Real-Time Environmental Gamma Dose Rates Measurement and Evaluation of Annual Effective Dose to population of Shahbag Thana, Dhaka, Bangladesh

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Abstract:
Background: In this study, environmental gamma radiation dose rates were measured in the area of Shahbag Thana under Dhaka city, 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 Method: The measurement was performed using a digital portable Gamma-Scout detector. The digital portable Gamma-Scout detector was placed at 1 meter above the ground on tripod and data acquisition time for each monitoring point (MP) was 1 hour. Total 27 MPs were selected for collection of gamma-ray dose rate in the outdoor environment of Shahbag Thana. The measurements were performed during light day from January to September 2017. The MPs were marked-out using Global Positioning System (GPS) navigation. The GP Sreading of the sampling locations were varied from E: 90°23'32.94" to E: 90°24'31.32" and from N:23°44'19.38" to N: 23°43'24.3". Results: The measured dose rates due to natural radionuclides were ranged from $0.085 \pm 0.0245 \mu Sv.h^{-1}$ to $0.190526 \pm 0.081886 \mu Sv.h^{-1}$ with an average of $0.145265 \pm 0.025192 \mu Sv.h^{-1}$.The annual effective dose to the population from outdoor environmental gamma radiation was varied from0.104244 ± 0.030041 mSv to 0.233661085 ± 0.100425 mSv. The range of dose rate and annual effective dosedue to outdoor environmental gamma radiation is lower than some countries like India, Sweden, China, CzechRepublic, Italy and higher than Canada, Turkey, Indonesia, Belgium, Albania, New Zealand and some other counties. Conclusion: From this study, it was observed that there is no burden of population exposure due to man-made sources. Therefore, it can be concluded that adequate safety and radiation protection of radiological facilities had been ensured which is required for minimizing of unnecessary exposure to populations from man-made sources. The estimated mean annual effective dose found in this study is not expected to contribute significant additional hazard from the radiological health point of view.

Key words: Environmental gamma radiation, effective dose, In-situ, Gamma-Scout detector.

1. Introduction
The exposure of human beings to ionizing radiation both from natural and man-made sources is a continuing and inescapable feature of life on earth [1] [2]. Environmental radioactivity measurements are necessary to determine the background radiation level due to natural radioactivity sources of terrestrial and cosmic origins [3]. Background radiation consists of three primary types: Primordial, cosmogenic and anthropogenic.

Primordial radionuclides are present in the earth's crust and found throughout the environment. Cosmogenic radionuclides are produced when cosmic radiation interacts with elements present in the atmosphere and are deposited through both wet and dry deposition. Anthropogenic sources of radiation result from human activities, but are considered background because their presence is ubiquitous [4]. According to UNSCEAR, about 87% of the radiation dose received by mankind is from natural sources and the remaining is due to anthropogenic sources [5]. The main sources of the external gamma radiation are from the primordial radio nuclides like ^{238}U, ^{232}Th and ^{40}K that are present in the earth since its formation [6], depending on the geological and geographical features of a region [3] [7] [9]. The primarily sources of cosmic radiation are the galaxies in outer space (galactic cosmic radiation) and secondarily source is the Sun in our solar system (significant during maximum sun cycle activity) [10] whose contribution to background changes mainly with elevation and latitude [11] [12]. The galactic cosmic radiation coming at the upper atmosphere is made up of about 98% baryons and 2% electrons [10]. ^{137}Cs, ^{134}Cs, ^{90}Sr is an anthropogenic radionuclide might also contribute to human external exposure [13] [14]. 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 and 20% of their outdoors [15]. In general, the health impact of exposure to radon (^{222}Rn) inhalation by humans in indoor environment is a major public concern worldwide. The exposure is due to the emanation of radon gas from the decay chains of radioactive thorium (^{232}Th) and uranium (^{238}U), which are present in soil layers and indoor construction materials especially granite [16]. The total amount of radioactivity in an environment should be accurately known and kept to a level as low as reasonably achievable (ALARA) [8].

Gamma ray accounts for the majority of external human exposures to radiation from all type of sources due to its high penetration ability [17]. 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 [18] [25].

