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Measurement of Indoor Terrestrial Gamma Radiation Dose and Evaluation of Annual Effective Dose at AECD Campus, Dhaka, Bangladesh

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Abstract:

Background: In this study, indoor terrestrial gamma radiation dose rates were measured at the Atomic Energy Centre Dhaka (AECD) Campus within Dhaka University area in Shahbag Thana of Dhaka, Bangladesh.
Aim of the study: This kind of study is required to detect the presence of natural and artificial radionuclides (if any) releasing from nuclear facilities in the country or from neighbouring countries. **Materials and Methods:** The measurement was performed using a portable High Purity Germanium (HPGe) detector (Model No. GEM25P4-83). The portable HPGe detector was placed at 1 meter above the ground facing downward and data acquisition time for each monitoring point (MP) was 10,000 sec. Total 21 monitoring points (MP) were selected for collection of gamma-ray spectrum in the indoor environment at the AECD Campus. The MPs were marked-out using Global Positioning System (GPS) navigation. The GPS reading of the sampling locations were varied from E: 90o23'42" — 90o23'47.4" and N: 23o43'49.8" — 23o43'53.4". Results: The measured dose rates due to natural radionuclides were ranged from 0.373 µGy.h-1 to 0.646 µGy.h-1 with an average of 0.494 ± 0.0682 µGy.h-1. The annual effective dose to the population from indoor terrestrial gamma radiation was varied from 1.83 to 3.17 mSv. Conclusion: The range of dose rate and annual effective dose due to indoor terrestrial gamma radiation is lower than some European Countries like Italy, Sweden and Czech Republic and higher than India, Iran and Azerbaijan. It was observed that ground floor dose rate is slightly higher than first floor dose rate because accumulation from radon gas near ground surface contributes to the higher gamma absorbed dose rate.

Key words: Terrestrial radiation, effective dose, In-situ, HPGe.

1. Introduction

One of the main external sources of ionizing radiation to the human body is represented by the gamma radiation emitted by naturally occurring radioisotopes. The most prominent naturally occurring radioisotopes are ^{40}K and the radionuclides from the ^{232}Th and ^{238}U series with their decay products, which exist at trace levels in all ground formations. The majority of human exposure to ionizing radiation occurs from natural sources including cosmic rays and terrestrial radiation [1]. Exposure to terrestrial gamma radiation depends mostly on geographical characteristics of a place such as altitude, latitude and solar activity [2, 3]. Indoor exposure to gamma rays is often greater than outdoor exposure if earth materials are used as construction materials. All building materials such as concrete, brick, sand, aggregate, marble, granite, limestone, gypsum, etc., contain mainly natural radionuclides, including uranium (^{238}U) and Thorium (^{232}Th) and their decay products, and the radioactive potassium (^{40}K). The knowledge of the natural radioactivity of building materials is important for the determination of population exposure to radiations, as most of the residents spend about 80% of their time indoors[4]. Gamma ray accounts for the majority of external human exposures to radiation from all type of sources due to its high penetration ability [5]. Gamma radiation is ubiquitous.

Great variations have been observed in environmental radiation levels and several international studies have been characterized gamma dose rates both in outdoor and indoor environments [6-14].

Both laboratory and in-situ gamma spectroscopy are often used for monitoring and assessment of radioactivity and radiation dose rates in the environment due to both natural and anthropogenic sources [15-20]. In-situ techniques for measuring the activity concentration resulting from the gamma radiation and characterizing its sources with gamma ray spectrometer have been used successfully in outdoor and indoor environment [12, 21-23].

