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A REVIEW OF NATURALLY OCCURRING RADIOACTIVE ELEMENTS IN COASTAL REGIONS OF BANGLADESH

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Abstract

Extensive and systematic study has been carried out globally to get a thorough understanding of the underlying dynamics of radionuclides in the environment. This study was aimed to examine the natural radioactivity level in coastal areas of Bangladesh by combining the main research carried out on environmental radioactivity, predominantly employing established nuclear methods and methodologies during the past. The concentrations of important radionuclides, including ^{226}Ra, ^{232}Th, ^{40}K, ^{238}U, and ^{235}U, were measured in those investigations. Soil samples showed the highest concentration of ^{226}Ra at Inani Beach, Cox's Bazar (21°8′ N latitude, 92°4′ E longitude), with a value of 61.66 Bqkg^{-1}. On the other hand, Cox's Bazar Sea Beach has the lowest ^{226}Ra concentration at 10.8 Bqkg^{-1}. In contrast, Cox's Bazar had the highest ^{226}Ra activity in the sand and silt samples (147.93 Bqkg^{-1}), whereas Kuakata Sea Beach (21° 48′ N latitude and 90° 10′ E longitude) had the lowest (2.82 Bqkg^{-1}). The research found that ^{226}Th activity varied from 1085.99 Bqkg^{-1} to 27.4 Bqkg^{-1} in soil samples from Cox's Bazar Sea Beach. In Cox's Bazar, the sand and silt samples showed the highest ^{226}Th activity at 1085.9 Bqkg^{-1}. In contrast, Kuakata Sea Beach has the lowest radioactivity at 9.22 Bqkg^{-1}. Soil samples showed that ^{40}K content was highest at Inani Beach (21°13′ N latitude and 92°3′ E longitude), Cox's Bazar (1304.11 Bqkg^{-1}) and lowest at Cox's Bazar Sea Beach (25.16 Bqkg^{-1}). The sand and silt sample from Kuakata Sea Beach had the greatest ^{40}K activity, measuring 852 Bqkg^{-1}. However, the sample from Cox's Bazar Sea Beach had the lowest amount (21.9 Bqkg^{-1}). Soil samples from Cox's Bazar Sea Beach showed ^{238}U activity of 455.99 Bqkg^{-1} and 110.84 Bqkg^{-1}, respectively. The highest ^{238}U activity sand sample was found in Cox's Bazar, measuring 460.5 Bqkg^{-1}. The Patenga region (22°14′ N latitude and 91°47′ E longitude) in Chattogram has the lowest radioactive level, 45.2 Bqkg^{-1}. The study's findings have been meticulously recorded as crucial foundational knowledge for forthcoming investigations on radionuclides in this coastal area. A comprehensive evaluation of prior published analyses of naturally occurring radioactive elements in the coastal regions of Bangladesh has shown that the level of activity is completely non-hazardous. The experimental areas' soils are ideal for a variety of agricultural and other purposes.

Key words: Natural Radioactivity, Radionuclide, Gamma spectrometry, Activity level.

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Introduction

Radiation is present in every ecosystem, whether it is on the surface, underneath the Earth, or in the atmosphere. According to UNSCEAR (1993), about 87% of the radiation dosage that people get, originates from natural radiation sources, while the remaining 13% is attributed to anthropogenic radiation (Kannan *et al.,* 2002). The Earth's environment contains natural radioactivity that is extensively spread and may be detected in many geological formations, such as soils, rocks, plants, sand, water, and air (Rozanski & Froehlich, 1996). Therefore, it is essential to get information about their local natural environment in terms of the possible ramifications of radiation arising from both naturally occurring and anthropogenic radioactive elements. (US EPA, 2023).

According to Shahbazi-Gahrouei *et al.* (2013), the main radioactive elements discovered in soil include primordial radionuclides from the uranium series, thorium series, and ^{40}K. "Fallout" is the term used to describe the radioactive materials that are released into the atmosphere and deposited on the Earth's surface as a result of nuclear weapons testing. The dispersion of this fallout in the environment varies depending on the nuclear device's yield, burst mode, and ambient conditions. Due to nuclear weapon testing and accidents, the environment contains notable amounts of artificial radionuclides such as ^{137}Cs and ^{90}Sr (IAEA, 1989). Naturally occurring radioactive nuclides are present in the soil, water, food, air, and even inside human bodies (Aswood *et al.,* 2013). These originate from the primary decay series of ^{238}U, ^{235}U, and ^{232}Th and their respective offspring. Long-lived radioactive nuclides such as ^{40}K may also be found (IAEA, 2007; UNSCEAR, 2008).

The weathering process that takes place inside the earth's crust is vital in releasing radioactive nuclides into the soil, making it the main source of natural background radiation. Animals ingest plants and plants may absorb these nuclides via their roots or leaves. The transfer of radioactive substances to the human body happens when we eat plants or drink water that contains these substances. It may also occur indirectly when we consume animal products like meat or milk that have been exposed to these substances (Alharbi, 2013).An accurate evaluation of the released radioactivity into the environment is crucial for protecting the health of the general population, especially when the released radioactivity becomes part of the food chain (El-Taher and Al-Turki, 2014).

Multiple inquiries have been carried out in these areas for the last thirty years to determine the concentrations of ^{226}Ra, ^{232}Th, ^{40}K, ^{238}U, and ^{235}U in samples of beach sand and soil. Considering the information provided from the earlier research, a comprehensive review has been conducted on the movement and behavior of natural radioactive elements in the coastal regions of Bangladesh.

