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Radiation hazards due to terrestrial radionuclides at the coastal area of Ship Breaking Industries, Sitakunda, Bangladesh

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ABSTRACT- One of the largest ship braking facilities in the world is situated in the sea shore along the Sitakunda coast line, Bangaldesh. So, this coastal region of the Bay of Bengal plays a vital role in the socio-economic development of poverty-stricken country Bangladesh. For the assessment of radiation risks due to terrestrial radionuclides in this coast, shore sediment was analyzed by a high quality gamma spectrometer. ^{238}U, ^{232}Th and ^{40}K radionuclides were found to have specific activity 30.93 Bq/kg, 61.65 Bq/kg and 467.8Bq/kg, respectively, on average. These observed values were higher than the world accepted value. So, Sitakunda coastal region emerged as to possess the high natural background radiation. Observation of higher activity for ^{40}K might have a link to the scraping of vessels of food stuffs. Strong correlated distribution ^{238}U and ^{232}Th indicated the abundance of monazite mineral in this coastal area. Atmospheric fallout of ^{137}Cs was negligible.

Keywords: Gamma spectrometry, ^{238}U, ^{232}Th, ^{40}K, Sediment, Monazite, Sitakunda,

Introduction

Since the creation of our earth soil and sediment contain different radionuclides. At the present age of our earth, these terrestrial radionuclides are mainly members of the two natural radioactive series, namely uranium (^{238}U) and thorium (^{232}Th) series, and the isotope potassium-40 (^{40}K). These natural radionuclides cause radiation exposure to us externally through gamma ray emission and internally as well, through inhalation and food chain [1]. Apart from the natural radionuclides, nuclear technology based on the nuclear fission generates many long lived radionuclides such as cesium-137 (^{137}Cs), strontium-90 (^{90}Sr), iodine-129 (^{129}I), technetium-99 (^{99}Tc), neptunium-237 (^{237}Np) etc. These anthropogenic radionuclides come into environment largely due to nuclear weapon tests, accidents in nuclear power plants and geological repository of high-level nuclear wastes [2]. Among these artificial radionuclides ^{90}Sr and ^{137}Cs are the most abundant ones [3].

Distribution of natural radionuclides in soil and sediment is not uniform, rather significantly varies from place to place [UNSCEAR 2008]. Although Bangladesh does not have any history of release of any long lived fission nuclides, small amount of ^{137}Cs was observed in this country due to stratospheric fallout [4, 5]. So, for the assessment of radiation hazard in Bangladesh, it is essential to determine the concentration of terrestrial radionuclides throughout the country. As a part of it, this study was conducted at the coast of the Bay of Bengal from Faujdarhat to Kumira, Chittagong. This part of the coast lies in the Sitakunda Upazila of the Chittagong district. This coast hosts the second largest ship breaking facility in the world, which is located about 10 km north of the Chittagong city. On average 180-250 old ships each year are scrapped in about 30 ship breaking yards located in this coast. Around 200,000 people are engaged in different business related to the ship breaking activity. So, this coast contributes a lot in both macro and micro-economic development of Bangladesh. But this industry has been grown without taking proper care on different environmental issues. In 1995 the Department of Environment, Bangladesh has classified this economically important coastal region as Red because of potential hazardous impact on the environment. This research work found out the distribution of different radionuclides in sediments of this coastal region and thereby assessed the radiation hazard. So, this work will be valuable in the development of rules and regulation for the health and environmental safety in the ship breaking industry.

Materials and Methods

Sample collection and preparation: For the assessment of radiation hazard due to terrestrial radionuclides in the coastal region of ship breaking industry, surface sediment was collected from 19 locations of the sea coastline; distance between two sampling sites was more or less 500 m. Locations of sampling sites were recorded by using the assisted global positioning system. Table-1 shows the locations of sample collection sites and dry weight of the sediment sample. As the coastal region selected in this study stretches from North to South, sediment samples were given identifications in two digit Arabic numbers in such way that the sample S01 was located at the northernmost site, locally known as Sandip Channel or Boat Ghat, and whereas

the last sample S19 was collected from the southernmost part, whose local name was North Solimpur sea beach.

