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The presence of radioactive materials in soil, sand and sediment samples of potenga sea beach area, Chittagong, Bangladesh: geological characteristics and environmental implication

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Abstract

Accurate quantification of naturally occurring radioactive materials in soil provide information on geological characteristics, possibility of petroleum and mineral exploration, radiation hazards to the dwelling populace etc. Of practical significance, the earth surface media (soil, sand and sediment) collected from the densely populated coastal area of Chittagong city, Bangladesh were analysed using a high purity germanium $\gamma$-ray spectrometer with low background radiation environment. The mean activities of $^{226}$Ra($^{238}$U), $^{232}$Th and $^{40}$K in the studied materials show higher values than the respective world average of 33, 36 and 474 Bq/kg reported by the UNSCEAR (2000). The deduced mass concentrations of the primordial radionuclides $^{238}$U, $^{232}$Th and $^{40}$K in the investigated samples are corresponding to the granite rocks, crustal minerals and typical rocks respectively. The estimated mean value of $^{232}$Th/$^{238}$U for soil (3.98) and sediment (3.94) are in-line with the continental crustal average concentration of 3.82 for typical rock range reported by the National Council on Radiation Protection and Measurements (NCRP). But the tonalites and more silicic rocks elevate the mean value of $^{232}$Th/$^{238}$U for sand samples amounted to 4.69. This indicates a significant fractionation during weathering or associated with the metasomatic activity in the investigated area of sand collection.

Keywords: Earth surface media; HPGe $\gamma$-ray spectrometry; $^{232}$Th/$^{238}$U ratio; Mass concentration; granite rocks; crustal minerals.

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1. Introduction

The natural radioactivity from primordial origins is the vast majority detected on the earth. Uranium in nature is found as $^{238}\text{U}$ (99.2739–99.2752%), one of the heaviest element exists mainly in the earth crust with activity appearing in soil, in water and/or in the earth-born materials (UNSCEAR, 1993). Uranium has been deposited on land by volcanic action, and occurring in many different rock types from sedimentary to volcanic (HPS Fact Sheet, 2011; NMBGMR, 1971). Chemical conditions sometimes elevate the concentrations of uranium, and significantly occur in some substances such as phosphate rock deposits, minerals (such as lignite) and monazite sands in uranium-rich ores. The redistribution of uranium in soil, rocks as well as in water is happening throughout the environment by wind, rain and geologic processes. Moreover, it can dissolve in the water to be consumed by any organism. The mean concentration of $^{238}\text{U}$ in the earth’s crust varied from 0.5 to 5 ppm (Ramola et al., 2011), and in granite it is 4 ppm (NMBGMR, 1971). The radioactive substance of thorium occurs naturally in the earth’s crust in combination with other minerals such as silica. More than 99% of natural thorium exists in the form of thorium-232 with a concentration range of 2-20 ppm (Ramola et al., 2011). Some rocks in underground mines contain more concentrated form of thorium. Natural weathering like wind and water action breaks these rocks, and makes the thorium and all other components of the rocks to become a part of the soil (ATSDR, 1999). Moreover, the soil containing high amount of clay materials show higher contents of thorium (Harmsen and Haa, 1980). The two natural isotopes of potassium $^{39}\text{K}$ (93.2581%) and $^{41}\text{K}$ (6.7302%) are needed for living species, however, the strong gamma radiation emitted from the primordial $^{40}\text{K}$ (0.0118%) causes various health hazards (Peterson et al., 2007; Farai et al., 2006). The aforementioned radionuclides and their progenies are the principal contributor to the background radiation in our living environment. The different physico-chemical forms of these radionuclides have influenced on their mobility and biological uptake. As for instance, uranium specially bonds to organic matter while potassium and thorium preferentially bond to clays, and hence these are more radioactive than the other sedimentary rocks.