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 [26] [30]. 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 [31] [33]. 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 [34]. The aim of the present study is to measure outdoor environmental 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 dose rate measurement
The In-situ gamma-ray dose rate measurement is highly reliable in indoor and outdoor environments [35]. A real-time digital portable radiation monitoring device which is known as GAMMA SCOUT was used for this study. GAMMA SCOUT is German designed and manufactured, built with a solid Novadur exterior. An optional stylish leather holster with belt strap can further protect the GAMMA SCOUT from the elements. The GAMMA SCOUT meets all European CE standards as well as US FCC 15. All units come with an industry leading 2-year manufacturer's warranty and a serialized test certificate. The GAMMA SCOUT is a fully featured Geiger counter with a form fitting ergonomic shape. The unit has a battery indicator, multiple unit conversion, real-time dose rate and cumulative dose display functions and programmable logging and alert functions. Advanced functions include PC data download via USB cable and an ultra low current power circuit for extended battery life [36].

2.2 Gamma-ray calibration sources

The GAMMA SCOUT was calibrated inbuilt by the manufacturer. The GAMMA SCOUT is also calibrated at Secondary Standard Dosimetry Laboratory under Bangladesh Atomic Energy Commission using gamma-ray standard sources. The GAMMA SCOUT accurately measure dose rate in the range of 0.01-5000 μSv/hr.

2.3 The Site

The study site is located from E: $90°23'32.94''$ to E: $90°24'31.32''$ and from N: $23°44'19.38''$ to N: $23°43'24.3''$. Twenty seven locations were selected to measure outdoor environmental gamma radiation dose rates in Shahbag Thana under Dhaka city. The measurements were performed during light day from January to September 2017. For each location, the real-time digital portable radiation monitoring device (GAMMA SCOUT) was placed on tripod at 1 m height and time for dose rate measurement was 1 hour. Figure 1 shows the location of area in Shahbag Thana under Dhaka city where outdoor environmental gamma radiation measurement was performed using portable Gamma-Scout detector through In-situ technique. Table 1 gives the description of monitoring points (MPs). This site was marked out using Global Positioning System (GPS) navigation.
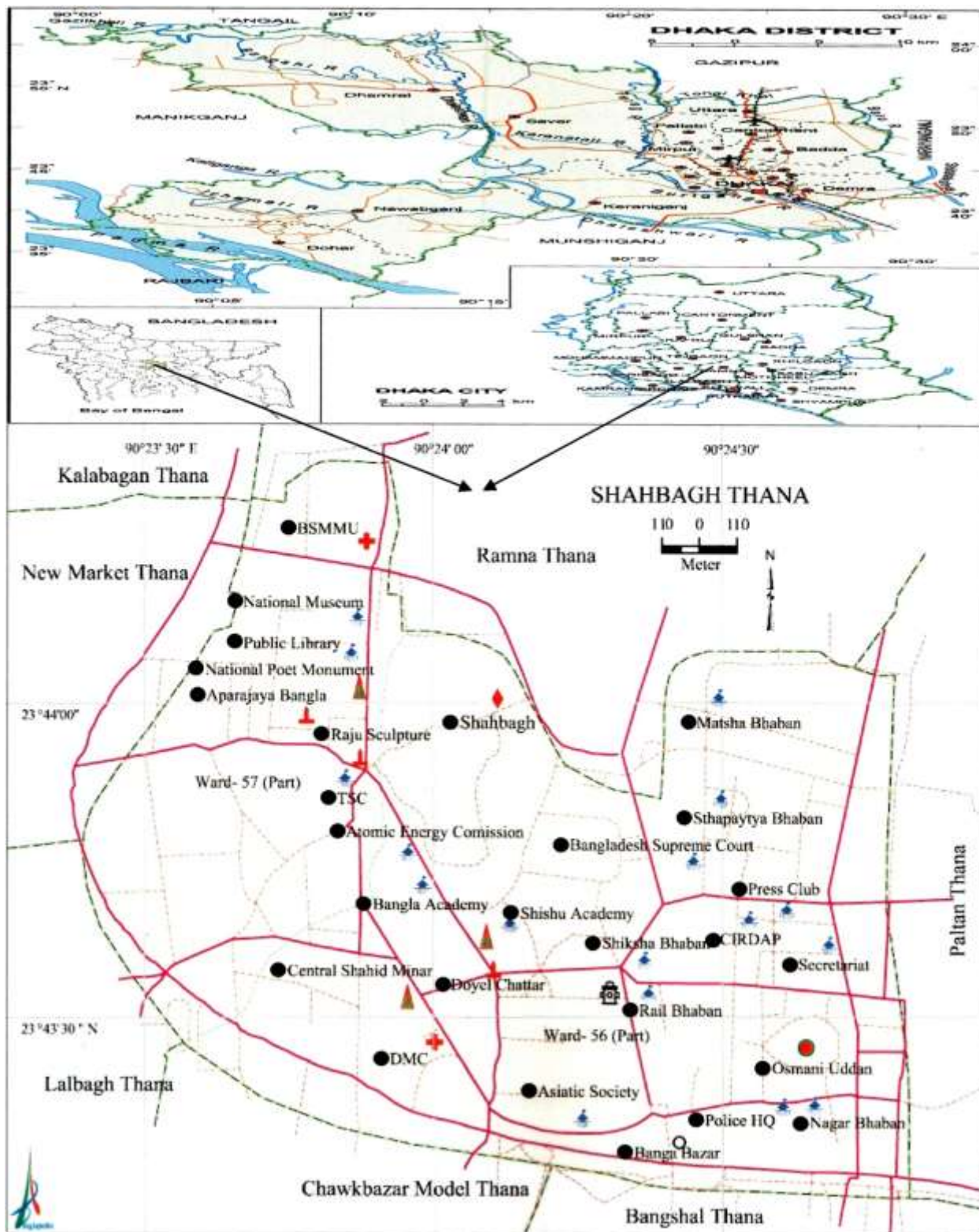
Figure 1: Shows the location (●) of Shahbag Thana under Dhaka city where outdoor environmental gamma radiation measurement was performed using portable Gamma-Scout detector through In-situ technique.

