard Index, $H_{\text{ex}}$	Absorbed dose rate, D ( $\text{nGyh}^{-1}$ )	Annual effective dose, E ( $\text{mSvyr}^{-1}$ )
INSAND 01	81.12	0.22	38.32	0.05
INSAND 02	136.90	0.37	63.93	0.08
INSAND 03	137.56	0.37	64.18	0.08
INSAND 04	114.23	0.31	54.48	0.07
INSAND 05	84.40	0.23	40.30	0.05
<b>AVG</b>	<b>110.84</b>	<b>0.30</b>	<b>52.24</b>	<b>0.06</b>
IN SEDI 01	123.03	0.33	57.47	0.07
IN SEDI 02	199.93	0.54	90.89	0.11
IN SEDI 03	145.72	0.39	66.69	0.08
IN SEDI 04	102.18	0.28	48.48	0.06
IN SEDI 05	92.42	0.25	43.48	0.05
IN SEDI 06	148.48	0.40	70.72	0.09
<b>AVG</b>	<b>135.29</b>	<b>0.37</b>	<b>62.96</b>	<b>0.08</b>
IN SOIL 01	202.17	0.55	95.71	0.12
IN SOIL 02	234.13	0.63	112.37	0.14
IN SOIL 03	289.68	0.78	137.25	0.17
IN SOIL 04	231.27	0.63	109.25	0.13
IN SOIL 05	252.80	0.68	120.31	0.15
IN SOIL 06	219.05	0.59	102.88	0.13
IN SOIL 07	121.95	0.33	57.01	0.07
<b>AVG</b>	<b>221.58</b>	<b>0.59</b>	<b>104.97</b>	<b>0.13</b>
<b>World AVG</b>	<b>370</b>	<b>...</b>	<b>55</b>	<b>0.07</b>

The values of radium equivalent activity sand, sediment, and soil were found to be varied from 81.12  $\text{Bqkg}^{-1}$  to 137.56  $\text{Bqkg}^{-1}$ , 92.42  $\text{Bqkg}^{-1}$  to 199.93  $\text{Bqkg}^{-1}$  and 121.95  $\text{Bqkg}^{-1}$  to 289.68  $\text{Bqkg}^{-1}$  with an average of 110.84  $\text{Bqkg}^{-1}$ , 135.29  $\text{Bqkg}^{-1}$ , and 221.58  $\text{Bqkg}^{-1}$ , respectively which were lower than the world average value of 370  $\text{Bqkg}^{-1}$  [21] reported by OECD.

The calculated values of external hazard index for sand, sediment and soil samples ranged from 0.22 to 0.37, 0.25 to 0.54, and 0.33 to 0.78 with an average of 0.30, 0.37, and 0.59, respectively which were lower than the world wide average value 1 [20].

The absorbed dose rate due to the terrestrial gamma rays at 1m above from the ground were in the range of 40.30 to 64.18  $\text{nGyh}^{-1}$ , 43.48 to 90.89  $\text{nGyh}^{-1}$  and 57.01 to 137.25  $\text{nGyh}^{-1}$  with the average values of 52.24  $\text{nGyh}^{-1}$ , 62.96  $\text{nGyh}^{-1}$  and 104.97  $\text{nGyh}^{-1}$ , respectively and the values (Sediment and Soil Samples) are higher than the world average value of 55  $\text{nGyh}^{-1}$  [22].

The outdoor annual effective dose equivalent was calculated from the air absorbed doses using the relation given in equation (5). The values varied from 0.05 to 0.08  $\text{mSvy}^{-1}$ , 0.05 to 0.11  $\text{mSvy}^{-1}$  and 0.07 to 0.17  $\text{mSvy}^{-1}$  with the mean values of 0.06  $\text{mSvy}^{-1}$ , 0.08  $\text{mSvy}^{-1}$  and 0.13  $\text{mSvy}^{-1}$  for sand, sediment, and soil samples, respectively. The values in two types of samples are just higher than the worldwide average values for outdoor annual effective dose of 0.07  $\text{mSvy}^{-1}$  [20].

The values of hazard index are lower than the unity, absorbed dose rate and annual effective dose found (Sediment and Soil samples) in the present study just exceed the standard limits for radiological safety. Therefore, though insignificant, these environmental components are unable to produce higher radiation exposure effect to the public living around the area. Therefore, no harmful radiation effects are posed to the public and tourists going to the beaches for recreation.