The theoretical principles of in-situ gamma-ray spectrometry were developed in the early 1970s [24]. The three-factor assay formula is given by

$$\frac{N_f}{I} = \frac{N_f}{N_o} \cdot \frac{N_o}{\Phi} \cdot \frac{\Phi}{I} \qquad \cdots \qquad \cdots \qquad \cdots \qquad (1)$$

Where N_f is the full-energy peak count rate of the measured radionuclide (in counts per second), No is the full-energy peak count rate of that radionuclide for a parallel beam of gamma-rays that is incident on the detector parallel to its symmetry axis, Φ is the gamma-ray un-scattered flux on the detector ($cm^{-2}.s^{-1}$) and I is the exposure rate (μR/hr). Φ/I is the ratio of the flux due to gamma-rays of energy E to the corresponding exposure rate for that nuclide; this value was taken from Beck's tabulated data [24] and it is expressed in ($\gamma.s^{-1}.cm^{-2}/\mu R.h^{-1}$).

The gamma dose rate can be calculated by the formula:

$$\dot{D} = k \sum_i \frac{(N_f)_i}{(N_f / I)_i} \qquad \cdots \qquad \cdots \qquad \cdots \qquad (2)$$

Where the sum is extended over all the peaks registered by the detector; $(N_f)_i$ are the counts per second of the peaks experimentally measured and k is the conversion factor from Roentgen to Gray.

The presence of naturally occurring radionuclides in the environment may result in an external and internal dose received by a population exposed to them directly and through the ingestion and inhalation pathways. The assessment of the radiological impact on a population as a result of the radiation emitted by these radionuclides is important since they contribute to the collective dose of the population [25]. The aim of the present study is to measure indoor terrestrial gamma-ray dose rates from natural and artificial radionuclides (if any) releasing from nuclear facilities in the country or from neighbouring countries in normal operation or in case of incident/accident through in-situ technique.

2. Materials and Methods

2.1 In-Situ gamma-ray spectrometer

An ORTEC HPGe detector was used. It is a portable instrument with a p-type crystal, a dewar for the liquid nitrogen along with digiDART. Gamma –ray spectra were measured by a tripod-mounted, downward-facing HPGe detector (ORTEC, Model: GEM25P4-83, CFG: POPTOP, Serial No.: 50-TP12792A) of 25% relative efficiency within the energy range 50 keV-2 MeV compared with a 3 in. by 3 in. NaI(Tl) detector and 1.70 keV FWHM (both at 1332 keV) energy resolution, located 1m above ground. Spectra of 8192 channels were analyzed by the Maestro-32 MCA Emulsion Software.

2.2 Gamma-ray calibration sources

Measurement of N_o/Φ was performed at a 1m distance by a fixed radionuclide gamma-ray standard sources containing the following radionuclides (energies in keV, emission probabilities in %): ^{133}Ba (276.398, 7.164; 302.853, 18.33; 356.017, 62.05; 383.851, 8.94), ^{137}Cs (661.660, 85.1), ^{60}Co (1173.237, 99.90; 1332.501, 99.982). Gamma-ray emission rates of the standards were calculated from the standards, certificates, correcting from the lapse of time from the reference date. The flux is given by the gamma-ray emission rate divided by 4π and by $1m^2$ (100^2 cm^2). A second order polynomial least-squares fitting determined the $\log(N_o/\Phi)$ versus log(gamma-ray energy) dependence, which is followed by the Eq. $\mathrm{Ln}(N_o/\Phi) = 4.48-1.03\ln E$ where E is in MeV.

2.3 The Site

he study site is located from E: 90^o23'42" to E: 90^o23'47.4" and from N: 23^o43'49.8" to N: 23^o43'53.4". Twenty one locations were selected to measure indoor terrestrial gamma radiation dose rates in the AECD Campus in Shahbag Thana under Dhaka City. The measurements were performed from March-August 2016. The indoor terrestrial gamma radiation dose rate was measured for 10,000 sec for each MP. Fig. 1 shows the location of AECD Campus in Shahbag Thana under Dhaka City where indoor terrestrial gamma radiation measurement was performed using portable HPGe detector through in-situ technique. The number of MPs was 21 as shown in the Table 1. Table 1 gives the description of MPs. These sites were marked out using Global Positioning System (GPS) navigation.

