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Assessment of radiation level and potential risk to public living around major hospitals in central and western Bangladesh

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ABSTRACT

Human beings are continuously bathed in radiation coming from natural and artificial sources. Although the use of radiation in medical applications is beneficial to patients, it also contributes significantly to the health hazard for radiation workers and the public if radiation-generating equipment and radioactive sources are not handled properly. 96% dose contributed from medical uses of ionizing radiation in the US population among man-made sources as per NCRP Report No. 160. There is no extensive study conducted on the large hospitals in Bangladesh following the In-Situ method. We used a real-time digital portable radiation monitor with Garmin eTrex Global Positioning System at 320 monitoring points for radiation monitoring and positioning around the ten largest hospitals in central & western Bangladesh from September to November 2021. The mean radiation dose rates around Bangabandhu Sheikh Mujib Medical University, Dhaka Medical College Hospital, Evercare Hospital, Khulna Medical College Hospital, Mitford Hospital, National Institute of Cancer Research Hospital, Popular Hospital, Rajshahi Medical College Hospital, Shaheed Suhrawardy Medical College Hospital, and Square Hospitals were measured as 0.145 ± 0.012 μSv/h, 0.135 ± 0.009 μSv/h, 0.148 ± 0.008 μSv/h, 0.139 ± 0.01 μSv/h, 0.133 ± 0.007 μSv/h, 0.153 ± 0.011 μSv/h, 0.144 ± 0.012 μSv/h, 0.137 ± 0.008 μSv/h, 0.145 ± 0.01 μSv/h, and 0.153 ± 0.009 μSv/h, respectively. The mean excess lifetime cancer risk (ELCR) of the public who lives nearby the hospital's boundary was estimated at 1.05×10^{-3}, 0.983×10^{-3}, 1.071×10^{-3}, 1.004×10^{-3}, 0.964×10^{-3}, 1.084×10^{-3}, 1.043×10^{-3},0.996×10^{-3}, 1.051×10^{-3} & 1.112×10^{-3} respectively. ELCR in most of the locations around the ten largest hospitals in central & western Bangladesh is higher than the global average value. Radiation monitoring is significant for minimizing the public's radiation risk and keeping hospital environments as radiation-free as possible.

1. Introduction

People are exposed to natural and artificial radiation in a variety of ways, including cosmic rays & terrestrial gamma rays from external radiation exposure, and radon inhalation & ingestion from internal radiation exposure [1–3]. 96% of radiation dose in the US

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public contributed from the medical usage of ionizing radiation alone among all man-made sources as per NCRP Report 160 [4]. Ionizing radiation affects the living cells and damages the genetic material (DNA) & reproductive cells [5–7]. Bangladesh has no nuclear power plant in operation but two units (each 1200 MWe) are now under construction. Ionizing radiation is used in various fields in Bangladesh such as medicine, industry, agriculture, research & education, etc. However, radiation workers & public are mainly exposed to the medical uses of ionizing radiation in Bangladesh. Radiation workers in hospitals are routinely monitored using the thermoluminescent dosimeter (TLD). But there is no extensive study carried out for estimation of the radiological risk to the public who are residing nearby the hospital's boundary. In hospitals, ionizing radiation is extensively used for diagnostic and therapeutic missions such as plain radiography, mammography, fluoroscopy, computed tomography (CT), diagnostic dental radiology, diagnostic medical radiology, nuclear medicine, radiation oncology, etc. Medical exposure is the second-largest source of ionizing radiation for the world's population. It constitutes over 99.9% of all man-made radiation exposure [8–10]. Approximately 377 million diagnostic radiology X-ray examinations are undertaken annually in the United States [11] and approximately 3.6 billion worldwide [12,13]. Among all diagnoses, X-ray examinations and CT scans generate higher radiation doses to workers & public, and 34% of the total dose arose from CT out of all medical exposures [14,15] has increased sharply in recent years. Natural radionuclides account for a greater share of public radiation exposure, and the presence of natural and man-made radioisotopes in the hospital's environment may provide a comparatively higher effective dose to the public. However, although low amounts of ionizing radiation have no immediate health impacts, they can increase the risk of cancer in the future [16,17] because radiation exposure amount is directly related to the duration of exposure through the Stochastic effects [18]. Among ionization radiation, gamma radiation is more dangerous than others by reason of its high penetrating power. It can completely pass through the human body. It creates long-term health effects such as cancer, DNA damage, Cardiovascular disease, Gene mutation, etc. [19–21]. According to recent scientific articles, CT scans and other radiation-related imaging treatments cause thousands of malignancies and cancer deaths per year in the U.S. population [22,23]. Ten large hospitals have routinely used a variety of radioactive materials and different types of radiation-generating equipment for service, treatment, and diagnosis missions. Gamma radiation released from the large hospital is linked to the possibility of developing cancer in the general population. So, it is absolutely essential to calculate the annual effective dose based on dose rate and assess the excess lifetime cancer risk (ELCR) in public around the large hospital campus. In-Situ radiation monitoring in the outdoor environment with a digital portable radiation monitoring device is very reliable and popular around the world because wide-area radiation monitoring is possible in a short time [24–26]. The aim of the study is to monitor the real-time radiation around the ten large hospitals in the central and western regions of Bangladesh through the In-Situ method and evaluate the excess lifetime cancer risk of the public staying a long time for resident and business purposes.

