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Real-Time Environmental Gamma Radiation Dose Rate Measurement around Major Nuclear and Radiological Facilities in Bangladesh

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Abstract:
Background: In this study, outdoor environmental gamma radiation dose rates were measured at area of Shahbag Thana under Dhaka city and Atomic Energy Research Establishment (AERE) Campus at Savar. Aim of the study: This kind of study is required to detect the presence of natural and artificial radionuclides (if any) releasing from nuclear and radiological facilities in the country or from neighbouring countries. Materials and Methods: The measurement was performed using a real-time portable radiation monitoring device from August-November 2017. The real-time portable radiation monitoring device was placed on tripod at 1 meter above the ground and data acquisition time for each monitoring point (MP) was 1 hour. Total 34 MP were selected around major nuclear and radiological facilities in Bangladesh for collection of dose rate due to gamma-ray. The MPs were marked-out using Global Positioning System (GPS) navigation. The GPS reading of the sampling locations were varied from E90º23'40.08" to E90º24'32.82" and from N23º44'58.62" to N23º43'26.58" for Shahbag Thana and from E90º16'26.58" to E90º16'50.52" and from N23º57'12.96" to N23º57'6.12" for AERE Campus, Savar. Results: The measured dose rates due to natural radionuclides were ranged from 0.105 ± 0.036056 $\mu Sv.h^{-1}$ to 0.208065 ± 0.106377$\mu Sv.h^{-1}$ with an average of 0.141568 ± 0.046995 $\mu Sv.h^{-1}$. The annual effective dose to the population from outdoor environmental gamma radiation was varied from 0.128772 ± 0.044218 mSv to 0.25517 ± 0.130461 mSv and the mean was found to be 0.17362± 0.057635 mSv. This value is lower than some countries like India, China, Sweden, Italy and Czech Republic; and higher than Canada, Mexico, Indonesia, Korea, Turkey, Finland, Spain and some other countries. 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 nuclear & 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 radiation, Effective dose, In-situ, Gamma-Scout.

1. Introduction

From the beginning of life on earth, all living things have been exposed to radiation. Life started and developed in spite of, or possibly because of, radiation. It is disquieting to people that they coexist with radiation yet it cannot be seen, heard or felt [1].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 [2]. Exposure to terrestrial gamma radiation depends mostly on geographical characteristics of a place such as altitude, latitude and solar activity [3, 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 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 [24]. The aim of the present study is to measure outdoor environmntal 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.

Biological effects of ionizing radiation on human are evaluated based on the effective absorbed dose rate. Annual effective absorbed dose from background gamma radiation was determined using the equation (1), (2) and (3)[25].

$E_{total} = E_{Out} + E_{In} = (D_{Out} \times OF_{Out} + D_{In} \times OF_{In}) \times T \times CC$ (1)

$E_{Out} = T \times D_{Out} \times CC \times O_{Fout}$(2)

$E_{In} = T \times D_{In} \times CC \times OF_{In}$(3)

Where, E_{total} = Total annual effective absorbed dose rate (mSv/y); E_{In}= Indoor annual effective absorbed dose rate (mSv/y); E_{Out} = Outdoor annual effective absorbed dose rate (mSv/y); T = Time in hours (8760 hours for a year); D_{In} = Absorbed dose rate in indoor (nSv/h); D_{Out} = Absorbed dose rate in outdoor (nSv/h); OF_{In} = Indoor occupancy factor (80% for indoor); OF_{out} = Outdoor occupancy factors (20% for outdoor); And CC = Conversion coefficient (0.7 $Sv{\bullet}Gy^{-1}$ for adult); Reported by UNSCEAR to convert absorbed dose in air to the effective dose in human [4].