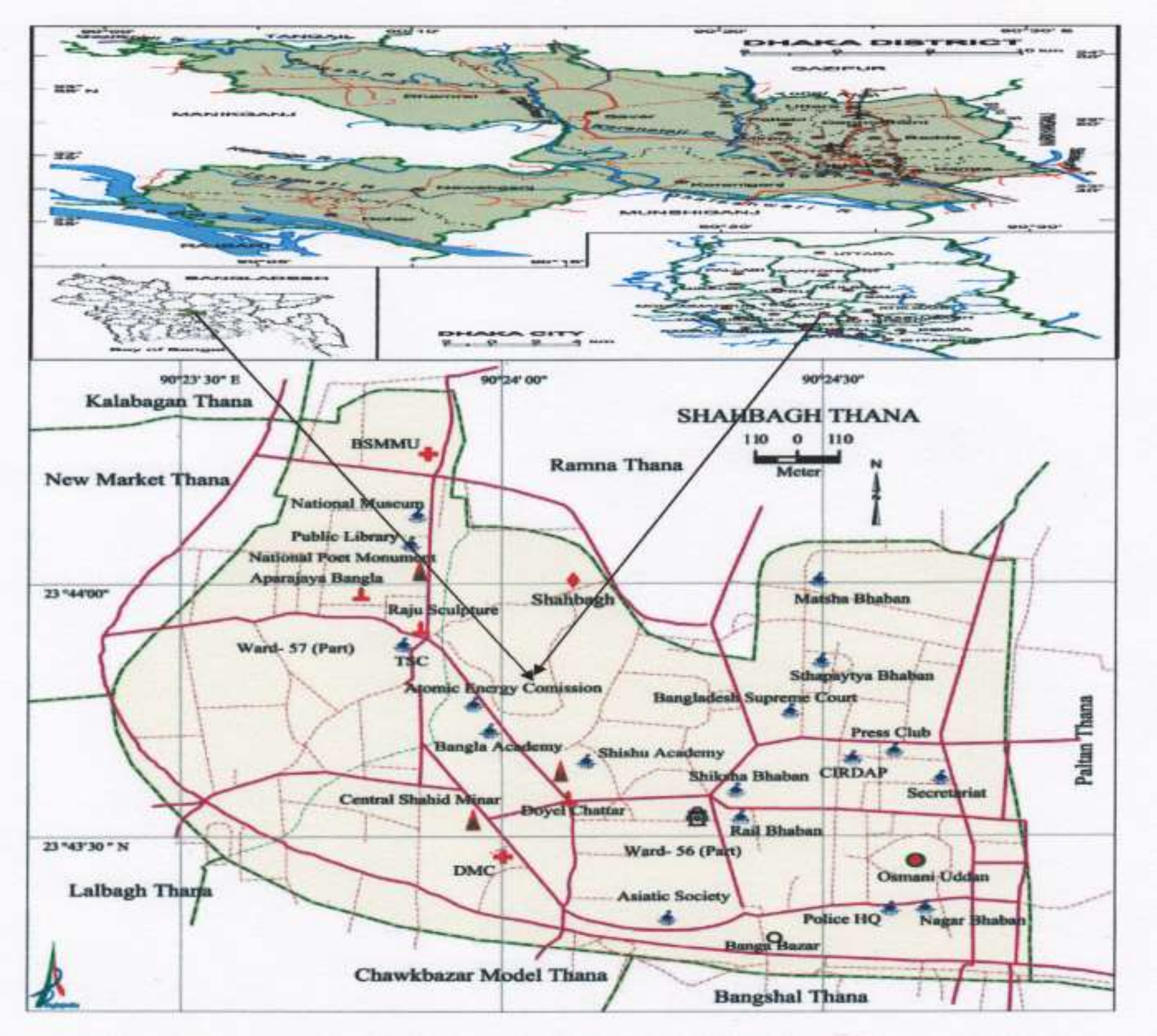

Figure 1: Shows the location of AECD Campus in Shahbag Thana under Dhaka City where indoor terrestrial gamma radiation measurement was performed using portable HPGe detector through in-situ technique.