Bangladesh, located on the northern coast of the Bay of Bengal, is a low-lying riverine land traversed by many branches and tributaries of the two Himalayan rivers, the Ganges and the Brahmaputra. On the other hand, the Karnaphuli, originated from the Lusai hills of India, is the largest and widest river in the south-eastern part of Bangladesh serving as the principal drainage of this region, and enters into the Bay of Bengal through the Potenga outfall in a
southerly direction. However, the riverine system of Bangladesh transports the largest sediment load including 1000 tons of natural uranium annually to the Bay of Bengal which is about 10% of the estimated global supply of natural uranium to the oceans (Ghose et al., 2003). Normally, sand is sourced from surface wash erosion of hillslopes, gully erosion etc., and suspended with water in sea shore/estuaries. Some of the suspended sand is deposited on the sea bed while others follow overbank deposition via flood plains and sea/tidal waves, and formed sandy sea beach. The potenga sea beach is located almost on the mouth of the Karnaphuli River and stretches to the Bay of Bengal. Just before the region of ‘estuary’ or ‘river delta’, the Karnaphuli river is surrounded by a dense population of more than 3 million people and covered by large scale shipping activities. There are about 200 industries identified as pollution causing units out of thousands of industries which were established near to the bank of Karnaphuli river (GSP Training Centre, 2003). Some of those units are cement factory, tannery, textile mill, DDT plant, oil refinery, chemical factory, fertilizer factory, power plant, dry-dock, paint factory, paper mills, rayon mills etc. These factories are continuously discharging unlawfully a huge amount of pollutants to the Karnaphuli river via many canals. Beside this, the municipal sewage discharge from the Chittagong city through many canals can be treated as another factor of pollution problem. Moreover, the mouth of the Karnaphuli river hosts the Chittagong sea port, the main port of Bangladesh, which is handling about 12.5 million tons of cargo per year via more than 1500 merchant ships and 3000 fishing vessels. The illegal/accidental discharges (i.e. grease, fish oil, bilge, garbage etc) from ships are causing a severe pollution. Furthermore, the shipbreaking yards located near this city are the Chittagong’s international claim to fame, but for the wrong reasons; these are considered one of the most polluted places on Earth with highly dangerous practices and hazardous working conditions. Therefore, the artificial and natural waste management processes are causing continuously severe pollution to the river (GSP Training Centre, 2003), and the adjacent areas such as the Potenga sea beach. Although, the levels of natural radioactivity vary greatly depending on the soil type, mineral make-up and density, but the aforementioned activities may redistribute the levels of naturally occurring radioactive materials (NORMs) in the study areas. In addition, the nuclear weapon testing of some neighborhood countries (India, Pakistan and China) may also elevate the level of natural radioactivity in the surrounding environment.

The Potenga sea beach is a very popular tourist place to all ages of people due to its closeness to the city and lack of available recreational places in Chittagong city. The beach is
quite sandy with a few rocky patches, and is known for having some of the most stunning
sunsets and sunrises in Bangladesh. Following the radiological health hazards especially from
the external exposure via gamma radiation, the concentrations of NORMs in this area should
be in periodic monitoring. Beside this, accurate knowledge of specific activities and
distributions of \(^{238}\text{U}\), \(^{232}\text{Th}\), \(^{40}\text{K}\) in soil, sand and sediment samples are of interest since they
provide useful information for soil configuration and also in monitoring of environmental
radioactivity towards human health implications.

A detailed review of literature reveals that only two earlier studies (Ghose et al., 2003;
Chakraborty and Alam, 2014) are available in the present area of interest, but a lots of similar
works are reported (Myrick et al., 1983; Kohman and Saito, 1954; Chiozzi et al., 2002;
Florou and Kritidis, 1992; Karahan and Bayulken, 2000; Al-Jundi, 2002; Ahmad et al., 1997;
Yu-Ming et al., 1987; Bellia et al., 1997; Fernandez et al., 1992; Baeza et al., 1992;
Nageswara et al., 1996; Shuaibu et al., 2017; Khandaker et al., 2018) throughout the world.
All of these studies bring to focus the necessity for continuous assessment of radiation dose
distribution in soil, sand, sediment so as to accurately evaluate the radiation risk to a
population and to effectively monitor the contributions of anthropogenic activities to
terrestrial gamma dose rates for any outdoor occupation. To this end, the study has been
conducted to investigate the level of natural radionuclides (\(^{226}\text{Ra}\), \(^{228}\text{Ra}\) and \(^{40}\text{K}\)) in Potenga
beach environment due to its importance as tourist palce for adequate radiological assessment
to the visitors and coastal population. This study is expected to contribute in development of
environmental regulatory frameworks, and also provide the knowledge on geological
characteristics and/or corresponding formation of the studied materials.