2. Materials and Methods

2.1 In-Situ gamma-ray dose rate measurement

Real-time gamma-ray dose rate measurement was performed around major nuclear and radiological facilities in Bangladesh through In-Situ technique using a portable radiation monitoring device (GAMMA SCOUT).The Gamma-Scout is a general purpose Geiger counter that measures alpha, beta, gamma and x-ray radiation. It has proven to be useful in the medical, nuclear, mining, metal scrap and foundry industries. It is also used by first responders, police, customs and border control, hobbyists, rock hounds and in personal or home survival kits.The Gamma-Scout is German designed and manufactured, built with a solid Novadur exterior. The Gamma-Scout Geiger counter has a large digital display that can display the radiation detected as dose rate (µSv/hr) or in pulses (total count or per second). There is also an analog logarithmic bar chart to quickly visualize the magnitude of the measured dose rate. 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[26].

2.2 Gamma-ray calibration sources

The GAMMA SCOUT was calibrated using standard sources such as ^{133}Ba, ^{137}Cs and ^{60}Co during manufacturing time. The GAMMA SCOUT was calibrated from Secondary Standard Dosimetry Laboratory under Bangladesh Atomic Energy Commission. The tested device must be within a confidence interval of 5% against a master, which in turn, is adjusted to a gauged reference ^{137}Cs emitter [27].Under environmental radiation, the counter tube is not subject to fatigue and, therefore, will not require re-calibration. However, if the user holds ISO certification, periodical calibration is mandatory [26].

2.3 The Site

The study had been performed over two sites; one is Shahbag Thana under Dhaka city and another is Atomic Energy Research Establishment (AERE) in Savar where major nuclear and radiological facilities were established. These sites are located from E90º23'40.08" to E90º24'32.82" and from N23º44'58.62" to N23º43'26.58" for Shahbag and from E90º16'26.58" to E90º16'50.52" and from N23º57'12.96" to N23º57'6.12" for AERE, Savar. Total thirty four locations (twenty seven in Shahbag Thana and seven in AERE had been monitored to measure outdoor environmental gamma radiation dose rate. These gamma dose rates had been measured for one hour in each location using portable Gamma-Scout detector through in-situ technique from August to November 2017. The field measurement of environmental gamma radiation was based on the assumption that there exist laterally uniform distribution of natural radionuclides in the environment and that the vertical contribution from the soil is limited to the first horizon (10 cm to 30 cm). The detector was set on a tripod at 1m height from the ground level. On the other hand, the latitude and altitude of the site locations had been measured by Global Positioning System (GPS) navigation. Figure 1 indicates all the monitoring points in Shahbag Thana under Dhaka city from where the outdoor environmental gamma dose rates were measured.

