Assesment of Natural Radioactivity and Radiological Analysis of Soil and Brick Samples Used as Building Materials in Bangladesh

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Abstract— The presence of natural radioactivity in building materials may cause both external and internal radiation exposure to the dwellers. Elevated level of radioactivity concentration in naturally occurring radioactive materials (NORMs) like sand, brick etc. may cause great harm to the dwellers via prolonged exposure when used as building materials. Different types of brick are popular building materials used for constructing houses in urban and sub-urban areas in Bangladesh. The current study presents probable radionuclide contents in these building materials, their activity concentrations and the effects of these radionuclides on the dwellers living in these houses. A total of 14 brick samples of three different types (burnt by wood, coal and gas) were collected from different brick fields of Dhaka and Savar areas of Bangladesh. Moreover, 14 soil samples which were used as the starting materials to make the bricks under study were also collected and analyzed. The samples were analyzed by gamma spectrometry technique using a Hyper Pure Germanium (HPGe) detector with 20% relative efficiency. The results showed that only the natural radionuclides such as ^{226}Ra, ^{232}Th and ^{40}K were present in the samples and no artificial radionuclide was detected in any of the samples. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the brick samples were 58.44±5.61 Bqkg^{-1}, 86.26±8.15 Bqkg^{-1} and 982.03±118.85 Bqkg^{-1} ,whereas 59.76 ±6.47 Bqkg^{-1}, 89.02 ±9.51 Bqkg^{-1} and 999.64 ±143.65 Bqkg^{-1} in soil samples respectively. To evaluate the radiological hazards, radium equivalent activity, various hazard indices, alpha index, gamma index and excess life-time cancer risk have been calculated, and compared with the literature values. The absorbed dose rate and outdoor annual effective dose are slightly higher than the world average values and found that the brick and soil samples of the study are not hazardous by the radiation and does not pose any harmful effect to the environment. The activity concentrations presented herein are expected to be useful in assessing the impact of future radiological loadings from use of construction and decorative materials in dwellings.

Index Terms— Brick,Building materials, Dose rate, Excess Lifetime Cancer Risk, Gamma spectroscopy, Natural radioactivity, Radiation hazard, Soil ,

1 Introduction

THIS Humans are exposed to natural radioactivity at different levels depending on natural radioactive elements present in each area; as such, researchers investigated the natural environmental radiation and radioactivity in soils to conduct background checks and detect environmental radioactivity [1]. The levels of radioactivity can be used to assess public dose rates and radioactive contamination and predict changes in environmental radioactivity caused by nuclear accidents, industrial activities, and other human activities [16] Ionizing radiation, arising either from external sources outside the body or from internal contamination of the body by radioactive substance, interacts with human body and may cause biological effects like radiation damage and biochemical change [2]. Human beings are exposed to radiation from the environment continuously. Naturally occurring radioactive materials (NORM) come mainly from cosmic and primordial radiation. Primordial radioisotopes coming from terrestrial sources like rocks and soils of the earth's crust frequently exist in building materials. The most prominent naturally occurring radioisotopes are ^{40}K and radionuclides from ^{238}U and ^{232}Th radioactive series with their decay products which represent the most commencing sources of ionizing radiation on earth [2].

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Most of the environmental elements and construction materials contain vestige amount of natural radioactivity [3]. It is important to estimate activity concentration of radionuclides in soil and building materials as they are source of external radiation exposure in dwellings [4].

Most inhabitants spend about 80% of their lifetime indoor surrounded by different types of building materials of which brick is notable [2],[5-8]. The materials used for construction purpose can result in long term exposure. Gamma-rays emitted from the radioactive isotope are the fundamental source of this radiation exposure in buildings [2]. Elevated level of radioactivity may cause any related health risk. So the study of assessment of natural radioactivity is an inevitable matter to radiological environmental protection[9]. Measurement of radioactivity levels will be helpful to estimate associated environmental and health venture as well as to place the standard and national guidelines used for providing recommendation [3].

Brick is one of the most eco friendly and popular building materials commonly used in urban and sub-urban areas in Bangladesh. Various types of bricks and soils, which are used as the starting materials to make these bricks, have been collected in this study. Building materials cause direct radiation exposure because of their radioactive content and as a result of their noxious health issue it is now a rising public concern [2].

In the present study, to assess the impact of some brick fields on the environment, the environmental pollution impact was analyzed by determining the concentrations of the radio-

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nuclides and other radioactive indices in soil and brick samples which were collected from some brick fields from where maximum bricks are delivered to populated city specially Dhaka city. Such information will lead to an accurate dosimetric evaluation of the risk of human exposure due to enhancements of TENORM (technologically-enhanced naturally occurring radioactive materials) levels.

2 METHODS AND MATERIALS

2.1 Study Area

Brick and soil samples (starting materials to make the bricks) were collected during 2014 from 3 locations in the area of Dhaka district at Savar Upazila province in the north of Bangladesh.

Savar is located at 23.8583°N 90.2667°E. It has 66956 units of household and a total area of 280.13 km². It is bounded by Kaliakair and Gazipur Sadar upazilas on the north, Keraniganj upazila on the south, Mirpur, Mohammadpur, Pallabi and Uttara thanas of Dhaka City on the east, and Dhamrai and Singair upazilas on the west. The southern part of the upazila is composed of the alluvium soil of the Bangshi and Dhalashwari rivers. Main rivers are Bangshi, Turag, Buriganga and Karnatali.