3. Results and Discussion

3.1 Collection of field gamma-ray spectrum

Measurement of indoor terrestrial gamma radiation dose rate was carried out at the AECD Campus in Shahbag Thana under Dhaka City during March-August 2016 following in-situ technique. Collecting spectra have been analyzed in order to determine the dose rate from natural radionuclides.

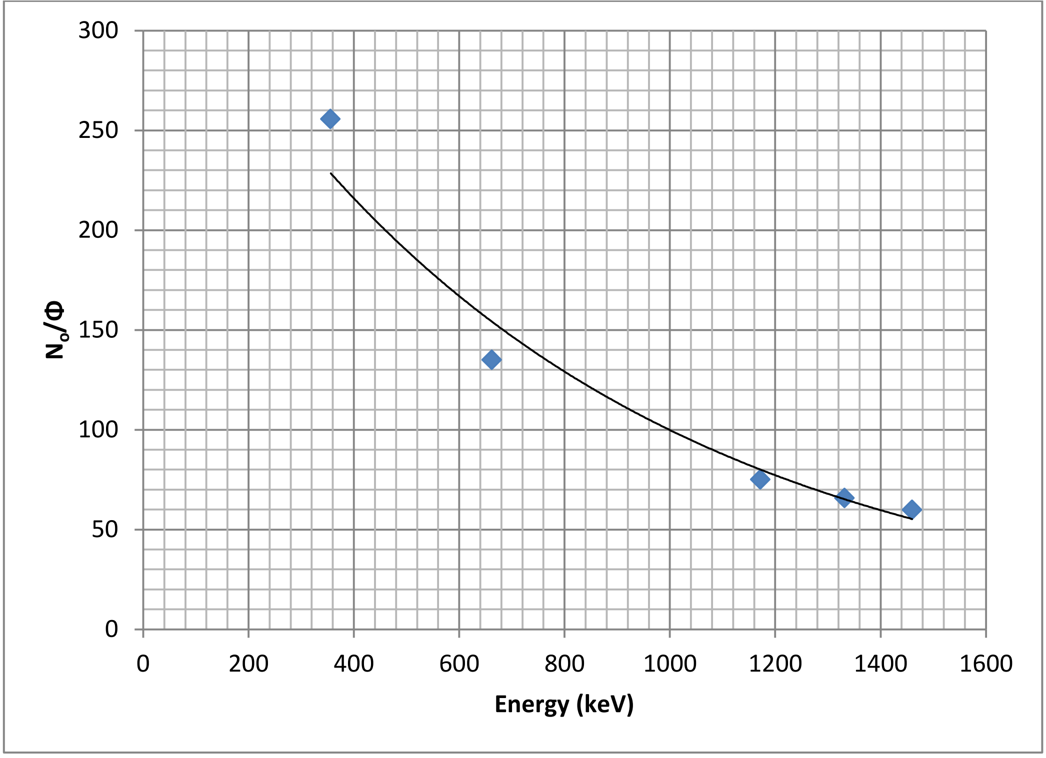

Figure 2: Variation of N_o/Φ with energy.

3.2 Absorbed dose rate and annual effective dose

The average indoor terrestrial gamma radiation dose rate in the study area was found to be 0.494096 ± 0.068165µGy.h^{-1}. The measured dose rates were ranged from 0.372533 to 0.645762µGy.h^{-1} with an average of 0.494096 ± 0.068165µGy.h^{-1}. Using the conversion factor of 0.7 Sv Gy^{-1} as recommended by UNSCEAR 2000 [23], and considering that people in Bangladesh spend approximately 20 % of their time outdoor and remaining 80% of time indoor; the annual effective dose received by people in Dhaka City due to the terrestrial gamma radiation is given in Table 1.The annual effective dose rates of the population due to the indoor terrestrial gamma radiation were also calculated and it was varied from 1.827498 to 3.16785 mSv. The mean annual effective dose was found to be 2.423837±0.334389 mSv. This type of study is very important for radiation protection purpose in the country because the usage of radioactive material is increasing day by day in the various fields like medicine, industry and research. Moreover, environmental radiation and radioactivity monitoring is crucial to generate the baseline data from natural sources and releasing (if any) from nuclear installations in the country or from neighboring countries. This kind of study will also be needed for measurement of environmental radioactivity in and around the Rooppur Nuclear Power Project (RNPP) site area in Pabna of Bangladesh.