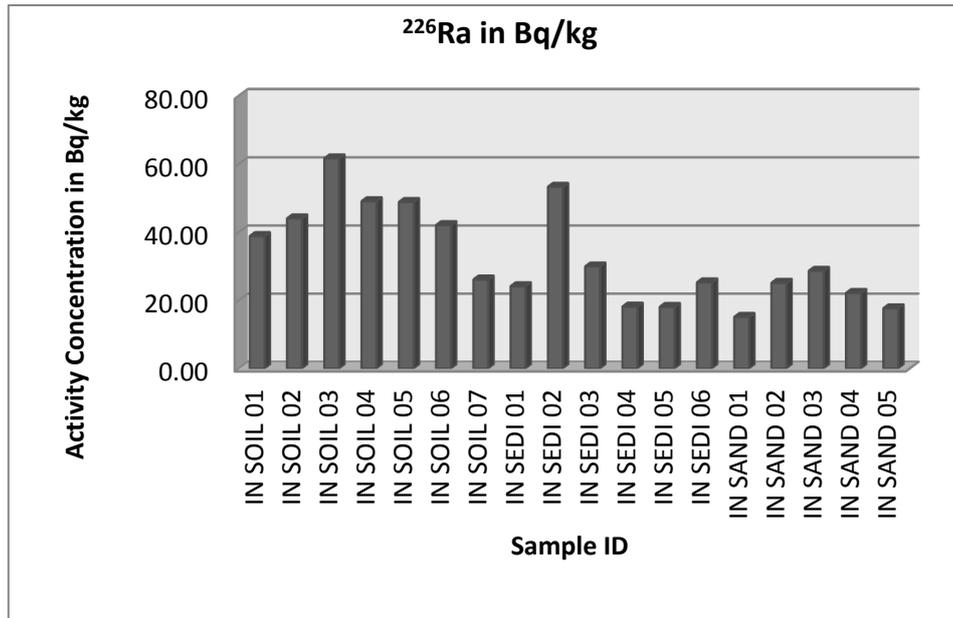


Figure 4. Distribution of  $^{226}\text{Ra}$  in all samples of Inani beach, Cox's Bazar, Bangladesh

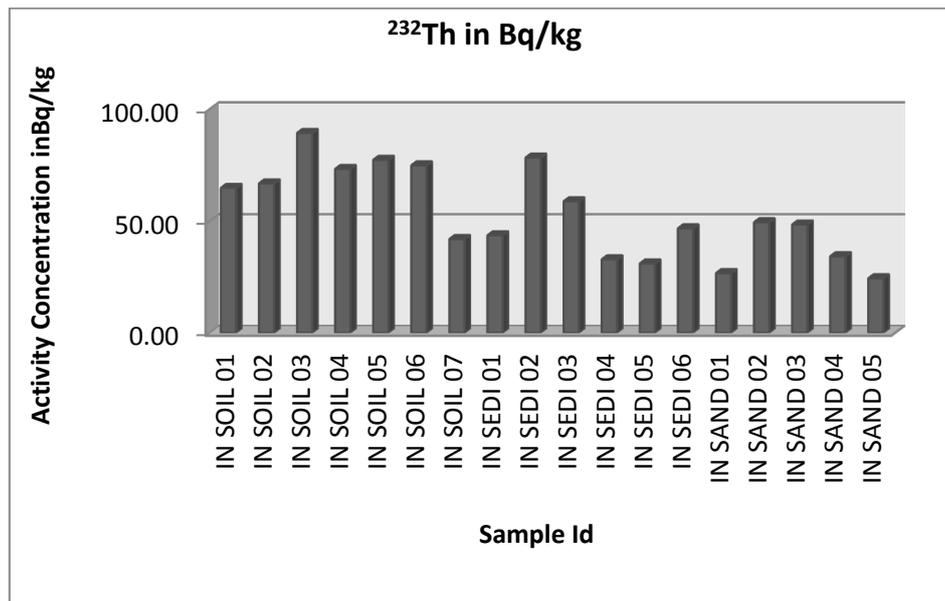


Figure 5. Distribution of  $^{232}\text{Th}$  in all samples of Inani beach, Cox's Bazar, Bangladesh