2.2 Sample Locations, Collection and Preparation

A total of 28 samples namely; 14 soil and 14 brick samples; were collected from in and around the brick field area. 14 brick samples of three different types (burnt by wood, coal and gas) were divided into three groups namely; gas, coal and wood brick samples. 14 soil samples which were used as the starting materials to make the bricks were given the similar name.

2.2.1 Sample Processing

After the collection of all soil and brick samples, they were transported and preserved at the sample preparation laboratory of the Health Physics and Radioactive Waste Management Unit of Bangladesh Atomic Energy Commission (BAEC), Savar, Dhaka. All Collected samples were purified by removing all contaminants such as rocks, woods, metals, vegetation residual parts etc and dried in the sun and crushed into fine powder by using a grinder and collected after passing through 400 μm mesh screen. The homogenized samples were then dried in an oven at about 110˚C for about 24 hours and the weights of the samples were recorded using an electrical balance. The processed samples were then transferred to sealable cylindrical plastic containers of 7 cm height and 5.5 cm in diameter, marked individually with identification parameters e.g, name and location of the sample, date of preparation and net weight. All the containers are then sealed tightly with an insulating tape around their neck and stored for about 30 days to attain radioactive secular equilibrium between ^{226}Ra and its daughter products.

Table 1: List of the collected soil samples for study

Collection Area	Sample Code	Type of Sample	Date of Collection	Quantity of Samples
Nabinagar, Savar	S1(G)	Soil	16.04.2014	165.60 gm
	S2(G)	Soil		204.90 gm
	S3(G)	Soil		225.26 gm
Genda, Savar	S4(G)	Soil	02.04.2014	172.90 gm
	S5(G)	Soil		195.60 gm
Doshail, Aukhpara, Savar	S6(G)	Soil	02.04.2014	170.60 gm
Ashulia Bridge, Ashulia	S7(C)	Soil	06.03.2014	126.30 gm
	S8(C)	Soil		150.60 gm
	S9(C)	Soil		143.30 gm
	S10(C)	Soil		125.70 gm
	S11(C)	Soil		124.40 gm
Ashulia Bridge, Ashulia	S12(W)	Soil	06.03.2014	138.00 gm
	S13(W)	Soil		136.30 gm
	S14(W)	Soil		127.40 gm
Nabinagar, Savar	B1(G)	Brick	16.04.2014	227.8 gm
	B2(G)	Brick		187.00 gm
	B3(G)	Brick		225.00 gm
Genda, Savar	B4(G)	Brick	02.04.2014	205.90 gm
	B5(G)	Brick		214.40 gm
Doshail, Aukhpara, Savar	B6(G)	Brick	02.04.2014	170.40 gm
Ashulia Bridge, Ashulia	B7(C)	Brick	06.03.2014	140.80 gm
	B8(C)	Brick		176.00 gm
	B9(C)	Brick		194.30 gm
	B10(C)	Brick		166.40 gm
	B11(C)	Brick		162.00 gm
Ashulia Bridge, Ashulia	B12(W)	Brick	06.03.2014	202.50 gm
	B13(W)	Brick		232.70 gm
	B14(W)	Brick		199.00 gm

2.2.2 Experimental Set-up

The detection and measurement of radionuclides in the samples were carried out by gamma spectrometry system using a vertical coaxial cylindrical high purity germanium (HPGe) detector of 172 cm^3 active volume and with 20% relative efficiency. The p-type HPGe detector supplied by CANBERRA (ModelGC4020), has a resolution of 2 keV at 1332 keV of Cobalt-60 gamma-ray line. The detector was coupled to a 16 k multi-channel analyzer. The spectra of all samples were perfectly analyzed 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}Ra, ^{232}Th and ^{40}K. All the samples were counted for 10 ks.