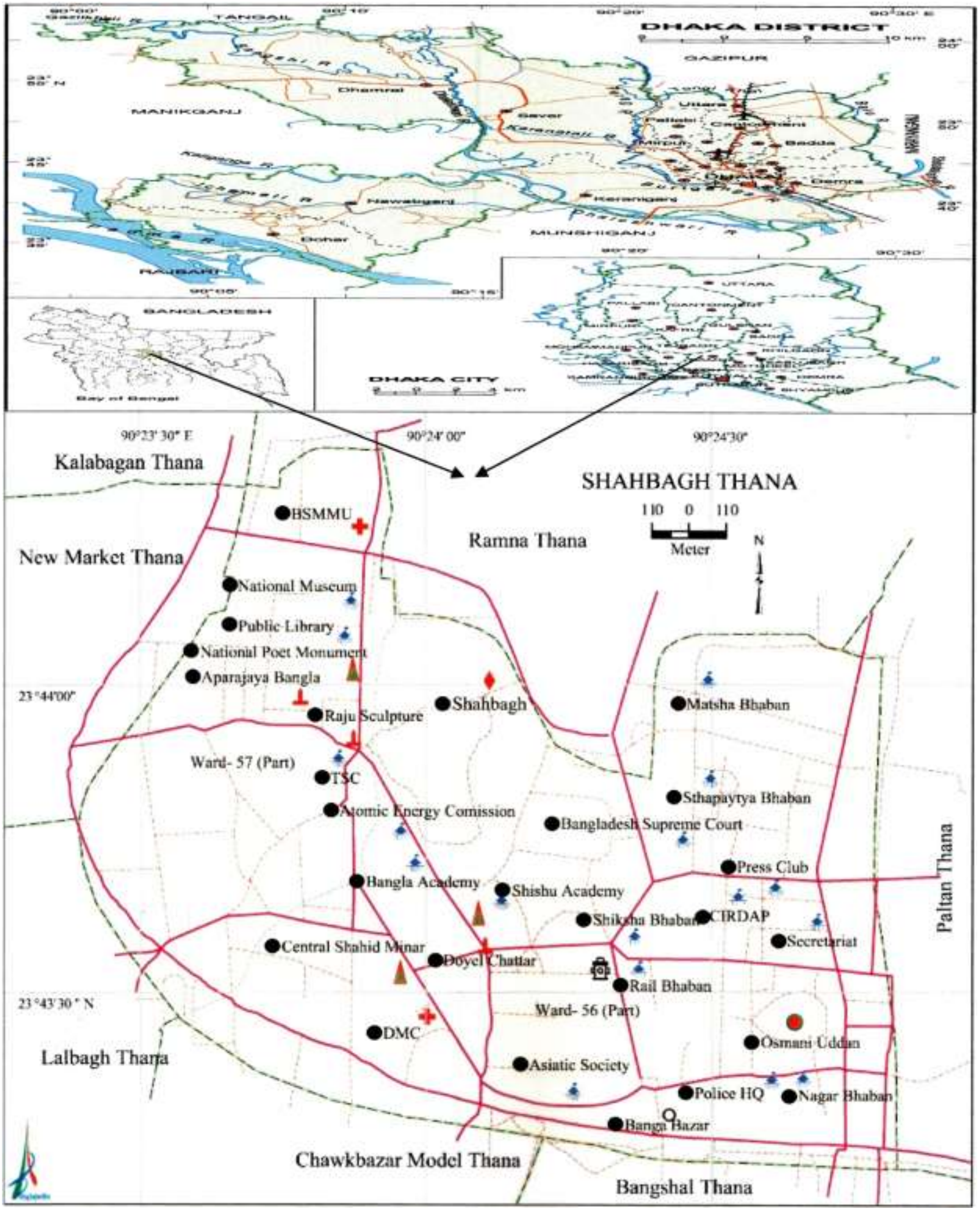

Figure 1: Shows the location (•) in Shahbag Thana under Dhaka city where outdoor environmental gamma radiation measurement was performed using portable Gamma-Scout detector through in-situ technique [27].

3. Results and Discussion

3.1 Absorbed dose rate and annual effective dose

The average gamma radiation dose rate of thirty four monitoring points was found to be 0.141568±0.046995µSv/hr; the minimum dose rate was found to be 0.105±0.036056µSv/hr and the maximum dose rate was found to be 0.208065±0.106377μSv/hr. So the range of the outdoor environmental gamma radiation dose rate in this whole study area was varied from 0.105±0.036056μSv/hr to 0.208065±0.106377μSv/hr with an average of 0.141568±0.046995μSv/hr. Using the conversion factor of 0.7 Sv/Gy as recommended by UNSCEAR 2000 [28] and considering that people in Bangladesh spend approximately 20 % of their time outdoor and remaining 80% of time indoor; the outdoor annual effective gamma radiation dose received by people in Shahbag Thana and AERE Campus has been calculated and the calculated data is given in Table 1. From the table, the average annual effective dose was found to be 0.17362 ± 0.057635 mSv. The minimum annual effective dose was found to be 0.128772 ± 0.044218mSv and the maximum was 0.25517 ± 0.130461mSv. So the outdoor environmental annual effective gamma radiation dose for the whole study area is ranged from 0.128772 ± 0.044218 mSv to 0.25517 ± 0.130461 mSv with an average of 0.17362 ± 0.057635 mSv.