Methodology

Sampling Technique

Upon reviewing the extensive research conducted on the south coast over the past thirty years, it was found that the majority researchers utilize a high-purity germanium (HPGe) detector for a minimum duration of 10,000 seconds with appropriate shielding to count the activity of the radionuclides (Islam *et al*., 2012). Conversely, only a small number of researchers employ a survey or radiation monitoring system. When employing HPGe for detection, the process involved configuring characteristics such as resolution and peak-to-compton ratio, as well as ensuring that the detectors maintained a minimal level of activity, among other considerations. All prior studies collected soil and sediment samples from the research locations and environs to estimate natural radionuclides. Each sample was collected one kilometer apart. The sample weighed (0.75-1) kilogram. Before being taken to the lab, each sample was bagged in polythene. Before being collected, each sample was weighed, dried in an oven at 110°C for 24 hours, roughly pulverized using a grinder, and filtered through a 10-mesh screen. A homogenized sample was placed in a sealed plastic container for measurements. All sample containers were air-tightened with polythene packs and sealed with caps before being wrapped with Teflon and thick vinyl tape around their screw necks and stored for minimum four weeks prior to counting allowing establishment of secular equilibrium between long-lived ^{238}U and ^{232}Th and their decay products (Islam *et al*., 2012).

Study Area

The majority of the studies on natural radioactivity in the coastal region of Bangladesh were conducted at specific locations: Cox's Bazar (21^0 8’ N latitude and 92^0 4’ E longitude), Kuakata Sea Beach (21^0 48’ N latitude and $90^0$10’ E longitude), Patenga, Chattogram ($22^0$14’ N latitude and $91^0$47’ E longitude), and Moheshkhali, Teknaf (20^0 51’ N latitude and $92^0$16’ E longitude). Figure 1 illustrates the geographical locations where the study was carried out.

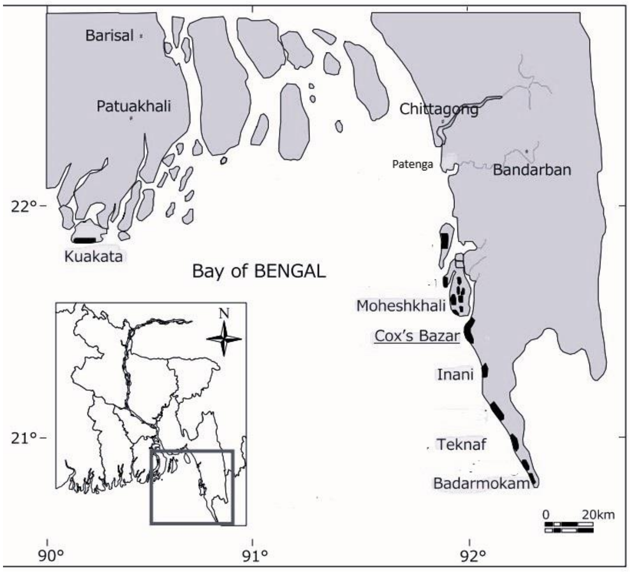

Fig. 1. Map of Costal Bangladesh indicating environmental radioactivity study sites.

Radionuclide Analysis

Gamma-ray spectrometry enables the identification of gamma-ray energies and, by extension, the radioactive species responsible for their emission. The region enclosed by the peak in a gamma-ray spectrum corresponds to the number of counts obtained only for that specific gamma-ray energy. The peak regions were used to determine the concentration of radioactivity for the radionuclides found in the sample. By taking the peak energy region away from a linear background distribution of the pulse height spectra, the net count of the sample was found. The activity concentration of the radionuclides was determined by calculating it from the net counts of the samples using the given formula.

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

where, A is the activity concentration in Bqkg^{-1}, CPS is the net peak counts per second of the samples, W is the weight of the sample in gm, ε(abs) is the absolute gamma peak detection efficiency, I_r (abs) is the absolute gamma intensity of the corresponding gamma ray energy. Gamma ray's intensities were taken from the literature (IAEA, 1989).

Findings of earlier studies and discussion

Since environmental radioactivity directly affects how much ionizing radiation the public is exposed to, it is essential to consider it while evaluating the radiological hazard associated with seashore. Numerous research have been carried out over time to look into the radioactive levels of various sea beaches in Bangladesh. The results of these investigations are reviewed and summarized in this part, which also offers information on the radiological danger connected to these regions.

In 1999, Chakraborty undertook a study to assess the levels of radiation and radioactivity in Bangladesh. While the research does not primarily focus on seashore, its findings are crucial for understanding the country's fundamental radiation levels. The study utilized a survey meter, specifically the PDR ISV provided by NE Technology Limited in England, to conduct a comprehensive field survey. Additionally, an HPGe detector, specifically the Intrinsic Germanium p-Type Coaxial supplied by SlLENA Detektor Systeme GmbH in Germany, was used to measure the radioactivity levels in soil and water samples collected from various locations in Bangladesh. The mean activity concentrations of ^{232}Th, ^{238}U and ^{40}K in the Kuakata Sea beach were determined to be 269.04±11.62 Bqkg^{-1}, 110.84±10.22 Bqkg^{-1} and 266.0±24.8 Bqkg^{-1}, respectively. In the Cox's Bazar Sea beach, the mean activity concentrations were 1085.99 ± 20.01 Bqkg^{-1}, 455.99 ± 16.35 Bqkg^{-1} and 25.16 ± 5.39 Bqkg^{-1}for ^{232}Th, ^{238}U and ^{40}K, respectively. The investigation revealed that the level of radiation exposure in sandy areas with a brown hue and glossy appearance was measured at 4.20±0.88 mSvy^{-1} for Kuakata Sea Beach and 8.94 ± 3.15 mSvy^{-1} for Cox's Bazar Sea Beach. Subsequent investigations can utilize the data obtained from this study as a benchmark.