2. Methods

2.1. Study area

Dhaka, the capital city of Bangladesh is the world's sixth most densely populated city, with 10.3 million people and 47,400 people per square kilometer bounded by the Buriganga, Turag, Dhaleshwari, and Shitalakshya rivers [27]. Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka Medical College Hospital (DMCH), Evercare Hospital, National Institute of Cancer Research Hospital (NICRH), Shaheed Suhrawardy Medical College Hospital (ShSMCH), Mitford Hospital, Square Hospital, and Popular Hospital are located in this city. The ranges of these hospitals are given in Table 1.

BSMMU, DMCH, NICRH, ShSMCH, & Mitford Hospital are the largest public hospitals, whereas Evercare Hospital, Square Hospital, & Popular Hospital are the largest private hospitals in Dhaka city. Khulna, Bangladesh's third-largest city, with approximately 1.039 million metropolitan population is located at the junction of the Rupsha and Bhairab rivers [28]. Khulna Medical College Hospital (KMCH) is the largest public hospital located in Khulna City ranging from N22°49.638′ to N22°49.834' & from E089°32.172′ to E089°32.283'. Rajshahi, Bangladesh's fourth-largest city, with approximately 1.0 million metropolitan population is located on the northern side of the Padma River, near the border of Bangladesh and India [28]. Rajshahi Medical College Hospital (RMCH) is the largest public hospital located in Rajshahi City ranging from N24°22.240′ to N24°22.464' & from E088°34.952′ to E088°35.288'. The locations of BSMMU, DMCH, Evercare Hospital, KMCH, NICRH, ShSMCH, Mitford Hospital, Square Hospital, Popular Hospital, and RMCH are shown in Fig. 1. The map is depicted using ArcGIS® software (Version 10.4.1) [29]. A total of 320 MPs were selected for dose rate monitoring around the ten large hospital campuses in Bangladesh's central and western parts.

Table 1
Monitored Dhaka city Hospital's range.

Hospital	Latitude Range	Altitude Range
BSMMU	N23°44.336' - N23°44.479′	E090°23.625' - E090°23.786′
DMCH	N23°43.434' - N23°43.660′	E090°24.019' - E090°24.670′
NICRH	N23°46.483' - N23°46.766′	E090°24.556' - E090°24.666′
ShSMCH	N23°46.074' - N23°46.217′	E090°22.134' - E090°22.375′
MITFORD	N23°42.614' - N23°42.745′	E090°23.975' - E090°24.081′
EVERCARE	N23°48.541' - N23°48.671′	E090°25.829' - E090°25.991′
SQUARE	N23°45.118' - N23°45.225′	E090°22.816' - E090°22.982′
POPULAR	N23°44.312' - N23°44.376′	E090°22.848' - E090°22.994′

2.2. Apparatus description

For the present study, real-time radiation was measured using a portable digital radiation monitor. It is a perfect Geiger counter created and produced in Germany by GmbH Co. & KG. The device complies with all European CE standards, including part 15 of the USA FCC rules. All units provide a successive test certificate for device safety that is tested by TÜV (German Technical Control Board) and a 2-year product guarantee. A stylish tight leather holster belt was used to protect this device. The device has real-time dose rate & cumulative dose display functions, multiple unit converter, battery indicator, and configurable recording & warning functions. Its