Table 1: Outdoor environmental gamma dose rate and annual effective dose for 34 MPs at Shahbag Thana and AERE Campus at Savar

Monitoring point	**Name of Place**	**Latitude/Altitude**	**Gamma Dose Rate Range (μSv/hr)**	**Mean Gamma Dose Rate with SD (μSv/hr)**	**Annual Mean Effective Gamma Dose with SD (mSv)**
1	BSMMU	N23°44'22.56" E90°23'44.64"	(0.05-0.32)	0.185±0.08226	0.226884±0.100883
2	Shahbag	N23°44'16.14" E90°23'44.7"	(0.07-0.18)	0.125±0.036056	0.1533±0.044218
3	National Museum	N23°44'14.46" E90°23'43.44"	(0.07-0.22)	0.145±0.04761	0.177828±0.058388
4	Public Library	N23°44'11.28" E90°23'40.08"	(0.05-0.45)	0.2080645±0.106377	0.2551703±0.130461
5	National Poet Monument	N23°44'6.12" E90°23'43.38"	(0.05-0.20)	0.125±0.04761	0.1533±0.058388
6	Aparajaya Bangla	N23°44'58.62" E90°23'43.74"	(0.05-0.17)	0.11±0.038944	0.134904±0.047761
7	Raju Sculpture	N23°43'56.16" E90°23'42.6"	(0.07-0.24)	0.155±0.053385	0.190092±0.065472
8	TSC	N23°43'54.96" E90°23'45.96"	(0.05-0.25)	0.15±0.062048	0.18396±0.076096
9	Atomic Energy Commission	N23°43'52.68" E90°23'49.62"	(0.07-0.20)	0.135±0.041833	0.165564±0.051304
10	Bangla Academy	N23°43'49.08" E90°23'52.92"	(0.07-0.19)	0.13±0.038944	0.159432±0.047761
11	DoyelChattar	N23°43'41.4" E90°24'0.12"	(0.07-0.17)	0.12±0.033166	0.147168±0.040675
12	Shishu Academy	N23°43'41.58" E90°24'4.2"	(0.10-0.25)	0.175±0.04761	0.21462±0.058388
13	Bangladesh Supreme Court	N23°43'42.54" E90°24'13.74"	(0.08-0.20)	0.14±0.038944	0.171696±0.047761
14	SikhshaBhaban	N23°43'45.18" E90°24'17.22"	(0.07-0.19)	0.13±0038944	0.159432±0.047761
15	CIRDAP	N23°43'46.32" E90°24'18.3"	(0.07-0.22)	0.14±0.050498	0.171696±0.06193
16	Secretariat	N23°43'43.02" E90°24'25.92"	(0.07-0.23)	0.15±0.050498	0.18396±0.06193