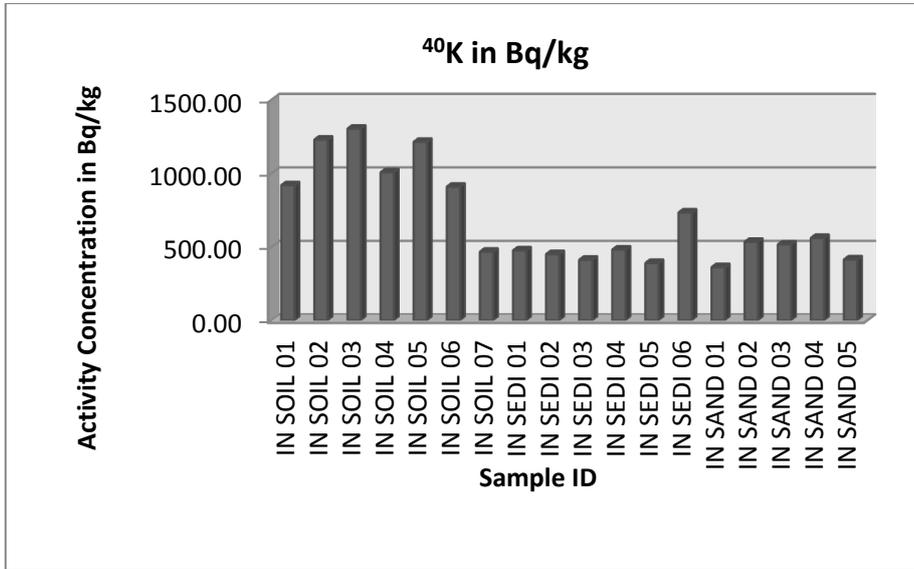


Figure 6. Distribution of <sup>40</sup>K in all samples of Inani beach, Cox’s Bazar Bangladesh

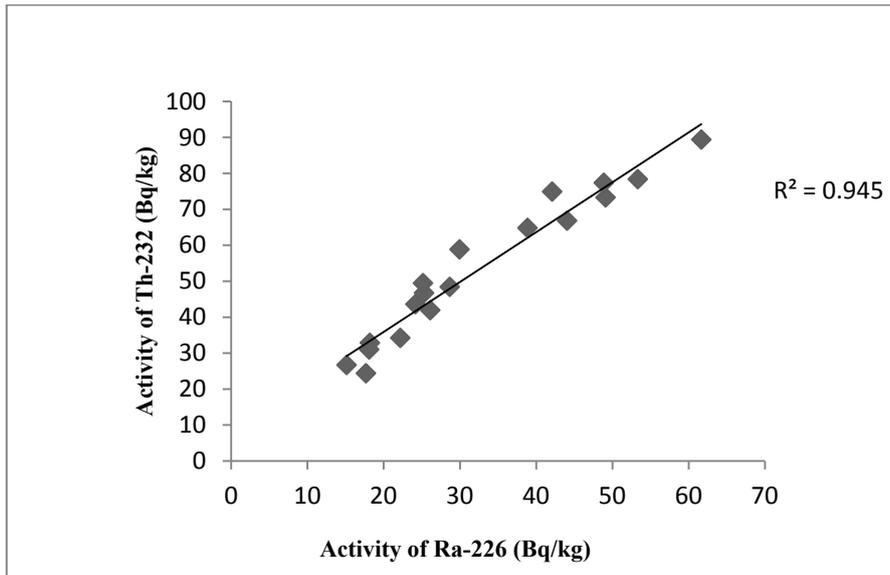


Figure 7. Correlation between activity concentrations of <sup>226</sup>Ra and <sup>232</sup>Th in all samples