After that a study conducted by Alam *et al.* (1999) aimed to evaluate the levels of activity of naturally occurring radionuclides, specifically ^{226}Ra, ^{232}Th and ^{40}K, in beach sand minerals and beach soils. This was achieved by utilizing a γ-ray spectrometry technique with a p-type coaxial high-purity Ge (HPGe) detector. The HPGe detector had a relative efficiency of 35%, an active volume of 132 cm^3, and a Full Width at Half Maximum (FWHM) of 1.8 keV for the 1332.5 keV γ-ray of ^{60}Co. The study was conducted in Cox's Bazar, Bangladesh. The occurrence of these radioactive isotopes in coastal ecosystems was worrisome since it poses possible radiological hazards to both local inhabitants and visitors. Significant fluctuations in the activity concentrations of the three examined radionuclides were seen in the Cox's Bazar region, as reported by the authors. The measured concentration of ^{226}Ra in the soil samples taken from the tourist zone's sea beach varied from 10.8±1.6 to 27.3±2.6 Bqkg^{-1}, with an average concentration of 19.0 ± 4.8 Bqkg^{-1}. The measured range for the isotope ^{40}K was from 117 ± 25 to 688 ± 33 Bqkg^{-1}, with an average value of 458 ± 160 Bqkg^{-1}. On the other hand, the range for the isotope ^{232}Th was found to be from 27.4 ± 3.7 to 49.4 ± 5.0 Bqkg^{-1}, with an average value of 36.7 ± 6.5 Bqkg^{-1}. Furthermore, it was calculated the absorbed dose rates caused by different radionuclides in sand minerals located more than one meter away from the plant's stacks. The average dosage rate was found to be 4.30 μGy h^{-1}, ranging from 0.05 to 13.0 μGy h^{-1}.

Kuakata, a coastal area, is situated in the Patuakhali district. In a study conducted by Chowdhury *et al.* (2006), the levels of primordial radionuclides were examined in this region. The specific activities of ^{226}Ra in three soil samples were found to be 36 ± 2, 39 ± 3, and 37 ± 2 $Bqkg^{-1}$. For ^{232}Th, the specific activities were measured to be 52 ± 5, 99 ± 8, and 93 ± 8 $Bqkg^{-1}$ in the same soil samples. Additionally, the specific activities of ^{40}K were discovered to be 549 ± 24, 631 ± 25, and 874 ± 28 $Bqkg^{-1}$. The measurements were conducted using a p-type coaxial lead shielded intrinsic high-purity germanium detector. The detector had a volume of 132 cm^3 and a relative efficiency of 35%. It had a resolution (FWHM) of 1.83 keV for the gamma-ray energy of 1332 keV emitted by ^{60}Co. The representative level index was determined to be 1.45, while the radium equivalent activity was measured at 195 $Bqkg^{-1}$.

In 2012, a research undertaken by Islam *et al.* at Kuakata Sea coastal is among the first to directly examine the levels of environmental radiation in a coastal region in Bangladesh. The study utilized a HPGe detector with a relative efficiency of 40% to measure radioactivity levels in sand and soil samples from Kuakata. This investigation provided valuable insights into the radioactive hazards linked to this well-liked tourist spot. The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the sand samples from Kuakata seabeach varied from 2.82 ± 4.89 to 87.96 ± 4.45 $Bqkg^{-1}$, 21.72 ± 16.27 to 290.93 ± 18.15 $Bqkg^{-1}$, and 26.24 ± 0.35 to 852.05 ± 142.15 $Bqkg^{-1}$, respectively. The average values for ^{226}Ra, ^{232}Th, and ^{40} K were 29.48 ± 3.85 $Bqkg^{-1}$, 93.72 ± 15.62 $Bqkg^{-1}$, and 551.24 ± 109.95 $Bqkg^{-1}$, respectively. The activity concentrations of the corresponding radioactive isotopes in soil samples ranged from 20.98 ± 3.96 to 42.92 ± 4.76 $Bqkg^{-1}$, 59.25 ± 15.62 to 144.34 ± 18.52 $Bqkg^{-1}$, and 570.43 ± 100.3 to 1165 ± 166.27 $Bqkg^{-1}$, with an average value of 29.19 ± 4.88 $Bqkg^{-1}$, 90.56 ± 17.94 $Bqkg^{-1}$, and 874.89 ± 119.96 $Bqkg^{-1}$, respectively. The sand was estimated to contain radionuclides with an average absorbed dose rate of 98.33 $nGyh^{-1}$, ranging from 51.84 to 246.55 $nGyh^{-1}$. The mean absorbed dose rate resulting from radionuclides in soil was calculated to be 110.04 $nGyh^{-1}$, with a variation ranging from 76.63 to 142.36 $nGyh^{-1}$.

In another investigation, Zaman *et al.* at 2012 discovered considerably higher levels of naturally occurring radionuclides in beach sands that were rich in heavy minerals. The research was crucial for comprehending the increased levels of radionuclides found in beach sands abundant in heavy minerals in the Cox's Bazar area of Bangladesh.This study investigates the levels of activity in five specific mineral fractions extracted from beach sands, as well as in the overall bulk beach sands. The measurements were conducted using two coaxial low-energy high-purity germanium detectors, specifically an n-type detector (ORTEC) with a 39 cm^3 active volume and a 0.5 mm Be window. The purpose of this study was to assess the potential environmental impact of radioactivity and the feasibility of utilizing the mineral deposits as a source of uranium and thorium. The study revealed that the levels of ^{232}Th, ^{40}K, ^{235}U, and ^{238}U in the beach sand samples were notably elevated and had a positive correlation with the sand's heavy mineral content. The zircon component of the mineral fractions exhibited the highest levels of activity concentrations, with garnet, rutile, ilmenite, and magnetite following in descending order. At the foredune and backdune sites that were examined, the beach sands had Raef activity levels that were 33, 18, and 15 times higher than the worldwide standard value of 370 Bqkg^{-1}(IAEA, 1996). Similarly, the beach sands had activity levels that were 10, 8, and 6 times higher than the global standard value.