17	Press Club	N23°43'47.16" E90°24'26.64"	(0.04-0.18)	0.11±0.044721	0.134904±0.054846
18	Rail Bhaban	N23°43'40.2" E90°24'21.48"	(0.07-0.17)	0.12±0.033166	0.147168±0.040675
19	OsmaniUddan	N23°43'39.18" E90°24'32.82"	(0.07-0.21)	0.14±0.044721	0.171696±0.054846
20	Police HQ	N23°43'29.16"; E90°24'26.28"	(0.07-0.20)	0.135±0.041833	0.165564±0.051304
21	Nagar Bhaban	N23°43'28.74"; E90°24'31.08"	(0.05-0.16)	0.105±0.036056	0.128772±0.044218
22	MatshaBhaban	N23°44'1.98"; E90°24'14.28"	(0.07-0.19)	0.13±0.038944	0.159432±0.047761
23	SthapaytyaBhaban	N23°43'57"; E90°24'16.62"	(0.08-0.27)	0.175±0.059161	0.21462±0.072555
24	Central ShaheedMinar	N23°43'39.96" E90°23'49.32"	(0.10-0.21)	0.155±0.036056	0.190092±0.044218
25	DMC	N23°43'34.68" E90°23'54.84"	(0.07-0.20)	0.135±0.041833	0.165564±0.051304
26	Bangabzar	N23°43'27.66" E90°24'19.56"	(0.04-0.19)	0.115±0.04761	0.141036±0.058388
27	Asiatic Society	N23°43'26.58" E90°24'9.84"	(0.02-0.23)	0.15±0.057271	0.18396±0.070238
28	Nuclear Medical Physics Institute (NMPI)	N23º57'12.9" E90º16'26.58"	(0.07-0.20)	0.135±0.041833	0.165564±0.051304
29	Centre for Research Reactor (CRR)	N23º57'10.08" E90º16'45.78"	(0.10-0.24)	0.17±0.044721	0.208488±0.054846
30	Radioactive Waste management facility (INST)	N23º57'11.46" E90º16'50.52"	(0.10-0.18)	0.14±0.027386	0.171696±0.033586
31	Radioisotope production facility (INST)	N23º57'10.98" E90º16'48.48"	(0.05-0.18)	0.115±0.041833	0.141036±0.051304
32	Tandem Accelerator facility	N23º57'12.96" E90º16'47.04"	(0.07-0.23)	0.15±0.050498	0.18396±0.06193
33	Institute of radiation and polymer technology (IRPT)	N23º57'6.12" E90º16'38.82"	(0.07-0.16)	0.115±0.030277	0.141036±0.037131
34	Institute of Food and Radiation Biology (IFRB)	N23º57'6.54" E90º16'41.28"	(0.10-0.32)	0.195263±0.065181	0.2394707±0.079938

From Table 1, it is stated that the minimum outdoor environmental gamma radiation dose rate was found in Nagar Bhaban and the measured value was 0.105±0.036056µSv/hr. On the other hand, the maximum outdoor environmental gamma radiation dose rate was found in Public Library and the measured value was 0.208065±0.106377µSv/hr. A wide variation is shown in measurements of gamma dose which is varied from 0.128772 ± 0.044218mSv to 0.25517 ± 0.130461mSv because of the geographical structures, positions and the variation in latitude and altitude of the study area.

It is also indicated that there is a direct relationship between background dose rate and latitude of the region. The minimum annual effective dose was found in Nagar Bhaban, located in south eastern part of Shahbag Thana. This place is located in lower latitude region and 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 [29, 30].