2. Materials and Method

The investigated samples of soil, sand and sediment were collected from the sea beach area
(in the period of April – June, 2015) along the bank of the Bay of Bengal located at Potenga,
Chittagong, Bangladesh. It lies between the longitudes of 91˚47.245' - 91˚47.710' and the
latitudes of 22˚14.440' - 22˚13.950' (Fig. 1). The soil samples (marked with code: Sb-L-01 to
Sb-L-10) were at detachment of sea water and all of them were collected from the nearby
agricultural field. The sand samples (marked with code: Sb-L-11 to Sb-L-20) were frequently
inundated by sea water because of much closer to the channel and the sediment samples
(marked with code: Sb-L-21 to Sb-L-30) were under the shallow sea water. The investigated
locations of soil, sand and sediment formed three adjacent rows and were along a line from
north to south. Each sample was about 101 m apart from the nearest one, and at each location
the sample was collected from 5 - 10 cm depth. All of the labelled samples were transported to the Radioactivity Testing and Monitoring Laboratory, Atomic Energy Center, Chittagong, Bangladesh for subsequent preparation and investigation.

After removing unwanted objects and drying under direct sunlight, each sample was also oven dried at about 105°C to obtain constant weight. To make certain the homogeneity of the sample, the investigated samples finally collected after passing through a 500 µm sieve. For the measurement of natural radioactivity, each dried sample was weighed and then taken into individual cylindrical plastic container of 2.8 cm height and 8 cm diameter. The container was simply shaken by hand to settle down the dry powder sample homogeneously. The volume of each sample was about 131 cm³ and kept equal to the standard gamma-ray source material. To ensure air tight condition, the containers were sealed tightly and wrapped with wide vinyl tapes around their screw necks. For allowing the secular equilibrium between 232Th and 226Ra and their progenies, the investigated samples were stored for four weeks before the measurement of radioactivity (Debertin and Helmer, 1980; Schötzig and Debertin, 1983).

A closed-end coaxial high-purity germanium (HPGe) γ-ray detector with a relative efficiency of 20%, resolution 1.8 keV (FWHM) at 1332 keV of 60Co was used to measure the radioactivities of the prepared samples and the International Atomic Energy Agency (IAEA) reference samples. The detector (GC2018, CANBERRA, USA) was coupled with digital spectrum analyzer, DSA-1000 and the γ-ray spectra were analyzed by using the program GENIE 2000. To reduce the γ-ray background, the detector was shielded by a cylindrical 5.08 cm thick lead with a fix bottom and removable cover. Within this shielding arrangement each sample was measured at position of surface of the detector. The sample counts at specific energies as well as background counts were taken to determine the radioactivity of the natural radioisotopes. Background count was determined by a blank plastic container of the same geometry of the sample. The duration of sample counting time was set to ensure a better counting statistics. To obtain the net peak areas, all the background counts were subtracted from original sample counts. The radioactivity concentrations of radionuclides present in the studied samples were determined by using these peak areas.