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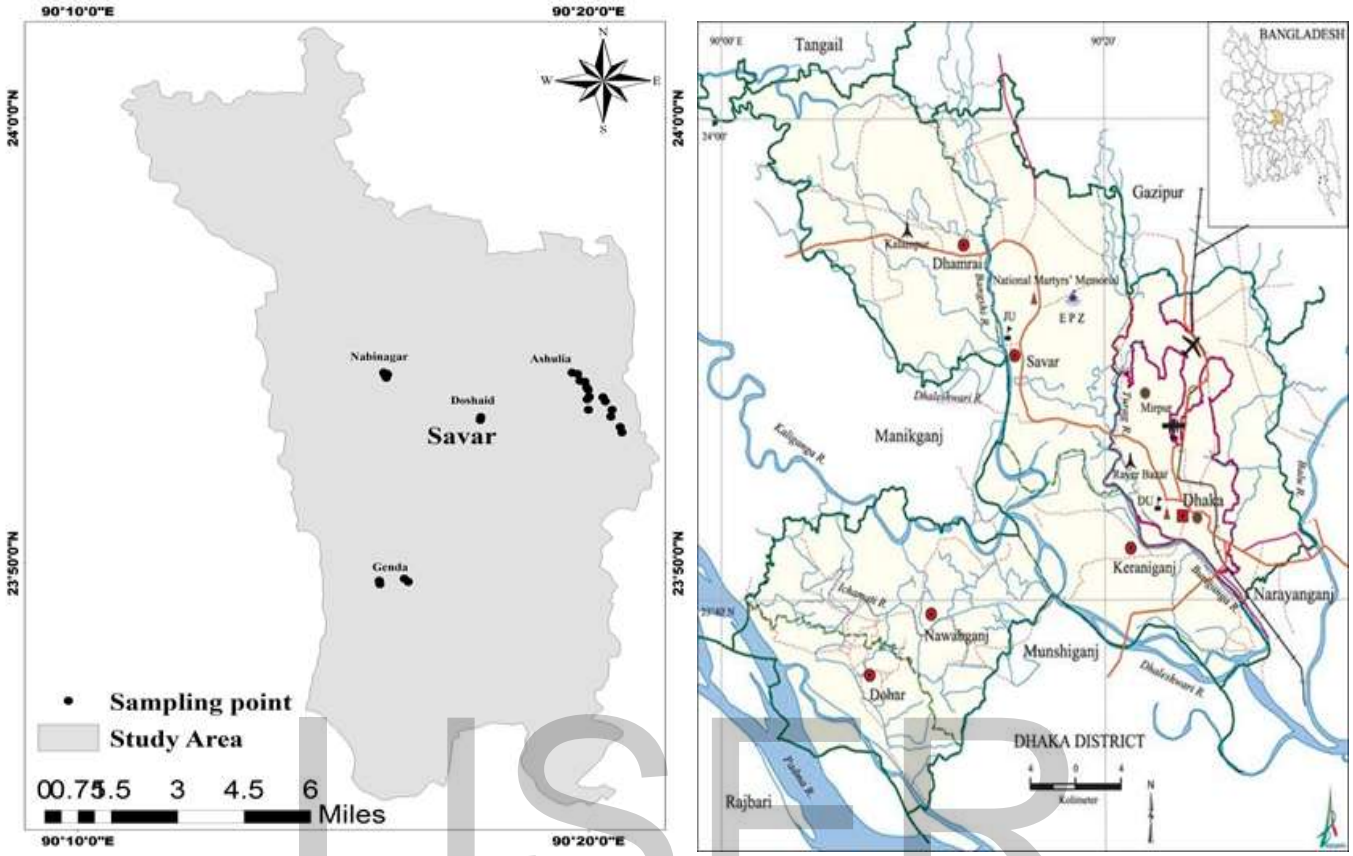

Figure 1: Location map of samples with Dhaka district map of Bangladesh

Prior to the measurement of the samples, the environmental gamma background at laboratory site was determined with plastic container used in the sample measurement. The gamma ray lines of 295.221 keV and 351.922 keV from ^{214}Pb, and 609.32 keV, 1120.31 keV and 1764.551 keV from ^{214}Bi were used to determine the activity concentrations of ^{226}Ra. The activity concentrations of ^{232}Th were determined using the net counts under the 238.63 keV and 300.087 keV photo-peaks from ^{212}Pb, 911.205 keV and 968.97 keV photo peaks from ^{228}Ac, and 583.19 keV and 2614.533 keV from ^{208}Tl. The single transition 1460.822 keV gamma-line was used to determine the activity concentrations of ^{40}K. For the evaluation of ^{226}Ra and ^{232}Th activity, a weighted mean approach was applied using the aforementioned gamma lines[10]-[11].

2.2.3 Calibration of the Detector

The efficiency calibration of the detector was performed by standard sources of solid matrices, prepared using ^{226}Ra standard using identical containers used for the measurement of the samples, e.g., 180 ml plastic container for solid samples. The preparation process of standard sources had been reported elsewhere [12]. The detector efficiency calibration curves as function of energy for solid matrices are shown in Figure **2.**

2.2.4 The Activity Concentrations

The activity concentrations (A) of each radionuclide in the sample was determined by using the count per second (cps) after subtracting the background counts from the gross counts for the 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 [13] :

$$A = cps/E \times I \times W \quad (1)$$

Where, A = Activity concentrations of the sample in Bqkg^{-1} or BqL^{-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 = Net weight of the sample (in kilogram or litre).

The errors in the measurements were expressed in terms of standard deviation (±2σ), where σ is expressed as [14]:

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

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

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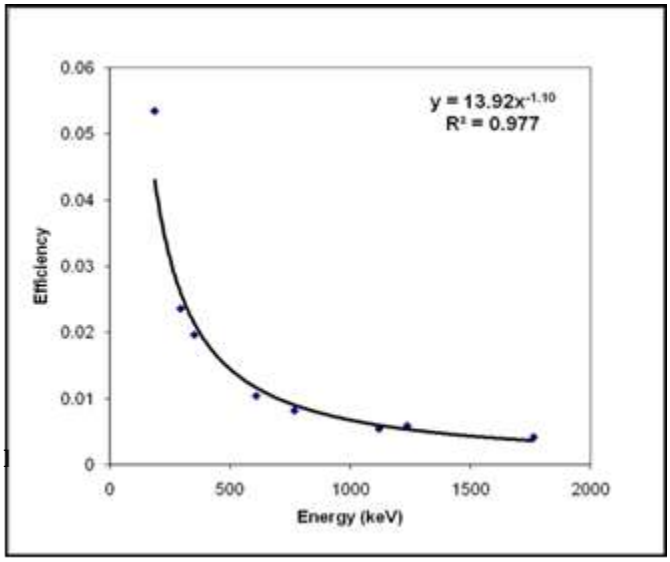

Figure 2: Efficiency curve for solid matrix

2.3 Estimation of radiation hazard indicators

2.3.1 Gamma Absorbed Dose Rates (D_R)

The external outdoor absorbed gamma dose rates due to terrestrial radionuclides ^{226}Ra, ^{232}Th and ^{40}K at 1m above the ground level was calculated as [15]:

$$D_R\ (nGyh^{-1}) = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.042\ A_K \quad (3)$$

where, A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bqkg^{-1}.