Table 1: Indoor absorbed dose rate and annual effective dose rate for 21 MPs at AECD Campus, Shahbag Thana under Dhaka City.

Date/Time	**Latitude/Altitude**	**Total counts in the peaks**	**Absorbed dose rate (μGy.h^{-1})**	**Annual effective dose (mSv.y^{-1})**
29032016 12.00PM	N23°43' 50.16" E90°23'44.88"	8017.528±89.54065	0.574845	2.81996
04042016 09.50AM	N23°43' 51.24" E90°23'45.96"	6743.6±82.11943	0.483506	2.371887
05042016 10.10AM	N23°43' 53.4" E90°23'42"	6278.246±79.23538	0.450141	2.208212
05042016 01.05PM	N23°43' 50.88" E90°23'44.52"	6914.26±83.15203	0.495742	2.431912
06042016 10.05AM	N23°43' 51.6" E90°23'45.24"	7400.875±86.02834	0.530632	2.603068
06042016 01.52PM	N23°43' 50.52" E90°23'45.6"	6332.375±79.57622	0.454022	2.22725
12042016 10.05AM	N23°43' 49.8" E90°23'45.96"	7730.064±87.92078	0.554234	2.71885
12042016 01.15PM	N23°43' 51.96" E90°23'44.16"	8024.615±89.58022	0.575353	2.822452
13042016 11.20AM	N23°43' 51.6" E90°23'44.52"	6231.928±78.94256	0.44682	2.19192
19042016 09.50AM	N23°43' 50.88" E90°23'44.52"	6345.408±79.65807	0.454956	2.231832
19042016 01.20PM	N23°43' 51.24" E90°23'44.16"	7452.24±86.32636	0.534314	2.621131
08062016 10.50AM	N23°43' 50.88" E90°23'46.68"	7923.584±89.01452	0.568109	2.786916
26072016 10.00AM	N23°43' 50.52" E90°23'43.8"	6441.498±80.25894	0.461846	2.265632
26072016 01.50PM	N23°43' 50.16" E90°23'44.52"	9006.63±94.90327	0.645762	3.16785
01082016 12.45PM	N23°43' 51.24" E90°23'47.04"	6457.68±80.35969	0.463006	2.271322
02082016 10.00AM	N23°43' 50.16" E90°23'46.32"	7747.4±88.01932	0.555477	2.724948
02082016 01.10PM	N23°43' 50.88" E90°23'45.6"	6863.584±82.84675	0.492109	2.41409
22082016 09.45AM	N23°43' 50.52" E90°23'45.96"	5195.832±72.08212	0.372533	1.827498
22082016 12.40PM	N23°43' 51.96" E90°23'46.68"	5632.436±75.04956	0.403837	1.981063
23082016 09.35AM	N23°43' 51.24" E90°23'47.4"	5830.089±76.35502	0.418009	2.050585
23082016 12.40PM	N23°43' 51.6" E90°23'46.68"	6147.411±78.40543	0.44076	2.162192

Table 2: Ground and first floor minimum, maximum and mean dose rate

Floors	**Monitoring points range**	**Minimum dose rate** (μGy.h^{-1})	**Maximum dose rate** (μGy.h^{-1})	**Mean ± SD (μGy.h^{-1})**
Ground floor	1-12	0.44682	0.575353	0.510223 ± 0.051759
First Floor	13-21	0.372533	0.645762	0.472593 ± 0.083799

From Table 2 we can see that the measurements were taken into two floors. In the ground floor, the minimum dose rate was 0.44682 μGy.h^{-1}, the maximum dose rate was 0.575353 μGy.h^{-1} and the average dose rate was (0.510223 ± 0.051759) μGy.h^{-1}. In the first floor, the minimum dose rate was 0.372533 μGy.h^{-1}, the maximum dose rate was 0.645762 μGy.h^{-1} and the average dose rate was (0.472593 ± 0.083799) μGy.h^{-1}. From Table 2, it can be clearly seen that the ground floor dose rates are slightly higher than those of first floor because accumulation from radon gas near ground surface contribute to the higher gamma absorbed dose rate.