The detector efficiency is an important factor for the measurement of radioactivity of bulk material. The detection efficiency curve depends on detection system, sample shape and sample matrix. It is done by measuring the known activity of the volume samples prepared using IAEA reference samples RGU-1, RGTh-1 and RGK-1 (IAEA, 1987). Both the IAEA-
RGU-1 and IAEA-RGTh-1 radioactive powder reference materials prepared by dilution of uranium ore and thorium ore with floated silica powder of similar grain size distribution, respectively, were provided by the IAEA. The IAEA reference samples namely RGU-1, RGTh-1 and RGK-1, amounted to 10.0140g, 10.0072g and 10.0053g respectively, were individually mixed homogeneously with average 179.62g of investigated soil, sand and sediment samples to make three separate standards gamma-ray source materials. It was strictly followed the volume same for all the investigated and standards samples. $^{226}$Ra and $^{210}$Pb are confirmed to be in radioactive equilibrium. The random coincidence loss made negligible by the sample-to-detector distance and the solid angle subtended by the sample of standard radioactive sources. These three standards gamma-ray sources of same volume were used for efficiency calibration. The efficiency of the detector was calculated using the equation (1), and obtained efficiency versus energy curve with error bars is shown in Fig. 2.

$$E_{\text{eff}}(\%) = \frac{\text{CPS}}{A_0 e^{-\lambda t} \times I_\gamma} \times 100 \% \quad \text{--------- (1)}$$

where, $E_{\text{eff}}$ is the efficiency of the detector as a function of gamma-ray energy, CPS is the counts per second, $A_0$ is the initial activity of the standard source, $\lambda$ is the decay constant of the source material, $t$ is the decay time of source, $I_\gamma$ is the gamma-ray emission probability.

A typical $\gamma$-ray spectrum of a soil sample (Sb-L-01) is shown in Fig. 3. The peaks of this spectrum are attributed to the decay products of $^{226}$Ra ($^{238}$U) and $^{232}$Th series and to $^{40}$K. The counts at peaks of energies 351.93 keV due to the decay of $^{214}$Pb and 609.32 keV formed in the decay of $^{214}$Bi were used to measure $^{226}$Ra ($^{238}$U) radioactivity. The $^{232}$Th radioactivity was determined by $\gamma$-ray counts at peak energies 238.632 keV and 911.204 keV formed via the decay of the $^{212}$Pb and $^{228}$Ac radionuclides, respectively. To end with, we took average of the values obtained from different peak energies. The radionuclide $^{40}$K was recognized by its single $\gamma$-line at energy of 1460.822 keV. It should be mentioned that the artificial radioactivity due to $^{137}$Cs in the investigated samples was below the detection limit. In this experiment the lower limit of detection for $^{137}$Cs was measured by 0.044 Bq following the equation given in (Khandaker et al., 2016). The measured gamma-ray count rate (CPS) is converted to the activity concentration of the $^{226}$Ra ($^{238}$U), $^{232}$Th and $^{40}$K radionuclides by using the equation (2) taken from Khandaker et al., (2017):

$$\Lambda = \frac{\text{CPS} \times 1000}{\varepsilon_\gamma \times I_\gamma \times W} \quad \text{--------- (2)}$$
where, \( A \) represents the specific activity (Bq kg\(^{-1}\)), \( \varepsilon_\gamma \) is the absolute efficiency of the detector for the corresponding peak, \( I_\gamma \) is the gamma-ray emission probability and \( W \) is the mass of the sample in gram.

The radioactivity of each sample is being reported with the counting error of one sigma. We have also calculated the standard deviation (SD) from the several values and their average for a radionuclide using the equation (3). It should be mentioned that the investigated sample had been divided into sub samples to get the SD for \(^{40}\)K.

\[
\text{SD, } \sigma = \left( \frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \cdots + (x_n - \bar{x})^2}{n} \right)^{1/2}
\]

The mass concentrations were determined from the activity concentration of \(^{238}\)U, \(^{232}\)Th and \(^{40}\)K radionuclides using the equation (4) taking from the ref. (Malain et al., 2012):

\[
C_E = \frac{M_E \times A_E \times 10^6}{\lambda_E \times N_A}
\]

where \( C_E \) is the mass concentration of the radionuclide \( E \) in ppm (parts per million), \( M_E \) is the atomic mass of the radionuclide’s of interest in g/mol, \( A_E \) is the specific radioactivity of the radionuclide in Bq/g, \( \lambda_E \) is the decay constant of the radionuclide and \( N_A \) is the Avogadro’s number (6.023 \times 10^{23} \text{ atoms/mol}).