After sweeping away all kinds of non-sediment materials from the sampling site, the surface sediment was collected by using a cylindrical iron corer of inner diameter 10 cm. In order to observe the radionuclides in the surface area of the coast, sediment was collected unto the depth of 5 cm. So, four to five drills were required to accumulate about 1 kg of wet sample from a sampling site. Sediments from different drills were thoroughly mixed by hands to make a uniform mixture. Each sample was dried in an oven at temperature 100^0C for 24 hours and then cleaned to remove pebbles, roots or any other impurities by using a 2 mm mesh-sized sieve. The homogenized sediment sample was kept in an airtight plastic container for a period of more than one month in order to ensure the state of secular equilibrium among the long lived parent radionuclides and their short lived progenies present in the soil samples.

Radioactive analysis of sediment samples: Since most of the radio-nuclides are gamma emitters, gamma spectroscopy can reveal dominant sources of radioactivity. A high purity germanium (HPGe) detector, BE3820, made by Canberra Industries Inc., USA was used to record the gamma ray emissions from the soil samples. This detector can efficiently measure gamma in the energy region from 3 keV to 3 MeV (Canberra, USA). The measured resolution of the detector was 1.9 keV (FWHM) at gamma energy 1332 keV. This gamma detector was coupled with a digital spectrum analyzer, DSA-1000, which provided a full featured multichannel analyzer of 16K channel based on digital signal processing techniques. Canberra's Genie-2000 spectroscopy software was used to record and analyze the gamma ray spectra of sediment samples.

Determination of counting efficiency and calibration were done by using the standard samples provided by the International Atomic Energy Commission (IAEA); these reference samples were RGU-1 for ^{238}U series, RGTh-1 for ^{232}Th series, RGK-1 for ^{40}K and IAEA-152 for ^{137}Cs. Th e detector was placed inside a massive lead shield in order to reduce the background radiation. Moreover, a background spectrum was recoded for 20,000 seconds for a blank sample container. This background reading was subtracted from the sample reading to determine the net count originated form the sample. Gamma spectrum for each sediment and reference sample was also recorded for 20,000 seconds. Since each sediment sample was kept hermetically for more than one month, analysis of gamma spectrum was done on the assumption of secular equilibrium state in ^{238}U and ^{232}Th series. Activity of ^{238}U radionuclide was determined from the observed counts at gamma energies 241.98 keV, 295.21 keV and 351.92 keV emitted by the daughter nuclide ^{214}Pb and also at energies 609.31 keV, 1120.29 keV and 1764.49 keV emitted by the another daughter ^{214}Bi. For the radionuclide ^{232}Th, counts at energies 238.63 keV of ^{212}Pb, 338.40 keV, 911.07 keV and 969.11 keV of ^{228}Ac and 583.19 of ^{208}Tl were used. Gamma peaks at energies 1460.75 keV and 661.66 keV, respectively, were used for the determination of activities of ^{40}K and ^{137}Cs.

Results and Discussion:

From the gamma spectrum, activity of a radionuclide due to one of its emitted gamma energy was calculated by using the counting efficiency of the detection system at that gamma energy and intensity of that gamma emission originated from the radionuclide. The unitary arithmetic method results in the following equation for the specific activity (A) of a radionuclide for a given gamma energy:

$$A\,(Bq/kg) = \frac{c}{\varepsilon\, i\, m}$$

Where, c is the observed net count rate at the specified gamma energy, ε is the counting efficiency (in fraction) of the detector at the measured gamma energy, i is the intensity of the measured gamma emission and m is the mass of sediment sample in kg.

The measured activity concentrations of natural radionuclides ^{238}U, ^{232}Th and ^{40}Ka in the shore sediment samples are given in Table-2.