The 2014 study conducted by Chakraborty and Alam provides a comprehensive assessment of the natural radioactivity levels throughout the beaches of Bangladesh. It helps to place the radiation dangers in these areas within a broader and more complete framework. The measurements were conducted using a high-resolution HPGe gamma-ray spectrometer equipment, which included a vertically mounted p-type intrinsic germanium coaxial detector (model: GX3018) linked to an 8 K multichannel analyzer (Canberra). The mean activity concentration of ^{232}Th was 461±16 Bqkg^{-1}, with a minimum value of 55.4 Bqkg^{-1}and a maximum value of 1085.9 Bqkg^{-1}. The ^{238}U exhibited a range of 23.3 to 460.5 Bqkg^{-1}, with an average of 208±11 Bqkg^{-1}. The sand collected from Cox's Bazar Sea beach exhibited a range of activity concentrations of ^{40}K, ranging from 21.9 to 41.6 Bqkg^{-1}, with an average of 27±6 Bqkg^{-1}. The average activity concentration of ^{232}Th in Kuakata was 158±9 Bqkg^{-1}, ranging from 105.4 to 269.0 Bqkg^{-1}. The average concentration of ^{238}U was 72±11 Bqkg^{-1}, ranging from 51.9 to 110.8 Bqkg^{-1}. The average activity concentration of ^{40}K was 237±24 Bqkg^{-1}, ranging from 192.9 to 292.8 Bqkg^{-1}. The average dose level at one meter above ground was 395 nGyh^{-1} for Cox's Bazaar sea beach and 146 nGyh^{-1} for Kuakata sea beach, both of which had brilliant brown sandy parts.

In 2014, Ahmed *et al.,* conducted a study to investigate the levels of natural radioactivity and the resulting radiological dangers in environmental samples obtained from Inani Beach in Cox's Bazar, Bangladesh. The study specifically investigates the radioactivity levels of sand, silt, and soil samples, analyzing their composition of naturally occurring radioactive elements such as uranium, thorium, and potassium. Their research unveiled disparities in radioactive levels across the various sample types, with sand displaying greater quantities in comparison to silt and soil. The gamma spectrometry system, equipped with a p-type co-axial HPGe detector of 93 cm^3 active volume and 20% relative efficiency (CANBERRA Model GC-2018,), was used to detect and measure radionuclides in the samples. The sand samples exhibited varying activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, ranging from 15.14 ± 2.62 to 25.16 ± 3.05 Bqkg^{-1}, 24.39 ± 2.50 to 49.46 ± 3.58 Bqkg^{-1}, and 362.00 ± 79.61 to 560.87 ± 81.40 Bqkg^{-1}, respectively. The mean values of these three variables were 21.26 ± 2.87 Bqkg^{-1}, 36.64 ± 3.20 Bqkg^{-1} and 477.57 ± 79.80 Bqkg^{-1}, respectively. The average values closely resemble those recorded at Kuakata Sea-Beach, Bangladesh, by K.M.N. Islam and colleagues (2012). The sediment samples exhibited varying levels of radioactivity for ^{226}Ra, ^{232}Th, and ^{40}K, ranging from 18.09 ± 2.66

to 53.32 ± 4.01 $Bqkg^{-1}$, 31.01 ± 2.73 to 78.37 ± 4.35 $Bqkg^{-1}$, and 390.26 ± 76.37 to 733.61 ± 85.80 $Bqkg^{-1}$, respectively. The respective average activity concentrations were 28.17 ± 3.12 $Bqkg^{-1}$, 48.57 ± 3.43 $Bqkg^{-1}$, and 490.59 ± 81.04 $Bqkg^{-1}$. The mean values obtained in this study closely resemble those found in a separate investigation undertaken by Miah *et al.* (2012) using sand samples collected from a popular tourist spot in Bangladesh. The mean activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in soil samples were 44.39 ± 4.91 $Bqkg^{-1}$, 69.79 ± 5.52 $Bqkg^{-1}$, and 1007.25 ± 130.85 $Bqkg^{-1}$, respectively. The activity concentrations for ^{226}Ra, ^{232}Th, and ^{40}K ranged from 26.11 ± 2.99 to 61.66 ± 5.88 $Bqkg^{-1}$, 41.93 ± 4.18 to 89.39 ± 6.15 $Bqkg^{-1}$, and 467.16±77.62 to 1304.11±147.07 $Bqkg^{-1}$, respectively. Chowdhury *et al.* (2006) reported that the activity levels in sea-beach soil are practically the same as those in mainland soil, as indicated by the findings of the present study.