The \(^{40}\)K concentration as a percentage (%) of mass in the sample of the total potassium was calculated by using the equation (5):

\[
\%C_K = \frac{M_K \times A_K \times 10^2}{N_K \times \lambda_K \times N_A}
\]

where \( C_K \) is the percentage of total potassium of the investigated sample, \( M_K \) is the atomic mass of \(^{40}\)K in g/mol, \( A_K \) is the specific radioactivity of \(^{40}\)K in Bq/g, \( N_K \) is the percent of natural abundance of \(^{40}\)K (0.0118%), \( \lambda_K \) is the decay constant of \(^{40}\)K, \( N_A \) is the Avogadro’s number.

3. Results and discussion

The measured activity concentrations of natural radionuclides in the studied surface media are presented in Table 1. The results are reported in Bq/kg on a dry-weight basis. The activity concentrations (Bq/kg) in the soil samples are in the range of 41.52 ± 7.27 - 86.12 ± 6.72 for \(^{226}\)Ra; 67.39 ± 7.45 - 102.64 ± 5.68 for \(^{232}\)Th and 787.5 ± 7.6 - 1125.4 ± 6.3 for \(^{40}\)K; in the
sand samples 24.72 ± 9.92 - 89.12 ± 2.73 for \(^{226}\text{Ra}\); 38.43 ± 8.34 - 98.59 ± 2.47 for \(^{232}\text{Th}\) and 401.8 ± 6.8 - 649.2 ± 3.7 for \(^{40}\text{K}\) and in the sediment samples 72.58 ± 8.78 - 114.0 ± 7.7 for \(^{226}\text{Ra}\); 105.7 ± 1.6 - 135.4 ± 5.9 for \(^{232}\text{Th}\) and 310.5 ± 6.3 - 651.0 ± 8.1 for \(^{40}\text{K}\). Overall, the measured mean activity concentrations of \(^{226}\text{Ra}\) (\(^{238}\text{U}\)) and \(^{232}\text{Th}\) in the studied samples show the following order Sediment > Soil > Sand. Table 1 shows the activity of \(^{232}\text{Th}\) chain to be greater than that of \(^{238}\text{U}\) chain in most of the studied samples, supportive to the fact that the presence of thorium is 1.5 times greater than that of uranium in the Earth's crust. It was observed that the activity concentrations of \(^{226}\text{Ra}\) and \(^{232}\text{Th}\) in the studied materials were not uniform, which represents the variations in the geological characteristics of the area under study. It was also observed that the measured activity of \(^{40}\text{K}\) exceeded by far the values of both \(^{232}\text{Th}\) and \(^{226}\text{Ra}\), being both the most abundant radioactive element present in the environment, and it also being noted that potassium is used extensively as part of a NPK fertilizer medium in intensive farming/agricultural activities to promote the vigorous growth of crops. The overall mean activities of \(^{226}\text{Ra}\), \(^{232}\text{Th}\) and \(^{40}\text{K}\) in the studied samples were found higher than that of the world mean values of 33, 36 and 474 Bq/kg (UNSCEAR, 2000), respectively.

The esmitted mass concentrations for the \(^{238}\text{U}\) (\(^{226}\text{Ra}\)), \(^{232}\text{Th}\) and \(^{40}\text{K}\) in the studied soil, sand and sediment samples are presented in Table 1 with SD%. The mean mass concentrations of \(^{238}\text{U}\), \(^{232}\text{Th}\) (ppm) and % of K in the soil samples were found as 5.30 ± 0.46, 20.42 ± 1.19 ppm and 2.96 ± 0.02 %, respectively. The results obtained for U are corresponding to the formation of granite rocks (1-10 ppm of U), while the Th concentrations are in the range of Th (3-30 ppm) corresponds to the crustal minerals (IAEA, 1989; Alnour et al., 2012). The concentrations of K obtained are in the range of the typical rocks (0.3 – 4.5%) (Alnour et al., 2012). The ratio of \(^{232}\text{Th}/^{238}\text{U}\) was found in the range of 2.85 - 5.16 with a mean value of 3.98. It shows that the investigated soil samples have uranium and thorium contents in the typical rock range and the mean value is closer to the continental crustal average concentration of 3.82 reported by the National Council on Radiation Protection and Measurements (NCRP, 1987). The agreement indicates that there is no significant fractionation during weathering or associated with the metasomatic activity in the investigated area of soil collection.