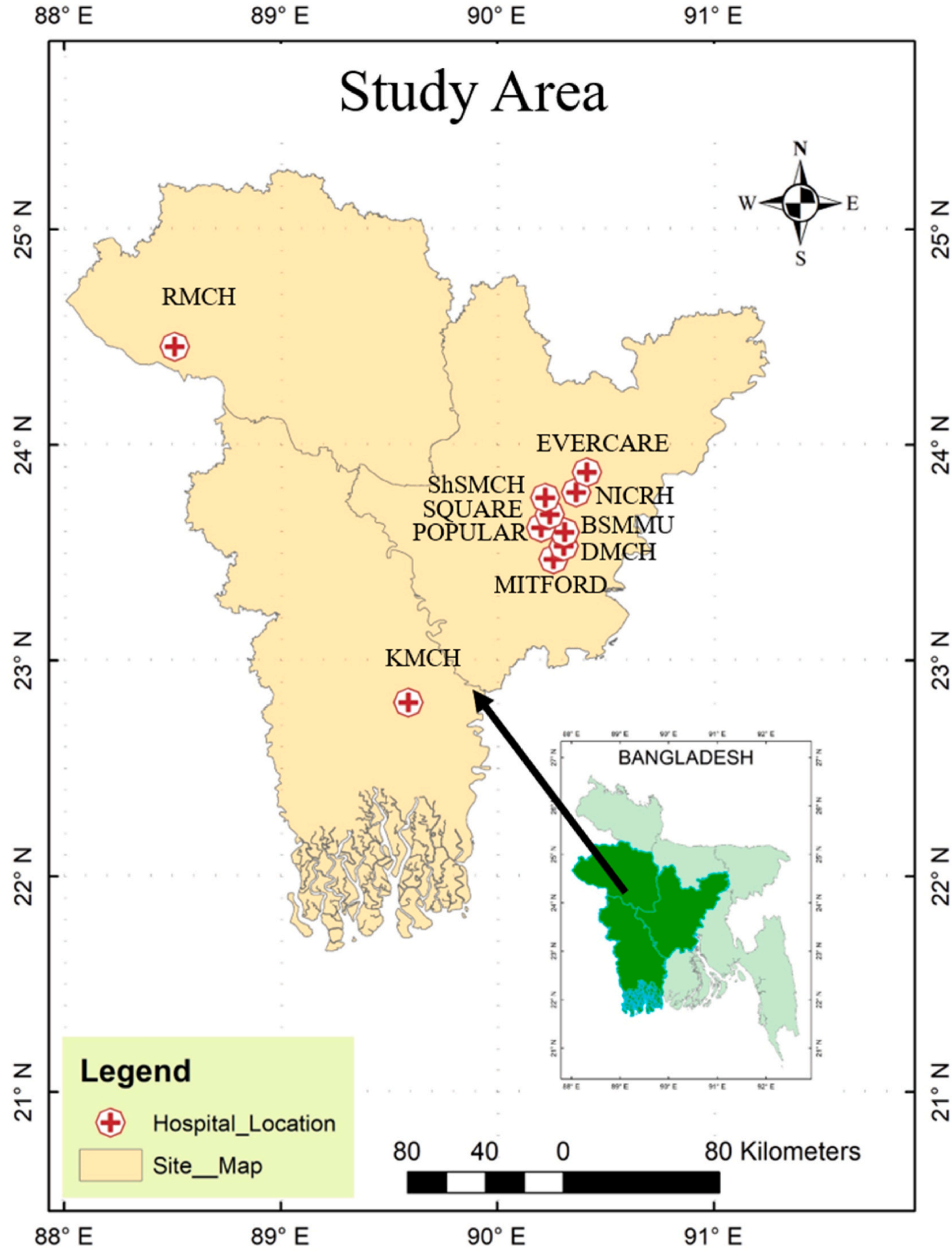

Fig. 1. Location map of the hospital is depicted using ArcGIS® software.

amazing features include a USB connector for data transfer to a computer and an ultra-low-power circuit to extend its battery life. It properly detects radiation rates between 0.01 and 5000 μSv/h [30].

A GARMIN eTrex HC series personal navigation device was used to identify the monitoring points. The device combines the well-proven & reliable performance of Garmin's high-sensitivity GPS with accurate mapping to provide the best transportable GPS receiver [31].