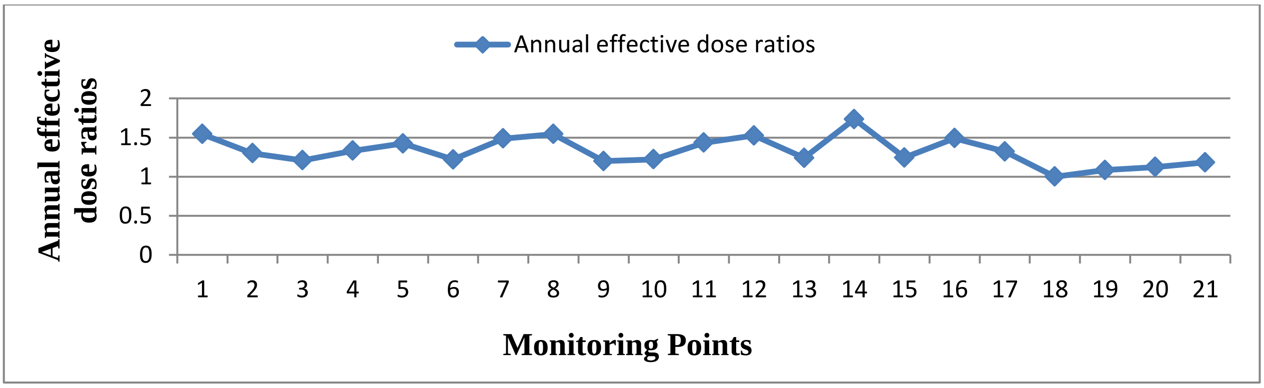

Figure 3: Indoor annual effective dose values normalized to the minimum annual effective dose for each MPs.

The frequency distribution of the terrestrial gamma absorbed dose rates follow a normal type distribution as shown in Figure 4.

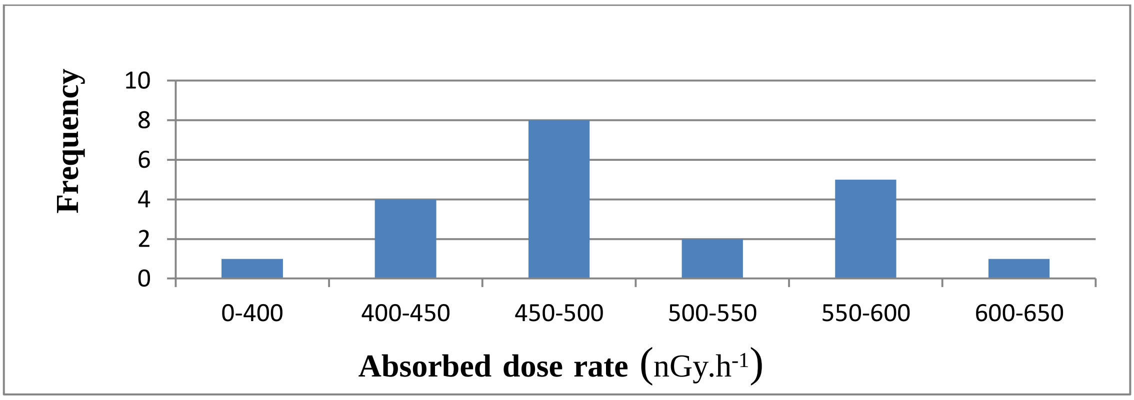

Figure 4: Frequency distribution of the absorbed dose rates (nGy.h^{-1}) at AECD Campus in Shahbag Thana under Dhaka City.