The average mass concentrations of \(^{238}\text{U}\) (\(^{226}\text{Ra}\)), \(^{232}\text{Th}\) and % of total K in the sand samples were found as 3.98 ± 0.51, 17.06 ± 0.91 ppm and 1.60 ± 0.01 % respectively. The concentrations of U and Th obtained are also corresponding to the formation of granite rocks.
and crustal minerals respectively (IAEA, 1989; Alnour et al., 2012), while the concentrations of K are in the range of the typical rocks (NCRP, 1987). The range of the $^{232}\text{Th}/^{238}\text{U}$ ratio was found as 3.38 - 7.53 with a mean value of 4.69, which is much higher than the continental crustal average concentration of 3.82 (NCRP, 1987). The reason may be the tonalites and more silicic rocks, which may elevate the mean value of the $^{232}\text{Th}/^{238}\text{U}$ ratio in the range of 4.5-5.5 (Larsen and Gottfried, 1960). The disagreement suggests that there is a significant fractionation during weathering in the monitored area of sand collection. Moreover, it is stated that the original U, Th and K concentrations in rocks may vary because of alteration or metamorphic processes (Verdoya et al., 2001).

The mean mass concentrations of $^{238}\text{U}$ ($^{226}\text{Ra}$), $^{232}\text{Th}$ and % of total K in the sediment samples were found as 7.59 ± 0.65, 29.93 ± 1.52 ppm and 1.56 ± 0.02% respectively. The obtained concentrations of U, Th and K are also corresponding to the formation of granite rocks, crustal minerals and typical rocks, respectively (IAEA, 1989; Alnour et al., 2012; NCRP, 1987). The $^{232}\text{Th}/^{238}\text{U}$ ratio was found to lie within the range of 3.30 - 5.39 which is almost in the typical rock range. The mean value of 3.94 found from these sediment samples is nearer to the continental crustal average concentration of 3.82 (NCRP, 1987). It indicates that there is no significant fractionation during weathering or associated with the metasomatic activity in the investigated area of sediment collection.

The above results reflect the involvement of granite rocks, crustal minerals, and typical rocks types to form the studied surface media of the investigated area. Granite is an igneous rock formed through the cooling and solidification of magma or lava. Granite rocks are geologically important because their features are usually characteristic of a specific tectonic environment, allowing tectonic reconstitutions. Moreover, in some special circumstances they host important mineral deposits for example, tungsten, tin, and uranium are commonly associated with granites and diorites, whereas ores of chromium and platinum are commonly associated with gabbros (Eby, 2011). As large bodies of granite solidify, the trace amounts of uranium become concentrated in the last bits of fluid left. Good specimens of uranium minerals are found in the final stage of granite solidification. The rare earth elements are the constituents of more than 100 minerals. Thorium as well as uranium appears as components in many of these minerals such as monazite, zircon, and allanite (Papadopoulos et al., 2014). The minerals of the continental crust is critically important to understand its formation and evolution and, ultimately, understanding of the Earth differentiation. The presence of
numerous crustal minerals suggests derivation from metasedimentary rocks subducted into
the mantle. Most of these minerals were derived from the crustal parts of subducted slabs and
were encapsulated into chromite grains precipitated from rising asthenospheric and
suprasubduction magmas (Robinson et al., 2015).