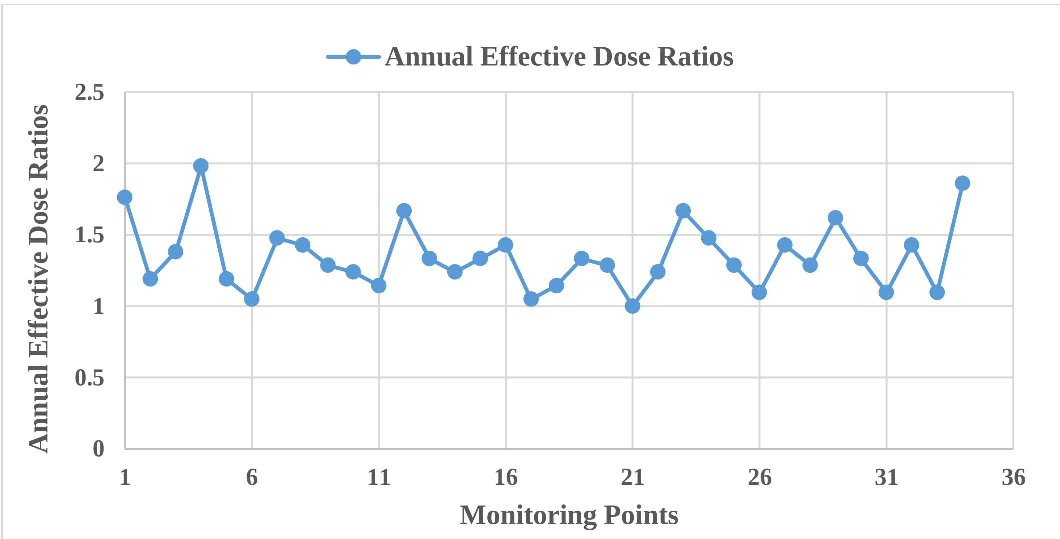

Figure 2: Outdoor annual effective dose values normalized to the minimum annual effective dose for each monitoring point.

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

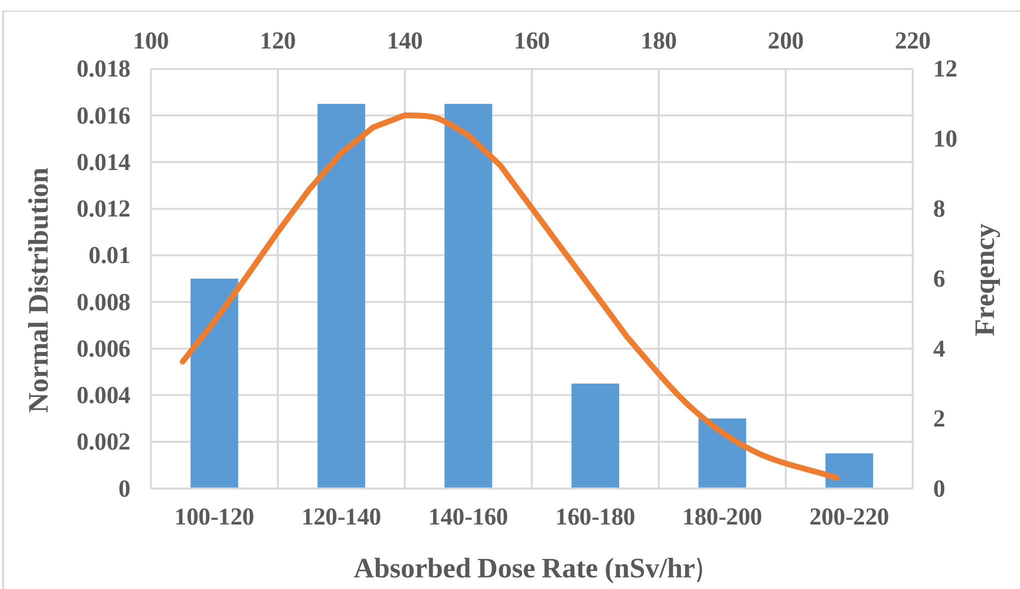

Figure 3: Frequency distribution of the absorbed dose rates (nSv/hr) at monitoring area follow normal distribution.

3.2 Comparison with Other Countries

From Table 2, it is shown that the maximum range of dose rate and annual effective dose, observed in this study, is lower than India, China, Sweden, Italy and Czech Republic; and higher than Canada, Mexico, Indonesia, Korea, Turkey, Finland, Spain and some other countries.

Table 2: Outdoor Environmental Gamma radiation dose rate range and annual effective dose range of Shahbag Thana and AERE Campus, Savar and comparison with other countries [UNSCEAR 2008] [31]