Natural radionuclides in coastal sediment along the Sitakunda sea beach were found to vary in wide range. ^{238}U was observed in the range 14.8 – 47.3 Bq/kg, ^{232}Th was found to be in the range 29.3 – 95.3 Bq/kg and activity of ^{40}K varied from 142.7 Bq/kg to 1092.5 Bq/kg. So, the sediment in this coastal area is heterogeneous in nature. This kind of distribution of ^{238}U and ^{232}Th was also observed in the sediments of other water bodies, for example the Karnaphuli river and baors (closed water body like shallow lake) in Jessore district, Bangladesh. Ratio of ^{232}Th to ^{238}U in sediment was found here in the range 1.72 – 2.17 with an average 1.99. This ratio was observed to be 1.82 and 1.12 in the sediments of the Karnaphuli river [8] and Baors in Jessore [9], respectively. So, in the perspective of natural radioactive series, there is no significant difference between the shore sediments of the Karnaphuli river and the Bay of Bengal whereas baors in Jessore contain sediment of different texture. Again, concen- tration of ^{40}K in the sediment of the Karnaphuli river was found to be in the range 217 – 320 Bq/kg [8]. As shown in the Table 2, specific activity of ^{40}K was higher in most samples. The Sitakunda costal region was not used for cultivation or plantation. So, the source of higher concentration of ^{40}K may have a link with the ship breaking industry because most of the vessels scraped here are the carriers of different food stuffs.

A strong correlation (R^2 = 0.97) was observed between ^{238}U and ^{232}Th in sediment of the Sitakunda coast as shown in the Figure-1. This characteristic revealed the presence of monazite mineral in beach sand.

Figure 1 Correlation between U238 and Th232 in sediment

For the assessment of radiation hazards associated with the natural radionuclides in soil, the outdoor gamma ray exposure rate in air at one meter height above the ground due to

natural radionuclides in soils was determined by the following equation [11]:

$$D\ (nGy/h) = 0.462A_U + 0.604A_{Th} + 0.0417A_K$$

Where, A_U, A_{Th}, and A_K are the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in soils in units of Bq/kg. The average annual effective dose (H) to adults due to outdoor exposure to natural radioactive series and ^{40}K in soils was estimated on the assumption that the outdoor occupancy fraction is 0.2 and Gray to Sievert transformation factor is 0.7 Sv/Gy.

Due to natural radionuclides in shore sediment, the outdoor absorbed dose rate was found in the range 35.4 – 125.0 nGy/h with an average 71.0 nGy/h. The annual effective dose was estimated in the range 0.043 – 0.153 mSv with an average 0.087 mSv, which was higher that the world accepted value 0.07 mSv [12].

Although there was no incident of release of nuclear fission products in environment, anthropogenic radionuclide ^{137}Cs was observed in small amount at different places [5, 12], in Bangla- desh due to stratospheric fallout. However, in the sediment of Sitakunda coast, ^{137}Cs was observed only in the sample S13 by an amount 3.83±0.44 Bq/kg. This sample was collect- ed from a ship breaking site located between Khadempara and North Jahanabad. ^{137}Cs poses serious risk when it enters into the food chain. In Bangladesh, maximum limits of this radionuclide in dairy and non-dairy food staffs are 95 Bq/kg and 50 Bq/kg, respectively [13]. So, optimistically, ^{137}Cs observed in the sample S13 could not contaminate the food stuffs unto the concerned level of radiation risk.

Conclusion:

In shore sediment of the Sitakunda coast of the Bay of Bengal, ^{238}U, ^{232}Th and ^{40}K radionuclides were found to have specific activity 30.93±2.51 Bq/kg, 61.65±4.58 Bq/kg and 467.8±31.2 Bq/kg, respectively. The world average values for ^{238}U, ^{232}Th and ^{40}K were, respectively, 33 Bq/kg, 45 Bq/kg and 412 Bq/kg [12]. So, in the coastal region of Sitakunda, concentrations of natural radionuclides were higher than the world average values. Consequently, the estimated value of the average outdoor absorbed dose rate in air was 71.03 nGy/h. This dose rate was equivalent to the effective annual outdoor dose of 0.087 mSv; which was higher than the accepted value 0.07 mSv. So, workers in different ship breaking industries were exposed to higher natural background radiation. Moreover, observed strong correlation between the radionuclides ^{238}U and ^{232}Th indicated the richness of the beach sediment in the monazite mineral. It was also revealed that in comparison to the sediment of small closed water body such as pond and shallow lake, sediment of open water body such as sea and river contained much higher amount of ^{232}Th than ^{238}U. Nuclear fission product ^{137}Cs was observed only in one location and specific activity was found to be 3.83±0.44 Bq/kg. So, the observed ^{137}Cs was too low to cause any serious health concern.