2.3.2 Annual Effective Dose Equivalent (AEDE)

The absorbed dose rate was converted into annual effective dose equivalent by using a conversion factor of 0.7 SvGy^{-1} recommended by the UNSCEAR (2000) and 0.2 for the outdoor occupancy factor by considering that the people on an average, spent 20% of their time in outdoors [17] . The effective dose due to natural radioactivity in the collected samples was calculated by:

$$AEDE = D \times 24 \times 365.25 \times 0.2 \times 0.7 \times 10^{-6} \quad (4)$$

2.3.3 Radium Equivalent Activity (Ra_{eq})

The radionuclides ^{226}Ra, ^{232}Th and ^{40}K are not homogeneously distributed in the studied sand sample. 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[18]:

$$Ra_{eq}\ (Bqkg^{-1}) = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K \quad (5)$$

2.4 Hazard Indices

2.4.1 External Hazard Index (H_{ex})

The external hazard index (H_{ex}) is the indoor radiation dose rate due to the external exposure to gamma radiation in construction materials of dwelling, which was calculated by [19].

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad (6)$$

2.4.2 Internal Hazard Index (H_{in})

Respiratory organs can be vulnerable to inhaled randon and its short-lived progency too, and the the value of internal exposure to radon and its progeny can be estimated using Eq (7) [7].

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \quad (7)$$

H_{in} must be less than 1 for the building materials to be considered as safe [7].

2.4.3 Gamma activity concentration index or gamma index (I_γ)

An index is defined for using as a screening tool for categorizing materials used in construction to control the excess gamma radiation from the building materials [21-24]. The European Commission (European Commission 1999) has recommended Eq (8) for estimating the gamma index for a typical building material :

$$I_\gamma = A_{Ra}/300 + A_{Th}/200 + A_K/3000 \quad (8)$$

where A_{Ra}, A_{Th} and A_K are the calculated activity concentrations in Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K, respectively; it is predicted that activity concentrations of 300 Bq kg^{-1} for ^{226}Ra, 200 Bq kg^{-1} for ^{232}Th and 3000 Bq kg^{-1} for ^{40}K each generate the same gamma dose rate. For a structural material, the exemption dose criterion (annual effective dose) of 0.3 mSv y^{-1} corresponds to a gamma index of $I\gamma \leq 0.5$, whereas the upper dose criterion of 1 mSv y^{-1} is satisfied for $I\gamma \leq 1$ [23-24].

2.4.4 Alpha index (internal index, Iα)

The alpha index (Iα), which has been applied by various researchers can be used to estimate excess alpha radiation caused by the inhalation of radon liberated from building materials[21-23].

$$I_\alpha = A_{Ra}/200 \quad (9)$$

where A_{Ra} is the activity concentration of the alpha emitter ^{226}Ra (Bq kg^{-1}). Radon exhalation from a given construction material may lead to indoor radon concentrations that exceed the recommended action level of 200 Bqm^{-3} if the activity concentration of ^{226}Ra in the material exceeds a value of 200 Bqkg^{-1} , thus the safe limit is defined by an alpha index of less than or equal to unity[21],[23],[26]-[27].

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2.4.5 Excess Lifetime Cancer Risk (ELCR)

The probability of occurrence of cancer and cancer-related diseases among workers who are involved with construction, sand collection type activities and the public due to their continuous exposure to low doses of radiation from resident and offices cannot be ignored. The risk of exposure called excess lifetime cancer risk (ELCR) was estimated based on 70 years lifetime of continuous population exposure to low-level radiation. It was calculated from the equation [2]:

$$ELCR=AEDE\times DL\times RF \quad (10)$$

Where, AEDE is the annual effective dose equivalent, DL is the average lifetime duration 60 countries including Bangladesh (70 years), and RF is the fatal risk factor per sievert assumed to be 0.05 in this study as per ICRP-106 [26].

2.4.6 **Significance of various hazard indices**

All earth born materials have some common elements like ^{238}U and ^{232}Th decay series radionuclides and also the ^{40}K. All radioactive progenies of ^{238}U and ^{232}Th parents emit α or β particles followed by γ-rays until their end-up to stable ^{206}Pb and ^{208}Pb, respectively. However, due to low penetration power of the majority of α and β particles emitted from the parents radionuclides cannot come out from the sample matrix to the outside environment but most of the γ-rays can easily penetrate the sample matrix and enter into the building atmosphere. Since γ-rays emitted from building material can easily travel long distances within the surrounding environment, human beings may continuously exposed to by gamma radiation and adverse health effects may occurred via extended period of exposure. Thus, the representative gamma-index, absorbed dose rate and annual effective dose find great significance to understand the health hazards from gamma-radiation exposures. Furthermore, external hazard index (H_{ex}) is often used to characterize the building materials via set up a limiting value on the acceptable equivalent dose (or to limit the external γ-radiation dose), Generally, the distribution of ^{226}Ra, ^{232}Th and ^{40}K in environmental sample including construction materials are not uniform. In order to overcome the non-uniformity of the radionuclides, a common index called "radium equivalent activity (Ra_{eq})" is used to obtain the representing activity and also to assess the radiological hazard caused by the building materials. Moreover, people can easily inhale sand's dust during construction and other activities with sand and then the α and β emitters (sub-series headed by ^{226}Ra and ^{228}Ra) can easily be attached to the living cell of the respiratory organs, causes the cell damage as well as create cancer. For these reasons internal hazard index (H_{in}), alpha index (Iα) and gamma index (Iγ) are often used to characterized building materials [2].