Das *et al.* (2015) conducted a thorough examination of the levels of natural radioactivity and the resulting radioactive dangers in soil, sand and sediment samples gathered from the coastal area of Cox's Bazar, Bangladesh. The results suggest that the research region displays different amounts of inherent radioactivity, with the sand samples usually demonstrating elevated values. The samples were analyzed for radionuclides using a gamma spectrometry system equipped with a p-type co-axial HPGe detector. The detector had an active volume of 93 cm^3 and a relative efficiency of 20%. The soil samples exhibited a range of values for ^{226}Ra, ^{232}Th, and ^{40}K, spanning from 15.34 ± 1.66 to 33.70 ± 2.08 $Bqkg^{-1}$, 30.09 ± 3.62 to 58.06 ± 4.23 $Bqkg^{-1}$, and 379.99 ± 33.43 to 755.26 ± 38.03 $Bqkg^{-1}$, respectively, among others. The sand samples exhibited activity values ranging from 8.98 ± 1.49 to 31.33 ± 2.04 $Bqkg^{-1}$, 16.82 ± 3.24 to 63.28 ± 4.37 $Bqkg^{-1}$, and 252.42 ± 31.72 to 565.72 ± 35.78 $Bqkg^{-1}$, respectively. The sediment sample yielded findings of 13.90 ± 1.64 to 38.41 ± 2.19 $Bqkg^{-1}$, 37.94 ± 3.82 to 51.92 ± 4.11 $Bqkg^{-1}$, and 367.70 ± 33.28 to 665.05 ± 36.97 $Bqkg^{-1}$, respectively. As stated by Ahmed *et al.* (2014), the mean value is similar. The measured absorbed dose rates for soil, sand, and sediment samples were determined to be 79.98, 77.17, and 57.86 $nGyh^{-1}$, respectively. The yearly effective doses received outdoors were 0.49, 0.47, and 0.36 $mSvh^{-1}$.

The researchers Yeasmin *et al.* (2015) examined the levels of radioactivity in the sand of a recently formed beach area in Cox's Bazar, a coastal region located in the southern part of Bangladesh. The examination identified varying levels of inherent radioactivity, with particular focus on the presence of radioactive elements such as potassium, thorium, and uranium. . The sand samples included radionuclides ^{226}Ra, ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs with average activity values of 147.93±3.13, 164.27±4.82, 254.41±5.43, 321.54±17.32, and 7.21±0.80 $Bqkg^{-1}$, respectively. The average values for radium equivalent activity, external and internal risks, and outdoor and indoor absorbed dose rates were 536.50 $Bqkg^{-1}$, 1.45 and 1.85, 245.48 $nGyh^{-1}$ and 294.58 $nGyh^{-1}$, respectively.

A study by Ahmed *et al.* (2016) investigated the levels of natural radioactivity in sand and soil samples collected from Kuakata Beach, Bangladesh. The samples were analyzed for radionuclides using a gamma spectrometry system equipped with a p-type co-axial HPGe detector. The detector had an active volume of 93 cm^3 and a relative efficiency of 20% The researchers discovered that the levels of ^{226}Ra, ^{232}Th, and ^{40}K in sand samples from the Kuakata sea beach varied from 22.83±4.11 to 100.21±2.39 $Bqkg^{-1}$, 68.76±2.86 to 297.37±4.32 $Bqkg^{-1}$ and 75.87±15.75 to 161.81±19.90 $Bqkg^{-1}$, respectively. The average values for these elements were 48.76, 126.11, and 292.38 $Bqkg^{-1}$, respectively. The mean values of the linked radionuclides in the sediment samples were 19.67, 32.13 and 243.38 $Bqkg^{-1}$, respectively. The values in the range for the other radionuclides were 12.11±1.99 to 31.64±1.64 $Bqkg^{-1}$, 18.94±1.90 to 71.11±2.88 $Bqkg^{-1}$, 182.73±19.81 $Bqkg^{-1}$ and 345.77±21.07 $Bqkg^{-1}$. The computed range of the absorbed dose rate was between 30.50 and 242.93 $nGyh^{-1}$, with an average value of 74.87 $nGyh^{-1}$.

Zaman *et al.* (2016) investigates the levels of uranium and thorium in zircon assemblages extracted from beach sands in Cox's Bazar, Bangladesh. The results indicate that zircon rocks, commonly present in the coastal sands of the region, may contain radioactive elements. Neutron Activation Analysis (NAA) determined that the mean concentrations of uranium and thorium were 122 and 220 ppm, respectively. The analysis revealed that the most elevated levels of thorium and uranium were found to be 506 and 141 ppm, respectively. A limited number of supplementary investigations (Alam *et al.*, 1999; Chowdhury, 2003; Kabir *et al.*, 2010) have utilized gamma spectrometry to quantify the levels of ^{238}U and ^{232}Th, together with other radioactive elements like as K, in certain soils and dense minerals found in the Cox's Bazar region.

In their study, Begum *et al.* (2018) conducted a thorough investigation to evaluate the levels of background radiation in different places around Bangladesh. It has been discovered that the coastal regions in the Cox's Bazar region have significantly increased levels of background radiation, with the highest recorded level being 38.89 $mSvy^{-1}$. However, outside of Cox's Bazar seashore, the amount of background radiation is significantly lower in and around Cox's Bazar town, with a minimum level of 1.40 $mSvy^{-1}$. The background radiation level in Cox's Bazar district ranges from 1.40 to 38.89 $mSvy^{-1}$. The researchers utilized Geiger-Muller based micro-Roentgen survey meter and digital survey meter (GAMMA SCOUT) to measure the radiation levels in their investigation. The elevated background radiation level in the coastal regions of Cox's Bazar region is attributed to the presence of monazite and zircon in the sand.

In this study, Uddin *et al.* (2019) examined and analyzed the extent to which the population in Bangladesh is exposed to elevated amounts of natural background radiation. Although the literature was a conference proceeding and offers limited information, its primary focus was on comprehending the radiological situation in Bangladesh. This study aims to investigate the levels of natural background radiation in Bangladesh and evaluate its possible effects on the population. The study was anticipated to address the presence of certain locations or places in Bangladesh that have higher amounts of natural background radiation. The provided data includes the radioactivity levels of ^{226}Ra, ^{232}Th, and ^{40}K isotopes in soil samples from Kuakata Sea Beach. The activity levels were found to be 23 $Bqkg^{-1}$, 80 $Bqkg^{-1}$, and 700 $Bqkg^{-1}$for ^{226}Ra, ^{232}Th, and ^{40}K, respectively.