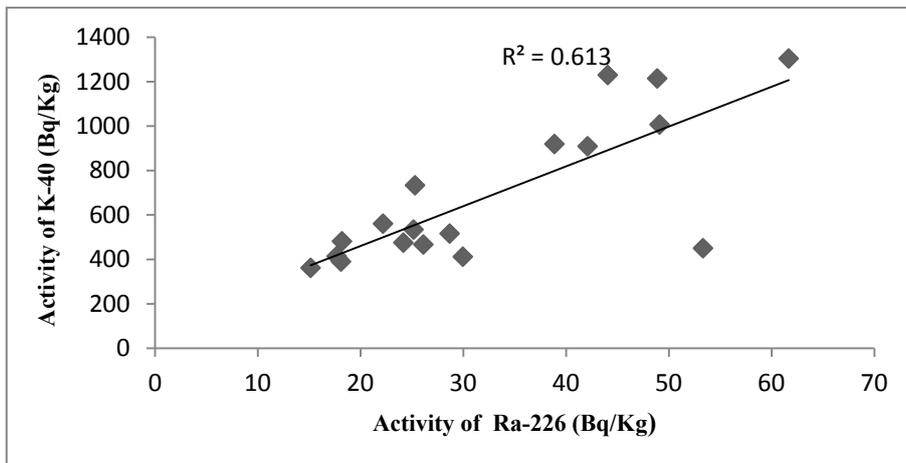


Figure 8. Correlation between activity concentrations of <sup>226</sup>Ra and <sup>40</sup>K in all samples

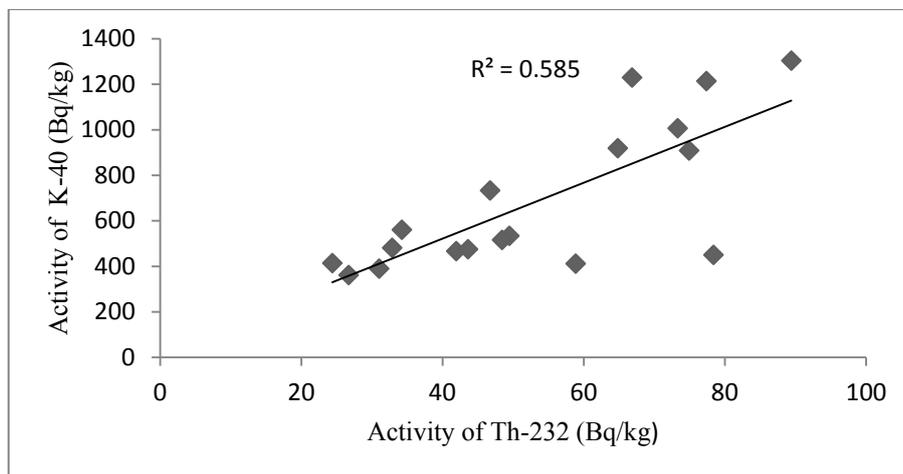


Figure 9. Correlation between activity concentrations of  $^{232}\text{Th}$  and  $^{40}\text{K}$  in all samples

## 4. Conclusions

The activity concentrations and radiological hazard associated with beach sand, sediment and adjacent soil samples collected from the Inani Sea-Beach, Cox's Bazar of Bangladesh were investigated in the present study. The results indicated that only the natural radionuclides were present in the samples. The radioactivity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  were just similar to the world average values. The activity levels in sand and sediment samples were also comparable to the other parts of the country. The calculated average absorbed dose rate and estimated outdoor annual effective dose were found lower than the worldwide average values. The average radium equivalent activity ( $R_{\text{eq}}$ ) and external hazard ( $H_{\text{ex}}$ ) index were less than the world average value. Therefore, the probability of the radiological impact on the inhabitants/public living in this area will be insignificant and there is no probability of radiological health effect on the tourists.