The indoor gamma radiation dose rates were measured at AECD Campus at 21 locations in the laboratories by in-situ method using portable HPGe detector, which are summarized in Table 1. The annual effective dose range due to the indoor terrestrial gamma radiation to the population of Dhaka City is tabulated in Table 3. It can be seen from Table 3 that range of annual effective is lower than some European Countries like Italy, Sweden and Czech Republic and higher than India, Iran and Azarbaijan. Higher levels of absorbed dose rate in indoor atmosphere are mainly depends on the use of rocks and building materials for the construction of buildings which contain higher concentrations of natural radionuclides such as ^{226}Ra, ^{232}Th, and ^{40}K [26,27]. The uses of different kinds laboratory equipments, soil, and other decorative stones for the construction of walls and floor and due to poor ventilation conditions inside the buildings enhances the radon concentration and also radon daughter concentration; this contributes to the elevated gamma absorbed dose.

Table 3: Indoor dose rate range and annual effective dose range due to natural radionuclide sources for selected countries and for this study [28].

Country	**Range of Dose rate (μGy.h^{-1})**	**Range of annual effective dose (mSv)**
Cuba	0.010-0.760	0.049-3.724
Azerbaijan	0.087-0.160	0.426-0.784
Taiwan	0.066-0.189	0.323-0.926
Kazakhstan	0.150-0.280	0.735-1.372
India[11]	0.114-0.333	0.559-1.631
Iran	0.070-0.165	0.343-0.806
Denmark	0.019-0.259	0.093-1.269
Finland	0.024-0.181	0.118-0.887
Iceland	0.014-0.032	0.069-0.157
Lithuania	0.034-0.224	0.167-1.098
Sweden	0.010-1.250	0.049-6.125
Belgium	0.032-0.180	0.157-0.882
Germany	0.020-0.700	0.098-3.430
Ireland	0.010-0.140	0.049-0.686
Italy	0.000-0.690	0.000-3.381
Spain	0.040-0.124	0.196-0.608
Bulgaria	0.057-0.093	0.279-0.456
Czech Republic	0.042-2.000	0.206-9.800
Romania	0.030-0.170	0.147-0.883
Slovenia	0.040-0.250	0.196-1.225
Greece	0.020-0.101	0.098-0.495
New Zealand	0.000-0.077	0.000-0.377
This Study	**0.373-0.646**	**1.83-3.17**

The estimated mean annual effective dose of 2.42 mSv is not expected to contribute significant additional hazard from the radiological health point of view. Due to comparison purposes, the annual dose limit for members of the public according to ICRP 103 (2007 recommendation) [29] is 1 mSv/year, and this limit is applicable to practices giving rise to controllable exposure and is not applicable to doses received from natural sources.

4. Conclusion

The present study has measured the indoor terrestrial gamma radiation dose rates at AECD Campus that is located in Dhaka University area under Shahbag Thana of Dhaka City. The average indoor terrestrial gamma radiation dose rate in the study area was found to be 0.494096 ± 0.068165μGy.h^{-1}. The measured dose rates were ranged from 0.372533 to 0.645762μGy.h^{-1} with an average of 0.494096 ± 0.068165μGy.h^{-1}. The annual effective dose rates of the population due to the indoor terrestrial gamma radiation were varied from 1.827498 to 3.16785 mSv. The mean annual effective dose was found to be 2.423837±0.334389 mSv. This type of study is very important for our country because the usage of radioactive material is increasing day by day in the various fields like medicine, industry and research & education. Moreover, environmental radiation and radioactivity monitoring is crucial to generate the baseline data from natural sources. This kind of study is very important for detection of natural radionuclides and artificial radionuclides (if any) releasing from nuclear installations in the country or from neighboring countries in normal operation or in case of incident/accident. From this study, it can be concluded that the assessment of the radionuclide level of the area did not detect the presence of any artificial radionuclides and thus no significant impact of the extensive usage of radioactive materials in and around AECD Campus and no radiation burden of the environment.

5. Acknowledgement

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