SL No.	Name of Country	Range of Dose Rate (μSv/hr)	Mean Dose Rate (μSv/hr)	Range of Annual Effective Dose (mSv)	Mean Annual Effective Dose (mSv)
1.	Libyan Arab Jamahiriya	0.048 - 0.054	0.051	0.058867 - 0.066226	0.062546
2.	Mauritius	0.08 - 0.126	0.098	0.098112 - 0.154526	0.120187
3.	Tanzania (United Rep. of)	0.098 - 0.121	0.104	0.120187 - 0.148394	0.127546
4.	Canada	0.031 - 0.075	0.054	0.038018 - 0.09198	0.066226
5.	Mexico	0.023 - 0.184	0.0883	0.028207 - 0.225658	0.108291
6.	Costa Rica	0.035 - 0.147	0.0659	0.042924 - 0.180281	0.08082
7.	Cuba	0.038 - 0.196	0.055	0.046603 - 0.240374	0.067452
8.	Azerbaijan	0.075 - 0.205	0.14	0.09198 - 0.251412	0.171696
9.	China	0.0116 - 0.523	0.0815	0.014226 - 0.641407	0.099952
10.	India [32]	0.251 - 0.879	0.4494	0.307826 - 1.078006	0.551144
11.	Indonesia	0.045 - 0.102	0.0675	0.055188 - 0.125093	0.082782
12.	Korea	0.018 - 0.2	0.079	0.022075 - 0.24528	0.096886
13.	Islamic Republic of Iran	0.069 - 0.1876	0.1115	0.084622 - 0.230073	0.136744
14.	Turkey	0.032 - 0.094	0.065	0.039245 - 0.115282	0.079716
15.	Denmark	0.056 - 0.101	0.066	0.068678 - 0.123866	0.080942
16.	Finland	0.077 - 0.171	0.103	0.094433 - 0.209714	0.126319
17.	Lithuania	0.079 - 0.115	0.095	0.096886 - 0.141036	0.116508
18.	Sweden	0.04 - 0.63	0.097	0.049056 - 0.772632	0.118961
19.	Belgium	0.045 - 0.12	0.076	0.055188 - 0.147168	0.093206
20.	Ireland	0.035 - 0.143	0.065	0.042924 - 0.175375	0.079716
21.	Italy	0.057 - 0.243	0.112	0.069905 - 0.298015	0.137357
22.	Spain	0.05 - 0.129	0.085	0.06132 - 0.158206	0.104244
23.	Switzerland	0.053 - 0.155	0.081	0.064999 - 0.190092	0.099338
24.	Bulgaria	0.075 - 0.14	0.1	0.09198 - 0.171696	0.12264
25.	Czech Republic	0.04 - 0.285	0.1	0.049056 - 0.349524	0.12264
26.	Poland	0.051 - 0.1262	0.0809	0.062546 - 0.154772	0.099216
27.	Romania	0.052 - 0.163	0.092	0.063773 - 0.199903	0.112829
28.	Albania	0.0772 - 0.103	0.094	0.094678 - 0.126319	0.115282
29.	Croatia	0.077 - 0.14	0.115	0.094433 - 0.171696	0.141036
30.	New Zealand	0.034 - 0.122	0.076	0.041698 - 0.149621	0.093206

31.	**This Study**	**0.105 - 0.208065**	**0.141568**	**0.128772 - 0.25517**	**0.17362**

In this study, the estimated mean annual effective dose is 0.17362 mSv which 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) is 1 mSv/year [33]. 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 at the area of Shahbag Thana under Dhaka city and Atomic Energy Research Establishment (AERE) Campus, Savar where major nuclear and radiological facilities were established of Bangladesh. The estimated mean annual effective dose of 0.17362 mSv is not expected contribute a statistically significant additional hazard from the radiological health point of view. For comparison purposes, the annual dose limit for members of the public as per ICRP (2011 recommendation) is 1 mSv.y^{-1}. This limit is applicable to practices giving rise to controllable exposure and is not applicable to doses received from natural sources. This type of study is very important for Bangladesh because the usage of radioactive material is increasing day by day in the various fields like medicine, industry and research & education. Moreover, real-time environmental gamma radiation monitoring is crucial to generate the baseline database from natural sources and releasing (if any) from nuclear installations in the country or from neighboring countries in normal operations or in case of accident/incident. This kind of study will also be needed for measurement of environmental radioactivity in and around the Rooppur Nuclear Power Project (RNPP) site area. 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 AERE Campus 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.

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