The 2020 study conducted by Deeba, Rahman and Kabir specifically examined the levels of radon in both soil and groundwater in the western coastal region of Bangladesh. The study also assessed the overall yearly effective dosage resulting from the intake and inhalation of radon. Radon plays a substantial role in the overall amount of radiation that occurs naturally. It is vital to comprehend the levels of radon in these regions. The research area was assessed for radon levels using the AlphaGUARD PQ2000 PRO radon detector. The radon levels in soil samples collected from Kuakata were evaluated at depths of 0, 20 and 40 cm below the surface. The radon concentration at the surface ranges from 10±04 to122± 28 Bqm^{-3}. At depths of 20 cm to 40 cm, the concentration ranges from 12±05 to 2800±44 Bqm^{-3}. At depths of 40 cm to 4790±51 Bqm^{-3}, the concentration is 4790±51 Bqm^{-3}. The radon concentrations in a given area are influenced by the depth of the ground surface and the placements of the sample sites in that region, as indicated by the findings of the soil radon concentration.

In 2021, Sarker and his colleagues utilized a gamma-ray spectroscopy device with an HPGe detector to quantify the radiation levels in sand samples collected from the Kuakata and Cox's Bazar Sea beaches. Their discoveries provided valuable information on the radioactive hazards present in these highly sought-after coastal areas, which attract both domestic and foreign visitors. The sand samples from Kuakata Sea Beach have activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K ranging from 24.48±2.17 to 76.14±3.25 $Bqkg^{-1}$, 9.22±2.15 to 46.80±2.17 $Bqkg^{-1}$, and 76.23±12.34 to 458.65±17.04 $Bqkg^{-1}$, respectively. Sand samples from Cox's Bazar Sea Beach show activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K ranging from 14.12±2.75 to 75.54±3.15 $Bqkg^{-1}$, 10.28±1.95 to 53.37±2.75 $Bqkg^{-1}$ and 56.42±10.16 to 341.22±14.64 $Bqkg^{-1}$. The mean activity concentration of the natural radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in sand samples collected at Kuakata beach is 41.22±2.56, 21.78±2.27 and 218.41±13.63 $Bqkg^{-1}$, respectively. In Cox's Bazar, the corresponding values are 54.01±2.65, 36.16±2.42 and 200.51±12.74 $Bqkg^{-1}$. The radium equivalent activity of sand samples collected from Cox's Bazar Sea beach ranges from 49.17 to 153.1 $Bqkg^{-1}$, whereas samples from Kuakata sea beach show a radium equivalent activity ranging from 61.02 to 163.14 $Bqkg^{-1}$. The sand samples from Cox's Bazar show a radium equivalent activity of 121.15±39.13 $Bqkg^{-1}$, whereas the samples from the Kuakata beach have an average of 83.94±35.99 $Bqkg^{-1}$. The mean internal and external hazard indices in Cox's Bazar Sea beach are 0.48±0.16 and 0.33±0.11, respectively. In Kuakata seashore, the corresponding values are 0.35±0.13 and 0.23±0.09. The average annual effective dose in Kuakata is 0.29±0.11 $mSvy^{-1}$, whereas at Cox's Bazar Sea beach it is 0.39±0.13 $mSvy^{-1}$.

The study clearly indicates that the majority of the research focused on measuring the levels of natural radioactivity in the soil, sand and beach sediments in the coastal areas of Kuakata and Cox's Bazar. Typically, the HPGe detector was utilized for estimating the activity. The exterior gamma absorbed dose measurement was conducted using survey meters, portable plastic scintillometers, and thermoluminescent dosimeters (TLDs). Tables 1 to 9 provide clear and well-documented evidence of regional differences in the levels of radionuclides, including ^{226}Ra, ^{232}Th, ^{40}K, ^{238}U and ^{235}U.

The examination of the soil samples indicated that the concentration of ^{226}Ra was greatest at Inani Beach, Cox's Bazar (21° 8′ N latitude and 92^{0} 4’ E longitude) with a value of 61.66 Bqkg^{-1} (Ahmed *et al.,* 2014*)*. On the other hand, the lowest concentration of ^{226}Ra was seen at Cox's Bazar Sea Beach, measuring 10.8 Bqkg^{-1} (Alam *et al.,* 1999).

In contrast, the sand and silt sample exhibited the maximum level of ^{226}Ra activity in Cox's Bazar (147.93 Bqkg^{-1}) (Yeasmin *et al.*, 2015), whilst the lowest activity was recorded at Kuakata Sea Beach (2.82 Bqkg^{-1}) (Islam *et al*, 2012).

The study of the soil sample indicated that the ^{226}Th activity ranged from its highest value of 1085.99 Bqkg^{-1} (Chakraborty, 1999) to its lowest value of 27.4 Bqkg^{-1} (Alam *et al.*, 1999) at Cox's Bazar Sea Beach.

The sand and silt samples had the most pronounced level of ^{226}Th activity in the Cox's Bazar area, at 1085.9 Bqkg^{-1}(Chakraborty *et al*., 2014). Conversely, the Kuakata Sea Beach had the lowest amount of radioactivity, measuring at 9.22 Bqkg^{-1} (Sarker *et al.,* 2021).

The study of the soil samples indicated that the concentration of ^{40}K was greatest at Inani Beach, Cox's Bazar, with a measurement of 1304.11 Bqkg^{-1} (Ahmed *et al.*, 2014), while it was lowest at Cox's Bazar Sea beach, with a measurement of 25.16 Bqkg^{-1} (Chakraborty, S. R., 1999).