3. Results and Discussion

3.1 Collection of field gamma-ray dose rate

Measurement of outdoor environmental gamma radiation dose rate was carried out at the area of Shahbag Thana under Dhaka city from January-September 2017 following In-situ technique. The contribution of dose rates in all monitoring points arising from natural radionuclides.

3.2 Absorbed dose rate and annual effective dose

The average outdoor environmental gamma radiation dose rate in the study area was found to be 0.145265 ± 0.025192μSv.h^{-1}. The measured dose rates were ranged from 0.085 ± 0.024495 μSv.h^{-1} to 0.190526 ± 0.081886 μSv.h^{-1} with an average of 0.145265 ± 0.025192 μSv.h^{-1}. Using the conversion factor of 0.7 Sv Gy^{-1} as recommended by UNSCEAR 2000 [8], 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 environmental gamma radiation is given in Table 1.The annual effective dose rates of the population due to the outdoor environmental gamma radiation were also calculated and it was varied from 0.104244 ± 0.030041 mSv to 0.233661 ± 0.100425 mSv. The mean annual effective dose was found to be 0.178153 ± 0.030895 mSv.

Table 1: Outdoor dose rate and annual effective dose for 27 MPs at Shahbag Thana under Dhaka city.

Name of Place	Latitude/ Altitude	Gamma dose rate (μSv/hr)			Annual effective dose due to gamma radiation (mSv) ± SD
		Range	Mean	SD	
BSMMU	N23°44'19.38" E90°23'40.62"	(0.06-0.18)	0.12	0.038944	0.147168 ± 0.047761
Shahbag	N23°44'16.44" E90°23'45.66"	(0.07-0.15)	0.11	0.027386	0.134904 ± 0.033586
National Museum	N23°44'15.18" E90°23'43.68"	(0.02-0.24)	0.156471	0.057981	0.191896 ± 0.071108
Public Library	N23°44'12.12" E90°23'39.78"	(0.05-0.21)	0.144615	0.048411	0.177356 ± 0.059371
National Poet Monument	N23°44'6.72" E90°23'42.06"	(0.07-0.18)	0.129	0.036652	0.158206 ± 0.044949
Aparajaya Bangla	N23°44'1.44" E90°23'32.94"	(0.05-0.32)	0.186087	0.081058	0.228217 ± 0.099409
Raju Sculpture	N23°43'57.78" E90°23'43.14"	(0.07-0.16)	0.115	0.030277	0.141036 ± 0.037131
TSC	N23°43'56.7" E90°23'44.8	(0.09-0.21)	0.15	0.038944	0.18396 ± 0.047761