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Table 1. Location of sample collection sites and sample's dry weight

Sample	Location of Sampling Site		Sample Dry Weight (gm)
	Latitude (N)	Longitude (E)	
S01	$22^0 29' 03.34''$	$91^0 42' 36.57''$	155.12
S02	$22^0 28' 50.88''$	$91^0 42' 46.21''$	153.43
S03	$22^0 28' 32.91''$	$91^0 42' 56.23''$	152.82
S04	$22^0 28' 13.76''$	$91^0 43' 03.23''$	106.94
S05	$22^0 28' 01.75''$	$91^0 43' 16.02''$	121.32
S06	$22^0 27' 36.68''$	$91^0 43' 30.78''$	118.57
S07	$22^0 27' 24.11''$	$91^0 43' 30.50''$	102.08
S08	$22^0 27' 07.88''$	$91^0 43' 34.34''$	129.21
S09	$22^0 26' 54.39''$	$91^0 43' 43.42''$	117.18
S10	$22^0 26' 38.60''$	$91^0 43' 49.43''$	118.07
S11	$22^0 26' 22.32''$	$91^0 43' 50.38''$	127.01
S12	$22^0 26' 06.53''$	$91^0 43' 54.57''$	103.56
S13	$22^0 25' 52.39''$	$91^0 44' 07.60''$	114.33
S14	$22^0 25' 37.09''$	$91^0 44' 14.75''$	135.86
S15	$22^0 25' 22.97''$	$91^0 44' 23.41''$	144.85
S16	$22^0 25' 09.40''$	$91^0 44' 33.28''$	157.74
S17	$22^0 24' 50.96''$	$91^0 44' 41.28''$	111.38
S18	$22^0 24' 33.61''$	$91^0 44' 24.16''$	154.98
S19	$22^0 24' 15.47''$	$91^0 44' 24.95''$	160.12

Table 2. Specific concentration of natural radionuclides in sediment

Sample ID	**Activity Concentration in Bq/kg†**		
	^{238}U	^{232}Th	^{40}K
S01	33.46 ± 4.33	72.54 ± 4.45	333.1 ± 25.2
S02	24.26 ± 2.45	49.09 ± 4.76	264.8 ± 24.2
S03	34.83 ± 3.23	71.73 ± 5.01	374.8 ± 25.2
S04	30.46 ± 3.42	59.6 ± 6.88	592.7 ± 39.0
S05	38.63 ± 3.39	79.64 ± 6.45	675.5 ± 34.8
S06	38.28 ± 3.28	78.19 ± 6	347.9 ± 31.4
S07	33.71 ± 1.73	59.7 ± 5.01	465.1 ± 47.2
S08	21.78 ± 1.08	43.58 ± 3.56	142.7 ± 27.3
S09	33.34 ± 1.29	69.87 ± 6.02	596.0 ± 31.0
S10	47.34 ± 1.81	95.32 ± 7.7	1092.5 ± 41.0
S11	40.82 ± 1.42	83.31 ± 3.55	548.1 ± 31.1
S12	36.29 ± 1.52	71.07 ± 4.2	672.2 ± 38.2
S13	34.92 ± 2.64	71.38 ± 4.34	501.0 ± 33.7
S14	26.78 ± 2.42	45.93 ± 3.77	370.1 ± 30.6
S15	27.61 ± 4.47	49.07 ± 3.28	382.7 ± 26.5
S16	15.86 ± 2.02	31.76 ± 2.66	300.6 ± 23.9
S17	38.71 ± 3.46	76.87 ± 4.97	625.0 ± 35.5
S18	15.71 ± 2.76	33.47 ± 2.21	341.7 ± 24.6
S19	14.81 ± 0.81	29.28 ± 2.25	261.5 ± 23.3
Average	30.93 ± 2.51	61.65 ± 4.58	467.8 ± 31.2

† Numerical figure after ± sign represents the standard deviation in the measurement.

Figure 1 Correlation between U238 and Th232 in sediment