Weathered and weakly-compacted sedimentary rocks, weakly-cemented sedimentary
rocks, schists, competent sedimentary rocks, some low-density coarse-grained igneous rocks,
competent igneous rocks, some metamorphic rocks, fine-grained sandstones, quartzites,
dense fine-grained igneous rocks etc. are the typical rock types. Potassium has significant
part in typical rock. It is one of the most reactive and electropositive of all metals and rapidly
oxidizes, and occurs in nature in ionic salts.

The correlations between $^{226}$Ra and $^{232}$Th activities as shown in Figs. 4-6 are
approximately linear with the correlation coefficients of 0.49, 0.89 and 0.28 in soil, sand and
sediment samples respectively. From these relations it is imitated that the sand samples are
originated from the same type of source, while the soil and sediment samples show the
variations in origin.

Figure 7 shows the concentrations of radionuclide in the studied materials in the
following order: sediment > soil > sand. On an average, the $^{232}$Th concentration is 75% higher
than the $^{238}$U concentration. The average concentration of $^{40}$K varied from 1.56 – 2.96 % and
decreased in order as, soil > sand > sediment. It should be mentioned that the most of the
sediment and sand samples had low content of K due to the absence of sufficient amount of
clay. The concentrations of natural radionuclides in soil and sediment may be enhanced due
to the presence of U and Th in clay and sea water, respectively.

The concentration of the studied radionuclides obtained from soil and sand samples
lie within the range of available literature (Ghose et al., 2003; UNSCEAR, 2000; Islam et al.,
2012; Ansary, 1997; Mohanty et al., 2004; Ali et al., 1996; Benjakul, 2007; Kessaratikoon
and Awackechi, 2008; Abdi et al., 2008; El-Arabi, 2005; Lu and Zhang, 2008; Veiga et al.,
2006), while sediment samples showed little bit higher concentrations for $^{238}$U and $^{232}$Th. It is
worth mentioning that the literature values in Bq/kg have also been converted into mass
concentration for comparison purpose. Table 2 shows that the worldwide mean values
(UNSCEAR, 2000) are rather low compared to the present investigation. The mean values
due to $^{238}$U obtained in this work (5.30, 3.98 and 7.59 ppm) are similar to those for Peshwar
and Songkhla. The reported data for Brazil are significantly higher, and the reason is high mineral deposition in that beach sand. The derived values for $^{232}$Th in this work (17.06, 20.42 and 29.93 ppm) are comparable to Potenga, Kuakata, Peshwar and Songkhla, but much lower than Cox’s Bazar, Orissa, and Brazil. The higher content of heavy minerals like Monazite, Kyanite, etc., in the soil/sand of Cox’s Bazar, India and Brazil cause this difference. The mean values in % of total K in the investigated samples (2.96, 1.60 and 1.56) are close to Potenga, Kuakata, Cox’s Bazar, Peshwar, Egypt and Xianyang. The rest of the locations presented in this table have lower mean values compared to this investigation. However, the distinction have found due to the differences in geological properties of soil and fractionation during weathering.

4. Conclusions

The geological formation of surface media (soil, sand and sediment) collected from the Potenga sea beach area of Chittagong, Bangladesh are investigated through determining the mass concentration of natural radionuclides ($^{238}$U, $^{232}$Th and $^{40}$K) using HPGe $\gamma$-ray spectrometry. No artificial radionuclide was found in any studied sample. It is observed that the average mass concentrations of $^{238}$U ($^{226}$Ra) and $^{232}$Th in the investigated samples decreased in order as sediment > soil > sand. The difference may be due to the geochemical variation of soil, sand and sediment samples and may have the effects of weathering. The strong correlation of $^{226}$Ra and $^{232}$Th in sand samples reflects the source of same origin. The comparison with the literature data of various beach sand/soil indicated that the analyzed soil, sand and sediment samples have lower deposition of minerals which represent safer radiological environment for dwelling populace. The deduced mass concentrations of $^{238}$U, $^{232}$Th and $^{40}$K in the investigated samples are corresponding to the granite rocks, crustal minerals and typical rocks respectively. Moreover, this study particularly important to provide information on the corresponding formation of different soil type and associated environmental radioactivity, and secondly, the analysis of selective elemental abundance (Th/U ratios) may also allow us to study the enrichment/reduction processes as a result of the complex metamorphic history, alteration and weathering that affected the investigated soil.