2.3. Calibration

The radiation monitoring device was pre-calibrated by the producer. Bangladesh Atomic Energy Commission's (BAEC's) Secondary Standard Dosimetry Laboratory (SSDL) also calibrated it using standard radiation sources. Standard sources such as ^{137}Cs, ^{60}Co, etc, and X-ray Units, are accessible at the BAEC's SSDL. BAEC's SSDL has been active since 1991, and it is traceable to the National Physical Laboratory's Primary Standard Dosimetry Laboratory in the United Kingdom. SSDL has an X-ray unit (30 kV–225 kV) for calibrating radiation generators. SSDL has routinely maintained performance with the standards of the International Atomic Energy Agency (IAEA) and World Health Organization (WHO) network. So, the dosages analyzed are traced back to the international measuring standard.

2.4. Dose rate measurement technique

Radiation monitoring was performed using the In-situ method from September to November 2021. The radiation monitoring device and the GARMIN eTrex GPS tracker were mounted on a twin-headed tripod 1 m above the ground. Each monitoring point's dose rate collection time was 1 h. *Thirty-two* MPs for each campus were chosen for gamma-ray dose rate collection around the ten large hospitals in the central and western regions of Bangladesh. Unidentical 10 to 45 dose rates were collected from each MP.

2.5. Calculation of annual effective dose

The effective dose was computed by multiplying the absorbed dose rate with the occupancy factor. The occupancy factor is the percentage of time a person spends in a certain location. UNSCEAR reported that a person spends 20% of the time outdoors and the remaining 80% at an indoor location. So, the occupancy factor for outdoor locations (OF_{out}) is 0.2 [6,32,33]. Therefore, the annual effective dose (AED) is given as follows:

$$\text{AED} = \text{Dose rate} \times \text{OF}_{\text{out}} \times \text{T} = \text{Dose rate } (\text{mSv} / \text{h}) \times 0.2 \times (24 \times 365) \text{ (h)} = \text{Dose rate} \times 1752 \text{ (mSv)} \quad (1)$$

2.6. Excess life-time cancer risk estimation

Excess life-time cancer risk (ELCR) was calculated using the following equation based on the annual effective dose:

$$\text{ELCR} = \text{AED} \times \text{RF} \times \text{LE} \quad (2)$$

LE, the life expectancy of Bangladeshi people is 72.59 years [34]. International Commission on Radiological Protection's (ICRP) suggested risk factor (RF) is 0.057 Sv^{-1} and Biological Effect on Ionizing Radiation's (BEIR) suggested risk factor (RF) is 0.064 Sv^{-1} [35–37].

3. Results

The range of real-time dose rates around the ten large hospitals in the central and western regions of Bangladesh varied from 0.012 to 0.355 μSv/hr. The range of annual effective doses around the ten large hospitals in the central and western regions of Bangladesh

Table 2
Measured dose rate & annual effective dose around ten large hospitals in the central and western regions of Bangladesh.

Hospital	Dose Rate (μSv/hr)		Annual Effective Dose (mSv)	
	Range	Mean	Range	Mean
BSMMU	0.049–0.288	0.145 ± 0.0121	0.082–0.505	0.254 ± 0.0212
DMCH	0.012–0.355	0.135 ± 0.0093	0.021–0.622	0.238 ± 0.0162
EVERCARE	0.056–0.226	0.148 ± 0.008	0.098–0.396	0.259 ± 0.014
KMCH	0.049–0.304	0.139 ± 0.0098	0.086–0.533	0.243 ± 0.0174
MITFORD	0.089–0.226	0.133 ± 0.007	0.156–0.466	0.233 ± 0.0122
NICRH	0.049–0.252	0.153 ± 0.0114	0.086–0.442	0.262 ± 0.02
POPULAR	0.049–0.259	0.144 ± 0.0115	0.086–0.454	0.252 ± 0.0201
RMCH	0.049–0.278	0.137 ± 0.0081	0.086–0.487	0.241 ± 0.0143
ShSMCH	0.025–0.252	0.145 ± 0.0101	0.044–0.441	0.252 ± 0.0177
SQUARE	0.094–0.252	0.153 ± 0.0087	0.164–0.441	0.269 ± 0.0153

varied from 0.021 to 0.622 mSv. Table 2 describes the measured dose rate range, calculated annual effective dose range & its mean value under the present study.