3 Results and Discussions

The activity concentration levels of the ^{226}Ra, ^{232}Th and ^{40}K in soil and brick samples were determined by following the standard procedure. The detailed results are given in **Table 2 and Table 3..**

The average activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil ranged from 37.47±4.51 to 76.21±7.63, 71.04±7.5-103.48±11.52 and 527.68±94.01 to 1282.96±174.52 with mean values 59.76±6.47, 89.02±9.51 and 999.64±143.65 $Bqkg^{-1}$ respectively.In brick samples, the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K ranged from 42.73±4.33 to 68.62±6.63, 67.87±6.56 to 99.26±7.95 and 635.54±95.26 to 1212.13±157.74 with mean values 58.44±5.61, 86.26±8.15 and 982.03±118.85 $Bqkg^{-1}$respectively.

Table 2: Specific activity levels ($Bqkg^{-1}$) of the detected radionuclides in different soil samples

Sample Code	Activity concentration in $Bqkg^{-1}$		
	^{226}Ra	^{232}Th	^{40}K
S1(G)	63.49±5.48	94.87±7.99	559.15±102.93
S2(G)	52.49±5.83	81.00±8.78	1095.75±135.38
S3(G)	55.80±4.93	94.15±7.56	527.68±94.01
S4(G)	53.02±5.67	84.01±8.59	887.26±126.50
S5(G)	37.47±4.51	71.04±7.5	740.17±110.95
S6(G)	55.28±6.05	100.1±9.20	835.99±126.95
S7(C)	70.05±7.71	82.59±10.54	1282.96±174.52
S8(C)	56.03±6.53	77.60±9.15	1147.59±147.75
S9(C)	55.45±6.70	80±9.59	1160.88±154.4
S10(C)	72.64±7.82	91.71±10.86	1306.25±175.69
S11(C)	76.21±7.63	103.48±11.52	1059.74±172.36
S12(W)	62.72±6.97	88.39±10.16	1111.65±158.49
S13(W)	63.00±7.3	103.03±10.77	1109.68±160.16
S14(W)	62.99±7.50	94.31±10.95	1170.27±171.01
Range (Average)	37.47±4.51 -76.21±7.63 (59.76±6.47)	71.04±7.5-103.48±11.52 (89.02±9.51)	527.68±94.01-1282.96±174.52 (999.64±143.65)

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Table 3: Specific activity levels (Bqkg^{-1}) of the detected radionuclides in different brick samples

Sample Code	Activity concentration in Bqkg^{-1}		
	^{226}Ra	^{232}Th	^{40}K
B1(G)	58.17±5.06	93.03±7.49	635.54±95.26
B2(G)	55.84±4.99	83.86±8.15	1120.35±122.74
B3(G)	57.93±5.36	89.01±7.38	777.71±99.08
B4(G)	60.84±5.35	94.92±8.04	954.64±110.28
B5(G)	65.36±5.47	99.26±7.95	806.09±103.79
B6(G)	63.07±6.2	95.84±9.08	1139.52±133.02
B7(C)	67.6±7.09	94.64±10.22	1212.13±157.74
B8(C)	60.44±5.975	80.43±8.35	945.19±125.72
B9(C)	48.62±5.2	73.92±7.59	911.69±114.95
B10(C)	63.28±6.33	85.26±8.82	1116.42±135.23
B11(C)	68.62±6.63	93.88±9.29	1146.74±138.9
B12(W)	57.03±5.44	81.82±7.70	1077.21±114.14
B13(W)	42.73±4.33	67.87±6.56	863.24±97.93
B14(W)	48.58±5.12	73.91±7.51	1041.95±115.13
Range (Average)	42.73±4.33-68.62±6.63 (58.44±5.61)	67.87±6.56-99.26±7.95 (86.26±8.15)	635.54±95.26-1212.13±157.74 (982.03±118.85)
World average value (UN-(UN-SCEAR 2000)	35 (17-60)	30(11-64)	400(140-850)

3.1 Radiological indices

In order to assess the health effects, the radiation hazards such as radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}), absorbed dose rate (D_R), outdoor annual effective dose equivalent (AEDE), alpha index (Iα), gamma index (Iγ) and excess life-time cancer risk (ELCR) have been calculated from the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K and the values are shown in **Table 4**.

From **Table 4**, it is seen that the mean value of radium equivalent activity was 263.83 Bqkg^{-1} for soil samples, 257.63 Bqkg^{-1} for brick samples. The radium equivalent activity falls below the world average value of 370 Bqkg^{-1}. It is apparent that the radium equivalent activity originating from different regions shows some variations, which are likely to be related to the position of collected soil and brick samples, transport process etc. This is important in selecting suitable soils and bricks not only for construction but also for agriculture purposes in order to keep the radiation hazard minimum.

The mean value of external and internal radiation hazard index were 0.71 and 0.87 for soil samples and 0.70 and 0.85 for brick samples respectively which was far less than the unity indicating the non-hazardous category of the samples. The values of hazard indices confirmed that it was safe for human to live and work at that area.

The absorbed dose rate was 91.31 to 143.82 nGyh^{-1} with an average 123.36 nGyh^{-1}for soil samples, for brick samples was 96.99 to 139.30 nGyh^{-1} with an average 120.54 nGyh^{-1}. These values were higher than the world average 57 nGyh^{-1} for the both samples.