	8"				
Atomic Energy Commission	N23°43'50.64" E90°23'47.52"	(0.02-0.30)	0.190526	0.081886	0.233661 ± 0.100425
Bangla Academy	N23°43'48.36" E90°23'52.26"	(0.08-0.23)	0.152667	0.048324	0.18723 ± 0.058388
Doyel Chattar	N23°43'40.62" E90°24'2.28"	(0.05-0.17)	0.11	0.038944	0.134904 ± 0.047761
Shishu Academy	N23°43'41.82" E90°24'4.2"	(0.07-0.19)	0.121538	0.053048	0.149055 ± 0.047761
Bangladesh Supreme Court	N23°43'42.24" E90°24'12.3"	(0.08-0.23)	0.155	0.04761	0.190092 ± 0.058388
Sikhsha Bhaban	N23°43'41.7" E90°24'15.54"	(0.07-0.19)	0.138182	0.036556	0.169466 ± 0.044833
CIRDAP	N23°43'45.12" E90°24'18.84"	(0.11-0.22)	0.165	0.036056	0.202356 ± 0.044218
Secretariat	N23°43'40.68" E90°24'31.32"	(0.05-0.23)	0.150625	0.054341	0.184727 ± 0.066643
Press Club	N23°43'46.86" E90°24'25.86"	(0.09-0.22)	0.145	0.04378	0.177828 ± 0.053691
Rail Bhaban	N23°43'39.36" E90°24'21.06"	(0.08-0.22)	0.145714	0.043095	0.178704 ± 0.052851
Osmani Uddan	N23°43'34.38" E90°24'30.84"	(0.07-0.20)	0.135	0.041833	0.165564 ± 0.051304
Police HQ	N23°43'29.1" E90°24'26.64"	(0.12-0.25)	0.183077	0.042892	0.224526 ± 0.051304
Nagar Bhaban	N23°43'27.3"	(0.07-0.20)	0.135	0.041833	0.165564 ± 0.051304

	E90°24'29.4"				
Matsha Bhaban	N23°44'1.32" E90°24'14.52"	(0.09-0.23)	0.164286	0.043095	0.20148 ± 0.052851
Sthapaytya Bhaban	N23°43'58.8" E90°24'17.4"	(0.07-0.20)	0.135	0.041833	0.165564 ± 0.051304
Central Shaheed Minar	N23°43'39.36" E90°23'46.02"	(0.10-0.22)	0.16	0.038944	0.196224 ± 0.047761
DMC	N23°43'35.04" E90°23'49.8"	(0.11-0.23)	0.17	0.038944	0.208488 ± 0.047761
Asiatic Society	N23°43'27.42" E90°24'8.88"	(0.09-0.26)	0.169375	0.052974	0.207722 ± 0.064967
Banga Bazar	N23°43'24.3" E90°24'19.32"	(0.05-0.12)	0.085	0.024495	0.104244 ± 0.030041

From Table 1 we can see that the highest dose rate was observed in Atomic Energy Centre, Dhaka (AECD) and the lowest in Banga Bazar with respective values of 0.190526 ± 0.081886 μSv/h and 0.085 ± 0.024495 μSv/h. The highest dose rate at AECD is observed because high activity industrial radiography source was placed in AECD campus. It is also indicated that there is a direct relationship between background dose rate and latitude of the region. Banga Bazar, located in south eastern part of Shahbag thana, has lower background gamma radiation in comparison to higher latitude regions of Shahbag thana. One main reason for this phenomenon is magnetic field of the earth which increases by latitude and reach to the optimum value at poles. Magnetic field of the earth can affect slow moving charged particles and diverts them towards the poles [37] [38].