## REFERENCES

- [1] Mirjana B, Radenković, Saeed Masud Alshikh, Veibor B. Andrić and Šćepan S. Miljanić., Radioactivity of sand from several renowned public beaches and assessment of the corresponding environment risks Journal of Serbian Chemical Society. JSCS.74 (4)461-470(2009) JSCS-3847, doi:10.2298/JSC0904461R.
- [2] Turner, J.E., Atoms, Radiation and Radiation Protection, J. Wiley, New York, 1-13(1995).
- [3] UNSCEAR, Report of the General Assembly with Scientific Annexes. <http://www.unscear.org/docs/reports/annex.pdf>(2000).
- [4] Pfennig, H., Klewe-Nebenius, H., Seelmann-Eggebert, W., Karlsruher Nuklidkarte, 6. Auflage (1995).
- [5] Peterson, J.M., Mac Donell, M., Haroun, L., Monette, F., Hildebrand, R.D., Taboas, A., Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas, Human Health Fact Sheet, Argonic, 38-39(2007).
- [6] M. N. Alam, M. I. Chowdhury, M. Kamal, S. Ghose, M. N. Islam and M. N. Mustafa, The  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  Activities in Beach Sand Minerals and Beach Soils of Cox's Bazar, Bangladesh, Journal Environmental Radioactivity, Vol.46, No.2,1999,pp.243-250.doi:10.1016/S0265-931X(98)00143-X.
- [7] Kannan, V., Rajan, M.P., Lyengar, M.A. and Ramesh, R. Distribution of natural and anthropogenic radionuclides in soil and beach sand Samples of Kalpakkam (India). Appl. Radiat. Isot. 57,109-119 (2002).
- [8] C.E. Roessier, Z.A. Smith, W.E. Bloch and R.J Prince, Uranium and radium in Floride phosphate materials, Health Phys. vol. 37, 1970, pp. 269-277.
- [9] S. Harb, K.S. Din and A. Abbady, Study of efficiency calibrations of HPGe detectors for radioactivity measurement of environmental samples, Proceedings of the 3rd Environmental Physics Conference, 19-23 Feb. 2008, Aswan, Egypt.
- [10] International Atomic Energy Agency, Measurement of Radionuclide in Food and the Environment: A Guide- book, International Atomic Energy Agency, Vienna, 1989, pp. 139-144. doi:10.4236/jep.2012.39126 published Online September 2012 (<http://www.SciRP.org/journal/jep>).
- [11] G. F. Knoll, Radiation Detection and Measurement, Third edn.1998, New York.
- [12] Beretka, J. and Mathew, P.J., Natural radioactivity of Australian buildings, materials, industrial wastes and by products, Health Physic, 48, 87-95 (1985).
- [13] UNSCEAR, 2000. Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York.
- [14] UNSCEAR, 1993. Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York.
- [15] K. Debertin and R.G. Helmer. Gamma and X-ray spectrometry detectors, North Holland, 1988.
- [16] Lu, X. And Xiolan, Z. (2006): Measurement of natural

- radioactivity in sand samples collected from the Booje Weithe sand park, China, *Environ. Geol.* 50, 977-988.
- [17] Khondaker Mohammed Nazrul Islam, Debasish Paul, Md. Mahbubur Rahman Bhuiyan, Amina Akter, Budrun Neher, Sheikh Mohammad Azharul Islam. Study of Environmental Radiation on Sand and Soil Samples from Kuakata Sea Beach of Patuakhali. *Journal of Environmental Protection*, 2012, 3, 1078-1084.
- [18] Alamgir Miah, M. M. H. Miah, Masud Kamal, M. I. Chowdhury, M. Rahmatullah; Natural Radioactivity and Associated Dose Rates in Soil Samples of Malnichera Tea Garden Sylhet District of Bangladesh, *Journal of Nuclear and Particle Physics* 2012, 2(6): 147-152, DOI:10.5923/j.jnpp.20120206.03.
- [19] M. I. Chowdhury, M. Kamal, M. N. Alam, Saleha Yeasmin and M. N. Mostafa, Distribution of Naturally Occurring Radionuclides in Soils of Southern Districts of Bangladesh. *Radiation Detection Dosimetry* (2005), 1of 5.doi:10.1093/rpd/nci335.
- [20] UNSCEAR, Sources and effects of ionizing radiation, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly, United Nations, New York, USA, (2000). Annex.
- [21] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Sources, Effects and Risks of Ionising Radiation, United Nations, New York, 1988.
- [22] M. R. Abdil, H. Faghihian, M. Kamali, M. Mostajbod-davati and A. Hasanzadeh, Distribution of Natural Radionuclides on Coasts of Bushehr, Persian Gulf, Iran, *Iranian Journal of Science & Technology: Transaction A*, Vol. 30, No. A3, 2006, pp. 259-269.
- [23] M. H El Mamoney, Ashraf E. M. Khater, Environmental Characterization and Radio-ecological Impacts of Non-nuclear Industries on the Red Sea Coast. *Journal of Environmental Radioactivity* 73(2004) 151-168.
- [24] S. Harb, Natural Radioactivity and External Gamma Radiation Exposure at The Costal Red Sea in Egypt. *Radiation Protection Dosimetry* (2008), Vol 130, No 3, pp. 376-384.