The outdoor annual effective doses for soil and brick samples were 0.11 to 0.17 mSvyr^{-1} with an average value of 0.15 mSvyr^{-1} and 0.12 to o.17 mSvyr^{-1} with an average value of 0.15 mSvyr^{-1} respectively. These values were less than the world average value of 0.480 mSvyr^{-1} for soil.

For a building material, the exempted dose criterion and dose criterion of values 0.3 mSvy^{-1} and 1mSvy^{-1}are satisfied for $I_\gamma \leq 0.5$ and $I_\gamma \leq 1$ respectively [23-24]. According to the dose criterion, those building materials should be avoided which have $I_\gamma \geq 1$ because this value of gamma index leads the dose rate higher than 1mSvy^{-1}[24].

For all collected samples, it was found that $I_\gamma > 0.5$ but $I_\gamma \leq 1$,indicating that the gamma dose contributions from the studied building materials exceeded the exemption dose criterion of 0.3 mSvy^{-1} while remaining lower than the upper dose criterion of 1 mSvy^{-1}, with the exception of six soil samples and five brick samples. The evaluated alpha index (Iα) values were well below the recommended upper level of 1 for internal exposure[20],[21],[23],[26]. It was found that six samples of soil and five samples of brick showed higher values and remaining samples of both type were in the range of permissible limit.

The computed average value of excess lifetime cancer risk is 0.54×10^{-3} and 0.52×10^{-3} for studied soil and brick samples respectively and both the samples exceeded the world average value of 0.29×10^{-3} [16].

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Table 4: Calculated various hazard indices associated with the radioactivity of the studied soil and brick samples

Sample Code	Ra_{eq} ($Bqkg^{-1}$)	H_{ex}	H_{in}	D_R ($nGyh^{-1}$)	AEDE ($mSvyr^{-1}$)	Iα	Iγ	ELCR×10^{-3}
S1(G)	242.03	0.65	0.83	110.12	0.14	0.32	0.87	0.49
S2(G)	252.49	0.68	0.82	119.19	0.15	0.26	0.95	0.53
S3(G)	230.89	0.62	0.77	104.81	0.13	0.28	0.83	0.46
S4(G)	241.29	0.65	0.80	112.50	0.14	0.27	0.89	0.49
S5(G)	195.89	0.53	0.63	91.31	0.11	0.19	0.73	0.39
S6(G)	262.58	0.71	0.86	121.11	0.15	0.28	0.96	0.52
S7(C)	286.72	0.77	0.96	136.13	0.17	0.35	1.07	0.60
S8(C)	255.16	0.69	0.84	120.95	0.15	0.28	0.96	0.53
S9(C)	259.03	0.70	0.85	122.69	0.15	0.28	0.97	0.53
S10(C)	304.14	0.82	1.01	143.82	0.18	0.36	1.14	0.63
S11(C)	305.55	0.83	1.03	142.22	0.17	0.38	1.12	0.60
S12(W)	274.50	0.74	0.91	129.05	0.16	0.31	1.02	0.56
S13(W)	295.54	0.80	0.97	137.94	0.17	0.32	1.10	0.60
S14(W)	287.74	0.78	0.95	135.22	0.17	0.32	1.07	0.60
Mean	263.83	0.71	0.87	123.36	0.15	0.30	0.98	0.54
B1(G)	239.95	0.65	0.81	109.76	0.13	0.29	0.87	0.46
B2(G)	261.82	0.71	0.86	123.50	0.15	0.28	0.98	0.53
B3(G)	244.90	0.66	0.82	113.19	0.14	0.29	0.90	0.49
B4(G)	269.87	0.73	0.89	125.53	0.15	0.30	1.00	0.53
B5(G)	269.16	0.73	0.90	124.00	0.15	0.33	0.99	0.53
B6(G)	287.63	0.78	0.95	134.88	0.17	0.32	1.07	0.60
B7(C)	296.04	0.80	0.98	139.30	0.17	0.34	1.10	0.60
B8(C)	248.05	0.67	0.83	116.20	0.14	0.30	0.92	0.49
B9(C)	224.35	0.61	0.74	105.40	0.13	0.24	0.84	0.46
B10(C)	270.96	0.73	0.90	127.62	0.16	0.32	1.00	0.56
B11(C)	290.94	0.79	0.97	136.57	0.17	0.34	1.08	0.60
B12(W)	256.78	0.69	0.85	121.01	0.15	0.29	0.96	0.53
B13(W)	206.09	0.56	0.67	96.99	0.12	0.21	0.77	0.42
B14(W)	234.31	0.63	0.76	110.84	0.14	0.24	0.88	0.49
Mean	257.63	0.70	0.85	120.54	0.15	0.29	0.95	0.52
Rec-ommended Values	370	1.0	1.0	55	0.46	1.0	1.0	0.29×10^{-3}

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Table 5: Comparison of specific activities of radionuclides in soil uses as the starting materials to make the bricks in Bangladesh with those in other countries