The annual effective dose range due to the outdoor environmental gamma radiation to the population of Dhaka city is tabulated in Table 2. It can be seen from Table 2 that the range of dose rate and annual effective dose to population of Shahbag is lower than some countries like India, Sweden, China, Czech Republic, Italy and higher than Canada, Turkey, Indonesia, Belgium, Albania, New Zealand and some other counties. The exact reason for high radiation doses are not known, but might be attributed to geographical, geological, and altitude of cities studied.
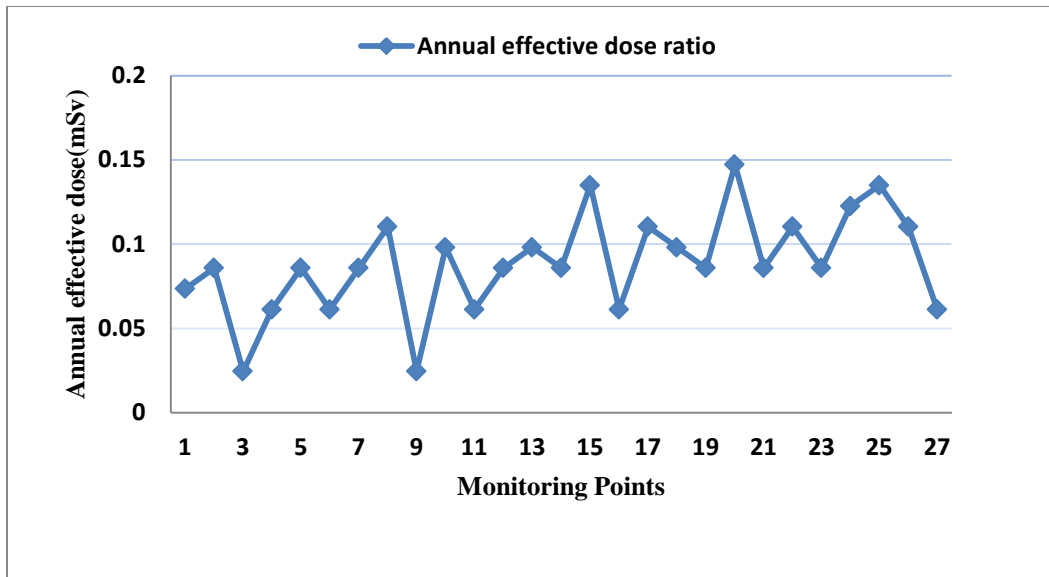
Figure 2: Outdoor annual effective dose values normalized to the minimum annual effective dose for each MPs.

The frequency distribution of the environmental gamma dose rates follow a normal type distribution as shown in Figure 3.
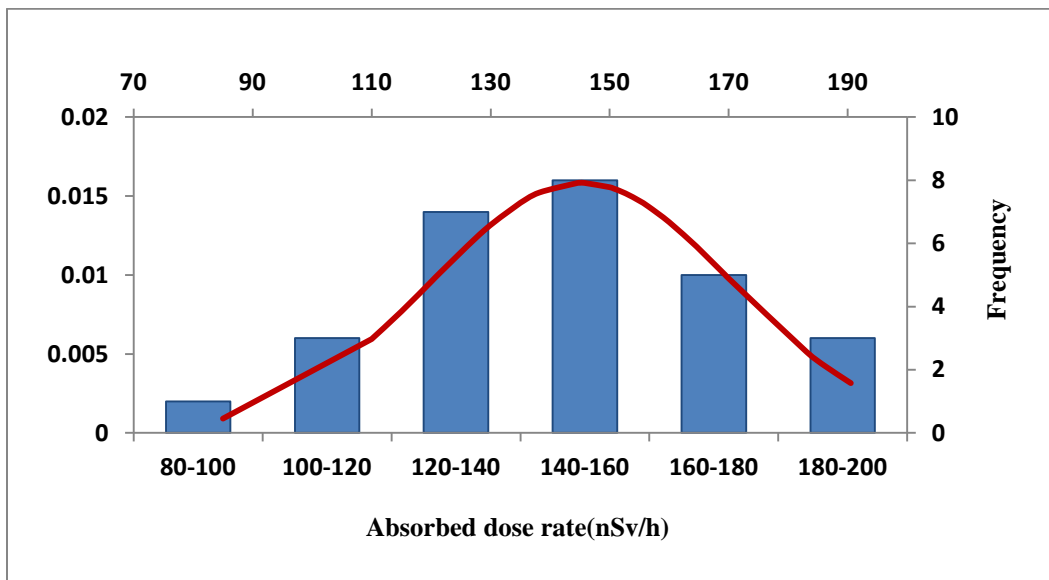

Figure 3: Frequency distribution of the dose rates (nSv.h^{-1}) at area of Shahbag Thana under Dhaka city follow normal distribution.