The sand and silt sample collected from Kuakata Sea Beach exhibited the highest amount of ^{40}K activity, measuring 852 Bqkg^{-1} (Islam *et al.,* 2012). In contrast, the sample obtained from Cox's Bazar Sea Beach had the lowest level, measuring 21.9 Bqkg^{-1} (Chakraborty *et al.*, 2014).

The soil samples collected from Cox's Bazar Sea Beach exhibited an activity of ^{238}U at a level of 455.99 Bqkg^{-1} and 110.84 Bqkg^{-1} (Chakraborty, S. R., 1999), respectively.

The sand sample with the highest level of ^{238}U activity was discovered at Cox's Bazar, measuring 460.5 Bqkg^{-1} (Chakraborty *et al.*, 2014). The Patenga area in Chattogram had the lowest radioactive level, measuring 45.2 Bqkg^{-1} (Chakraborty *et al.*, 2014).

Table-9 displays the presence of ^{235}U in the minerals extracted from sand. The maximum concentration of ^{235}U was found in Bodarmukam, Cox's Bazar (specifically in the Foredune region) at a level of 145 Bqkg^{-1} (Zaman *et al.*, 2012). Conversely, the lowest concentration was observed in Fakirahata, Cox's Bazar (specifically in the Backdune area) at a level of 30 Bqkg^{-1} (Zaman *et al.*, 2012).

Table 1. Comparison of activity concentration of ^{226}Ra in the soil

^{226}Ra ($Bqkg^{-1}$)	Location	Reference
36±2 to 39±2	Patuakhali District	Chowdhury *et al.*, 2006
20.98 ± 3.96 to 42.92 ± 4.76	Kuakata Sea Beach	Islam *et al.*, 2012
23	Kuakata Sea Beach	Uddin *et al.*, 2019
10.8 ± 1.6 to 27.3 ± 2.6	Cox's Bazar Sea Beach	Alam *et al.*, 1999
26.11 ± 2.99 to 61.66 ± 5.88	Inani Beach, Cox's Bazar	Ahmed *et al.*, 2014
15.34 ± 1.66 to 33.70 ± 2.08	Coastal Area, Cox s Bazar	Das *et al.*, 2015

Table 2. Comparison of activity concentration of ^{226}Ra in the sand and sediment

^{226}Ra ($Bqkg^{-1}$)	Location	Sample type	Reference
2.82 ± 4.89 to 87.96 ±4.45	Kuakata Sea Beach	Sand	Islam *et al.*, 2012
22.83 ± 4.11 to 100.21 ± 2.39	Kuakata beach	Sand	Ahmed *et al.*, 2016
12.11 ± 1.99 to 31.64 ± 1.64	Kuakata beach	Sediment	Ahmed *et al.*, 2016
24.48 ± 2.17 to 76.14 ± 3.25	Kuakata Sea Beach	Sand	Sarker *et al.*, 2021
14.12 ± 2.75 to 75.54 ± 3.15	Cox's Bazar	Sand	Sarker *et al.*, 2021
15.14 ± 2.62 to 25.16 ± 3.05	Inani Beach, Cox's Bazar	Sand	Ahmed *et al.*, 2014
18.09 ± 2.66 to 53.32 ± 4.01	Inani Beach, Cox's Bazar	Sediment	Ahmed *et al.*, 2014
8.98 ± 1.49 to 31.33 ± 2.04	Coastal Area, Cox s Bazar	Sand	Das *et al.*, 2015
13.90 ± 1.64 to 38.41 ± 2.19	Coastal Area, Cox s Bazar	Sediment	Das *et al.*, 2015
147.93 ± 3.13 (mean activity concentration)	Cox's Bazar	Sand	Yeasmin *et al.*, 2015

Table 3. Comparison of activity concentration of ^{232}Th in the soil

^{232}Th ($Bqkg^{-1}$)	Location	Reference
269.04 ± 11.62 (average)	Kuakata Sea Beach	Chakraborty, 1999
1085.99 ± 20.01	Cox's Bazar Sea Beach	Chakraborty, 1999
52 ±5 to 99±8	Patuakhali District	Chowdhury *et al.*, 2006
59.25 ± 15.62 to 144.34 ± 18.52	Kuakata Sea Beach	Islam *et al.*, 2012
80	Kuakata Sea Beach	Uddin *et al.*, 2019
27.4 ± 3.7 to 49.4 ± 5.0	Cox's Bazar Sea Beach	Alam *et al.*, 1999
41.93 ± 4.18 to 89.39 ± 6.15	Inani Beach, Cox's Bazar	Ahmed *et al.*, 2014
30.09 ± 3.62 to 58.06 ± 4.23	Coastal Area, Cox s Bazar	Das *et al.*, 2015

Table 4. Comparison of activity concentration of ^{232}Th in the sand and sediment

^{232}Th (Bqkg^{-1})	Location	Sample type	Reference
21.72 ± 16.27 to 290.93 ± 18.15	Kuakata Sea Beach	Sand	Islam *et al.*, 2012
55.4±7.9–1085.9±20.0	Cox's Bazar	Sand	Chakraborty *et al*., 2014
105.4±9.2–269.0±11.6	Kuakata	Sand	Chakraborty *et al.*, 2014
96.8±9.1–121.7±9.7	Potenga	Sand	Chakraborty *et al.*, 2014
68.76 ± 2.86 to 297.37 ± 4.32	Kuakata beach	Sand	Ahmed *et al.*, 2016
18.94 ± 1.90 to 71.11 ± 2.88	Kuakata beach	Sediment	Ahmed *et al.*, 2016
9.22 ± 2.15 to 46.80 ± 2.17	Kuakata Sea Beach	Sand	Sarker *et al.*, 2021
10.28 ± 1.95 to 53.37 ± 2.75	Cox's Bazar	Sand	Sarker *et al.*, 2021
24.39 ± 2.50 to 49.46 ± 3.58	Inani Beach, Cox's Bazar	Sand	Ahmed *et al.*, 2014
31.01 ± 2.73 to 78.37 ± 4.35	Inani Beach, Cox's Bazar	Sediment	Ahmed *et al.*, 2014
16.82 ± 3.24 to 63.28 ± 4.37	Coastal Area, Cox s Bazar	Sand	Das *et al.*, 2015
37.94 ± 3.82 to 51.92 ± 4.11	Coastal Area, Cox s Bazar	Sediment	Das *et al.*, 2015
254.41 ± 5.43 (mean activity concentration)	Cox's Bazar	Sand	Yeasmin *et al.*, 2015