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**Contribution**

All authors contributed equally in the preparation of this manuscript.

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**References**


International Atomic Energy Agency (IAEA), 1989. Construction and use of calibration facilities for radiometric field equipment, Technical reports series no 309, IAEA,
Vienna.


New Mexico Bureau of Geology & Mineral Resources (NMBGMR), 1971. New Mexico Institute of Mining & Technology, 801 Leroy Place, Socorro, NM 87801-4796.


Table 1: Measured radioactivity and estimated mass concentrations of $^{238}\text{U}$ ($^{226}\text{Ra}$), $^{232}\text{Th}$ (ppm) and % of total K in the investigated samples collected from Potenga sea beach area of Chittagong. The values are presented together with ± (SD%).

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Sample ID</th>
<th>Radioactivity concentrations (Bq/kg) of</th>
<th>Mass concentrations (ppm) of</th>
<th>Activity ratio (Th/Ra)</th>
<th>Mass ratio (Th/Ra)</th>
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<td>$^{238}\text{U}$</td>
<td>$^{232}\text{Th}$</td>
<td>$^{40}\text{K}$</td>
<td>$^{238}\text{U}$</td>
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<td>86.12 ± 6.72</td>
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<td>SB-L-2</td>
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<td>SB-L-3</td>
<td>73.01 ± 5.45</td>
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<td>SB-L-4</td>
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<td>SB-L-5</td>
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<td>SB-L-6</td>
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<td>SB-L-7</td>
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<td>67.39 ± 7.45</td>
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<td>SB-L-8</td>
<td>70.41 ± 3.96</td>
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<td>83.17 ± 4.83</td>
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<td>Sand</td>
<td>SB-L-11</td>
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<td>95.29 ± 9.19</td>
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<td>SB-L-12</td>
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<td>SB-L-13</td>
<td>27.82 ± 9.71</td>
<td>45.77 ± 3.00</td>
<td>510.6 ± 3.5</td>
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<td>SB-L-14</td>
<td>71.87 ± 1.36</td>
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<td>SB-L-15</td>
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<td>SB-L-23</td>
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<td>SB-L-24</td>
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<td>SB-L-25</td>
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<td>SB-L-26</td>
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<td>SB-L-27</td>
<td>76.89 ± 9.88</td>
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<td>SB-L-29</td>
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<td>SB-L-30</td>
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<td>498.0 ± 7.4</td>
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</table>
Table 2: Average mass concentrations derived from the values of activity concentrations (Bq kg\(^{-1}\)) in the investigated samples compared against the few existing literature values reported for soil and sand from various beaches. Note that the literature values in Bq/kg have also been converted in this present work into mass concentration for comparison purpose.

<table>
<thead>
<tr>
<th>Location</th>
<th>Studied materials</th>
<th>Mean elemental concentration</th>
<th>References</th>
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<td>Potenga, Bangladesh</td>
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<td>Sand</td>
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</table>
Fig. 1: Map of study area with the specific sampling (L1-L30) locations.

Fig. 2: Efficiency vs energy curve for HPGe $\gamma$-ray detector

Fig. 3: A typical $\gamma$-ray spectrum of a soil sample (Sb-L-01)
Fig. 4: Correlation between $^{238}\text{U}$ ($^{226}\text{Ra}$) and $^{232}\text{Th}$ in beach soil samples

Fig. 5: Correlation between $^{238}\text{U}$ ($^{226}\text{Ra}$) and $^{232}\text{Th}$ in beach sand samples
Fig. 6: Correlation between $^{238}$U ($^{226}$Ra) and $^{232}$Th in beach sediment samples

Fig. 7: Comparison of average concentration of $^{238}$U, $^{232}$Th in ppm and % of total K with respect to soil, sand and sediment samples