Country	^{226}Ra	^{232}Th	^{40}K	References
Soil				
Present study	59.76 ±6.47	89.02 ±9.5	999.64 ±143.65	
Australia	62.9	162.8	403.3	[27]
China	44	47	593.1	[28]
Egypt	13	6	433	[29]
Pakistan	46.5	60.8	698.6	[30]
India (South-west)	50±12	58±10	380±61	[20]
Brick				
Present study	58.44 ±5.61	86.26 ±8.15	982.03 ±118.85	
Italy	20±2 −110 ±9	25±2 −97± 8	160±10 −680± 60	[25]
China (Xian)	58.6± 4.7	50.4± 3.5	713.9± 8.2	[31]
China (Urumqi)	49.3± 2.9	44.5± 1.7	860.4± 65.7	[32]
Greece	35±11	45±15	710±165	[33]
South Korea	33.3	79.8	698	[34]
Cuba	57±16	12±10	857±759	[35]
Egypt (Qena)	33±20	37±17	511±158	[36]
Turkey (Manisa)	42.4	16.1	553.3	[5]
India (South-West)	21±4	21±3	290±20	[20]
India (Tamil-nadu)	18.3	19.4	238.4	[37]
Pakistan (Punjab)	58±4	84±5	542±18	[38]
Bangla-desh (Dhaka)	43.4± 2.7−45. 9±2.8	97.1± 6.7−105 .6±7.2	1550.8 ±119.2−1 564.2±12 0.1	[39]
Brazil	51.7	65.3	747	[40]
Recom-mended Values	35	30	400	[16]

4 Conclution

The activity concentrations of 226Ra, 232Th and 40K found in building materials suggest that the use of such building materials in the construction of buildings is unlikely to give rise to any significant radiation exposure (< 1 mSv per annum) to the occupants. In this respect the materials analyzed comply with the parameters outlined in the relevant national and international legislation and guidance. The natural radioactivity concentrations of 226Ra, 232Th and 40K were higher than the world average values in soil, brick samples. The values of external hazard indices and the radium equivalent activity were lower than the global average value; whereas mean absorbed dose rate and outdoor annual effective dose were slightly higher than the global average value.

In general, the radionuclide activity concentrations noted in the building materials analyzed are comparable with the results of similar studies performed in other countries. Whereas the results found in the building materials used in Bangladesh were higher than those obtained in other studies, though such results were still of no radiological health significance.

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References

[1] Radhakrishna AP, Somashekarappa HM, Narayana Y, and Siddappa K (1993) A new natural background radiation area on the southwest coast of india. Healt Phys 65(4): 390– 395

[2] Asaduzzaman Kh, Mannan F, Khandaker MU, Farook MS, Elkezza A, Amin YBM, et al (2015) Assessment of Natural Radioactivity Levels and Potential Radiological Risks of Common Building Materials Used in Bangladeshi Dwellings. PLoS ONE 10(10): e0140667. https://doi.org/10.1371/journal.pone.0140667

[3] Raghu Y, Ravisankar R ,Chandrasekaran A ,Vijayagopal P,Venkatraman B (2017) Assessment of natural radioactivity and radiological hazards in building materials used in the Tiruvannamalai District, Tamilnadu, India, using a stastical approach. J Taib Univ Sci. 11(4): 523-533

[4] Shoeib MY, Thabayneh KM (2014) Assessment of natural radiation exposure and radon exhalation rate in various samples of Egyptian building materials. J Radiat Res Appl Sci. 7(2): 174-181 https://doi.org/10.1016/j.jrras.2014.01.004

[5] Erees FS, Dayanikli SA, Çam S (2006) Natural Radionuclides in the

International Journal of Scientific & Engineering Research, Volume 11, Issue 1, January-2020
ISSN 2229-5518

Building Materials used in Manisa City, Turkey. Indoor Built Environ. 15(5): 495–498.

[6] Asaduzzaman Kh , Khandaker MU, Amin YM, Bradley DA (2014) Natural radioactivity levels and radiological assessment of decorative building materials in Bangladesh. Indoor Built Environ 25(3):1–10

[7] Ghose S, Asaduzzaman Kh, Zaman N (2012) Radiological significance of marble used for construction of dwellings in Bangladesh. Radioprot 47(1): 105–118

[8] Llope WJ (2011) Activity concentrations and dose rates from decorative granite countertops. J Environ Radioact 102 (6): 620–629 doi: 10.1016/j.jenvrad.2011.03.012 PMID: 21507535

[9] Al-Zahrani JH (2017) Estimation of natural radioactivity in local and imported polished granite used as building materials in Saudi Arabia, J Radiat Res Appl Sci 10(3) 241-245. https://doi.org/10.1016/j.jrras.2017.05.001

[10] Khandaker MU, Heffny NA, Amin YM, Bradley DA (2019) Elevated concentration of radioactive potassium in edible algae cultivated in Malaysian seas and estimation of ingestion dose to humans. Algal Research 38: 101386

[11] Khandaker MU, Uwatse OB, Shamsul Khairi KA, Faruque MRI, Bradley DA (2019) Terrestrial Radionuclides in Surface (Dam) Water and Concomitant Dose in Metropolitan KualaLumpur. Radiat Prot Dosim 1–8. https://doi.org/10.1093/rpd/ncz018

[12] Harb S, Din KS and Abbady A (2008) Study of efficiency calibrations of HPGe detectors for radioactivity measurement of environmental samples. Preceding of the 3rd Environmental Physics Conference, Aswan, Egypt

[13] Hasan MM, Ali MI, Paul D, Haydar MA, Islam SMA (2014) Natural radioactivity and assessment of associated radiation hazards in soil and water samples collected from in and around of the Barapukuria 2×125 MW coal fired thermal power plant, Dinajpur, Bangladesh. J. Nucl. Particle Phys. 4 (1), 17-24

[14] Hasan MM, Ali M, Paul D, Haydar M, Islam S (2013) Measurement of natural radioactivity in coal, soil and water samples collected from Barapukuria coal mine in Dinajpur district of Bangladesh. J Nucl Part Phys 3(4):63–71

[15] UNSCEAR (1993)) 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

[16] UNSCEAR (2000) United Nations Scientific Committee on the Effects of Atomic Radiation Sources, Effects and Risks of Ionizing Radiation. Report to the General Assembly with Annex Exposures from Natural Sources of Radiation. United Nations, New York

[17] Debertin K, Helmer RG (1980) Gamma and X-ray Spectrometry with Semiconductor Detectors. Elsevier Science, Amsterdam.