Table 5. Comparison of activity concentration of ^{40}K in the soil

^{40}K (Bqkg^{-1})	Location	Reference
266.00 ± 24.80	Kuakata Sea Beach	Chakraborty, S. R., 1999
25.16 ± 5.39	Cox's Bazar Sea Beach	Chakraborty, S. R., 1999
549±24 - 874±28	Patuakhali District	Chowdhury *et el.*, 2006
570.43 ± 100.3 to 1165 ±166.27	Kuakata Sea Beach	Islam *et al.*, 2012
700	Kuakata Sea Beach	Uddin *et al.*, 2019
117 ± 25 to 688 ± 33	Cox's Bazar Sea Beach	Alam *et al.*, 1999
467.16±77.62 to 1304.11±147.07	Inani Beach, Cox's Bazar	Ahmed *et al.*, 2014
379.99 ± 33.43 to 755.26 ± 38.03	Coastal Area, Cox s Bazar	Das *et al.*, 2015

Table 6. Comparison of activity concentration of ^{40}K in the Sand and Sediment

^{40}K (Bqkg^{-1})	Location	Sample type	Reference
26.24± 0.35 to 852.05 ± 142.15	Kuakata Sea Beach	Sand	Islam *et al.*, 2012
21.9±5.1–41.6±6.6	Cox's Bazar	Sand	Chakraborty *et al.*, 2014
192.9 ± 20.4–292.8 ± 25.4	Kuakata	Sand	Chakraborty *et al.*, 2014
236.5±24.4–293.8±25.6	Potenga	Sand	Chakraborty *et al.*, 2014
75.87 ± 15.75 to 161.81± 19.90	Kuakata beach	Sand	Ahmed *et al.*, 2016
182.73 ± 19.81 to 345.77 ± 21.07	Kuakata beach	Sediment	Ahmed *et al.*, 2016
76.23 ± 12.34 to 458.65 ± 17.04	Kuakata Sea Beach	Sand	Sarker *et al.*, 2021
56.42 ± 10.16 to 341.22 ± 14.64	Cox's Bazar	Sand	Sarker *et al.*, 2021
362.00 ± 79.61 to 560.87 ± 81.40	Inani Beach, Cox's Bazar	Sand	Ahmed *et al.*, 2014
390.26 ± 76.37 to 733.61 ± 85.80	Inani Beach, Cox's Bazar	Sediment	Ahmed *et al.*, 2014
252.42 ± 31.72 to 565.72 ± 35.78	Coastal Area, Cox s Bazar	Sand	Das *et al.*, 2015
367.70 ± 33.28 to 665.05 ± 36.97	Coastal Area, Cox s Bazar	Sediment	Das *et al.*, 2015
321.54±17.32 (mean activity concentration)	Shaplapur, Inani and Himchori villages of Cox's Bazar	Sand	Yeasmin *et al.*, 2015

Table 7. Comparison of activity concentration of ^{238}U in the soil

^{238}U (Bqkg^{-1})	Location	Reference
110.84 ±10.22	Kuakata Sea Beach	Chakraborty, S. R., 1999
455.99 ± 16.35	Cox's Bazar Sea Beach	

Table 8. Comparison of activity concentration of ^{238}U in the sand

^{238}U (Bqkg^{-1})	Location	Sample type	Reference
23.3±7.8–460.5±16.4	Cox's Bazar	Sand	Chakraborty *et al.*, 2014
51.9±8.6–110.8±10.2	Kuakata	Sand	Chakraborty *et al.*, 2014
45.2±8.2–59.4±8.9	Potenga	Sand	Chakraborty *et al.*, 2014
164.27±4.82 (mean activity concentration)	Shaplapur, Inani and Himchori villages of Cox's Bazar	Sand	Yeasmin *et al.*, 2015

Table 9. Comparison of activity concentration of ^{235}U in the separated minerals from sand

^{235}U ($Bqkg^{-1}$)	Location	Reference
145 ± 18	Bodarmukam, Cox's Bazar (Foredune area)	Zaman *et al.*, 2012
87 ± 14	Monkhali, Cox's Bazar (Foredune area)	
65 ± 13	Kalatoli, Cox's Bazar (Foredune area)	
43 ± 12	Lomburi, Cox's Bazar (Backdune area)	
39 ± 10	Shaplapur, Cox's Bazar (Backdune area)	
30 ± 8	Fakirahata, Cox's Bazar (Backdune area)	

Conclusion

The coastal region of Bangladesh has great prospective not only in tourism but also in agriculture. Based on the available information, a thorough review has been carried out on the naturally occurring radioactive elements in the coastal areas of Bangladesh and found that the level of activity is not harmful at all (Islam ***et al.,*** 2012; Ahmed *et al.*, 2014). The soil of the study areas could be used for the agricultural and other purpose. The study's findings are extensively recorded as foundational knowledge for future investigations on radionuclides, particularly the transmission of radionuclides from soil to different crops and ecosystems as well.

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