Table 2: Environmental gamma dose rate range and annual effective dose range due to natural radionuclide sources for selected countries and for this study [UNSCEAR 2008] [39]

Country	Range of Dose rate (µSv.h^{-1})	Mean Gamma Dose rate (µSv.h^{-1})	Range of annual effective dose (mSv)
Libyan Arab Jamahiriya	0.048 - 0.054	0.051	0.059 - 0.066
Mauritius	0.08 - 0.126	0.098	0.098 - 0.155
Tanzania	0.098 - 0.121	0.104	0.120 - 0.148

(United Rep. of)			
Canada	0.031- 0.075	0.054	0.038 - 0.092
Mexico	0.023 - 0.184	0.088	0.028 - 0.226
Costa Rica	0.035 - 0.147	0.066	0.043 - 0.180
Odisha, India	0.251 - 0.879	0.449	0.308 - 1.078
Cuba	0.038 - 0.196	0.055	0.047 - 0.240
Azerbaijan	0.075 - 0.205	0.140	0.092 - 0.251
China	0.011 - 0.523	0.815	0.013 - 0.641
Indonesia	0.045 - 0.102	0.0675	0.055 - 0.125
Korea	0.018 - 0.200	0.079	0.022 - 0.245
Turkey	0.032 - 0.094	0.065	0.039 - 0.115
Denmark	0.056 - 0.101	0.066	0.069 - 0.124
Finland	0.077 - 0.171	0.103	0.094 - 0.209
Lithuania	0.079 - 0.115	0.095	0.097 - 0.141
Sweden	0.040 - 0.630	0.097	0.049 - 0.773
Belgium	0.045 - 0.102	0.076	0.055 - 0.125
Ireland	0.035 - 0.143	0.065	0.043 - 0.175
Italy	0.057 - 0.243	0.112	0.069 - 0.298
Spain	0.050 - 0.129	0.085	0.061 - 0.158
Switzerland	0.053 - 0.155	0.081	0.065 - 0.190
Bulgaria	0.075 - 0.140	0.100	0.092 - 0.172
Czech Republic	0.040 - 0.285	0.100	0.049 - 0.349
Poland	0.051 - 0.126	0.080	0.063 - 0.155
Romania	0.052 - 0.163	0.092	0.065 - 0.199
Albania	0.077 - 0.103	0.094	0.094 - 0.126
Croatia	0.070 - 0.140	0.115	0.086 - 0.172
New Zealand	0.034 - 0.122	0.076	0.042 - 0.149
This Study	**0.085 - 0.191**	**0.145**	**0.104 - 0.234**

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated global dose rate in outdoor due to natural background radiation to be on average 59 nGy/h and population weighed average of effective environmental gamma dose rate is 0.072 mGy/y [8]. Assuming this dose rate as a normal level, doses quantified in my study area are approximately 1.45 to 3.25 times higher than worldwide population weighted average and that people living in this area receive on average approximately 2.5 times higher environmental gamma radiation than the world population weighted average.

The estimated mean annual effective dose of 0.178 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) [40] 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 outdoor environmental gamma radiation dose rates in the area of Shahbag Thana under Dhaka city. The average outdoor environmental gamma radiation dose rate in the study area was found to be $0.145265 \pm 0.025192 \mu Sv.h^{-1}$ which is higher than the world average value. The measured dose rates were ranged from 0.085 ± 0.024495 $\mu Sv.h^{-1}$ to 0.190526 ± 0.081886 $\mu Sv.h^{-1}$ with an average of 0.145265 ± 0.025192 $\mu Sv.h^{-1}$. The annual effective dose rates of the population due to the outdoor environmental gamma radiation were varied from 0.104244 ± 0.030041 mSv to 0.233661 ± 0.100425 mSv. The mean annual effective

dose was found to be 0.178153 ± 0.030895 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 required to detect the presence of natural radionuclides and artificial radionuclides (if any) releasing from nuclear installations in the country or from neighboring countries in normal operations or in case of accident/incident. 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 within and around the area of Shahbag Thana and no radiation burden of the environment. 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 for generation of baseline database. From this study, it can be concluded that the assessment of the dose 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 Shahbag Thana and no radiation burden to the environment. Finally, it can be concluded that adequate safety and radiation protection of nuclear & radiological facilities had been ensured which is required for minimizing of unnecessary exposure to populations from man-made sources.

5. Acknowledgement

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