[18] Beretka J and Mathew PJ (1985) Natural radioactivity of Australian building materials, industrial wastes and by products. Health Physics 48: 87-95

[19] Lu X, Xiolan Z (2006) Measurement of natural radioactivity in sand samples collected from the Booje Weithe sand park, China. Environ Geol 50: 977-988

[20] Khandaker MU, Jojo PJ, Kassim HA, Amin YM (2012) Radiometric analysis of construction materials using HPGe gamma-ray spectrometry. Radiat Prot Dosim 152: 33–37

[21] Gupta M, Chauhan RP (2012) Estimation of Low-Level Radiation Dose from Some Building Materials Using Gamma Spectroscopy. Indoor Built Environ 21(3): 465–473

[22] Ghose S, Asaduzzaman Kh, Zaman N (2012) Radiological significance of marble used for construction of dwellings in Bangladesh. Radioprot 47(1): 105–118

[23] Solak S, Turhan S, Ugur FA, Goren E, Gezer F, Yegingil Z, et al. (2014) Evaluation of potential exposure risks of natural radioactivity levels emitted from building materials used in Adana, Turkey. Indoor Built Environ 23(4): 594–602

[24] European Commission (1999) Radiological protection principles concerning the natural radioactivity of building materials. Radiation protection 112. Directorate General Environment, Nuclear Safety and Civil Protection (Geneva: EC)

[25] Righi S, Bruzzi L (2006) Natural radioactivity and radon exhalation in building materials used in Italian dwellings. J Environ Radioact 88(2): 158–170

[26] ICRP(1994) Protection against Rn-222 at home and at work. ICRP Publication 65. Ann. ICRP 23(2): 1–48

[27] Beretka J, Mathew PJ (1985) Natural radioactivity of Australian build-ing materials, industrial wastes and by-products. Health Phys 48(1): 87–95

[28] Ziqiang P, Yin Y, Mingqiang G (1988) Natural radiation and radioac-tivity in China, Radiat Prot Dosim 24 (1-4): 29-38

[29] Sroor A, El-Bahi SM, Ahmed F, Abdel-Haleem AS (2001) Natural radioactivity and radon exhalation rate of soil in southern Egypt,Appl. Radiat. Isot. 55 (6) 873–879

[30] Tufail M, Ahmad N, Mirza NM, Mirza SM (1992) Activity Con-centration in Building Materials. Report No. CNS-25, Centre for Nuclear Studies, Islamabad, Pakistan

[31] Xinwei L (2005) Natural radioactivity in some building materials of Xi'an, China. Radiat. Meas 40(1): 94–97

[32] Ding X, Lu X, Zhao C, Yang G, Li N (2013) Measurement of natural radioactivity in building materials used in Urumqi, China. Radiat Prot Dosim 155(3):374-379

[33] Stoulos S, Manolopoulou M, Papastefanou C (2003) Assessment of natural radiation exposure and radon exhalation from building materials in Greece. J Environ Radioact. 69(3): 225–240

[34] Lee SC, Kim CK, Lee DM, Kang HD (2001) Natural radionuclides contents and radon exhalation rates in building materials used in South Korea. Radiat Prot Dosim 94(3): 269–274.

International Journal of Scientific & Engineering Research, Volume 11, Issue 1, January-2020
ISSN 2229-5518

[35] Flores OB, Estrada AM, Suarez RR, Zerquera JT, Perez AH (2008) Natural radionuclide content in building materials and gamma dose rate in dwellings in Cuba. J Environ Radioact 99(12): 1834–1837

[36] Ahmed NK (2005) Measurement of natural radioactivity in building materials in Qena city, Upper Egypt. J Environ Radioact 83(1): 91–99.

[37] Ravisankar R, Vanasundari K, Chandrasekaran A, Rajalakshmi A, Suganya M, Vijayagopal P, Meenakshisundaram V (2012) Measurement of natural radioactivity in building materials of Namakkal, Tamil Nadu, India using gamma-ray spectrometry. Appl Radiat Isot 70(4): 699–704

[38] Rahman SU, Rafique M, Jabbar A, Matiullah (2013) Radiological hazards due to naturally occurring radionuclides in the selected building materials used for the construction of dwellings in four districts of the Punjab province, Pakistan. Radiat Prot Dosim 153(3): 352–360

[39] Roy S, Alam MS, Begum M, Alam B (2005) Radioactivity in building materials used in and around Dhaka city. Radiat Prot Dosim 114(4): 527–532.

[40] Malanca A, Pessina V, Dallara G (1993) Radionuclide Content of Building Materials and Gamma Ray Dose Rates in Dwellings of Rio Grande Do Norte, Brazil. Radiat. Prot. Dosim. 48(2):199–203