The frequency distribution of radiation dose rates around ten major hospitals is shown in Fig. 2.

It can be seen from Fig. 2 that the highest frequency lies between 136 and 150 nSv/h absorbed dose rate region caused by mean background radiation. From the previous study, the background radiation due to natural radionuclides of Motijheel & Ramna thana, the heart of Dhaka city, ranged from 0.095 to 0.185 μSv/h (mean: 0.147 ± 0.047 μSv/h) & from 0.115 to 0.186 μSv/h (mean: 0.145 ± 0.044 μSv/h) [38,39]. The mean dose rate around the hospital's environment is shown in Fig. 3.

It is clearly seen from Fig. 3 that among ten large hospitals, the highest average dose rate was obtained from NICRH & Square Hospital's environment. NICRH is the only National Cancer Research Institute dedicated to cancer patient management, education & research, and Square Hospital is the second largest private hospital. The reason behind this is possibly geographical characteristics of the location, improper manipulation of shielding material, and quantity usage of artificial radionuclides & radiation-generating equipment. The lowest value was obtained from the Mitford Hospital's environment. The annual effective dose of monitoring points 3 & 27 for BSMMU, 10 for DMCH, 10 & 16 for ShSMCH, 13 for Square, 10 for NICRH, 8, 10 & 15 for RMCH, 19 for Popular, 15 & 21 for Mitford, 2 for Evercare are comparatively higher than others because these monitoring points are situated near the radioactive waste storage rooms, radioactive substance handling rooms, and radiation generating equipment rooms. The remaining monitoring points' ratios are also likely similar because of the geological aspect of the location and distance from the radioactive sources. It is because the radiation intensity is inversely related to distance square [40,41]. ICRP, 2007 reported that the mean effective dose for the public worldwide is 0.48 mSv [42,43]. Calculated annual effective doses in several locations are higher than that value and all data are below the acceptable limit of 1 mSv for the public [44,45]. Table 3 recounts the estimated ELCR on public according to ICRP & BEIR recommended guidelines.

4. Discussion

The dose rates around the ten large hospitals in the central and western regions of Bangladesh are higher than that of the green field, because of radiation coming from the hospitals. The real-time radiation dose rates around the ten large hospitals in Bangladesh were higher than that of Nigeria, India, and Switzerland (Table 4). The higher radiation dose rates were found around the ten large hospitals in Bangladesh due to a number of reasons: (1) healthcare workers of Bangladesh do not have sufficient knowledge regarding radiation protection and safety; (2) lack of modern radiation-generating equipment; (3) a few numbers of large hospitals have heavy workload because Bangladesh is the eighth-most populated country in the world with a density of 23,234 people per square kilometer in Dhaka; (4) many private diagnostic centers were constructed around the large hospitals with lack of safety measures; and (5) insufficient quality control (QC), quality assurance (QA) of the radiation generating equipment due to the absence of qualified medical physicist. Evercare and Square are the largest and busiest private hospitals in the capital city. These two private hospital campuses are smaller than those of the largest government hospitals. For example, if one of the hospital campus areas is double compared to others, in that case, the radiation dose rate outside of the large hospital campus area (double) would be one-fourth (1/4) as radiation follows inverse square law. For that reason, mean dose rates around the two largest and busiest private hospital campuses are higher than those of the other largest government hospitals except the NICRH (Table 2). The NICRH is the largest and busiest government cancer hospital in the country locating the heart of Dhaka city. The NICRH uses a conventional Cobalt-60 (Co-60) teletherapy machine for cancer patient treatment. The two high energies gamma-rays (1173 keV & 1332 keV) emit from the Co-60 teletherapy machine. High energies gamma-rays easily travel many kilometers distances beyond the large hospital campus area. That is why, the mean dose rate around the NICRH is the highest among the largest and busiest government & private hospitals of the central and western regions of Bangladesh. The dose rates at locations around the large hospitals were recorded high when a maximum number of radiations generating equipment were in "on state" conditions. The time for the diagnosis to the patient using CT scans is much higher than that of the X-rays. For that reason, the dose rates at locations nearby to the CT scan rooms were also recorded as high compared to the X-ray machine rooms. Ten hospitals (Table 2) also have nuclear medicine departments where different types of radioactive substances are

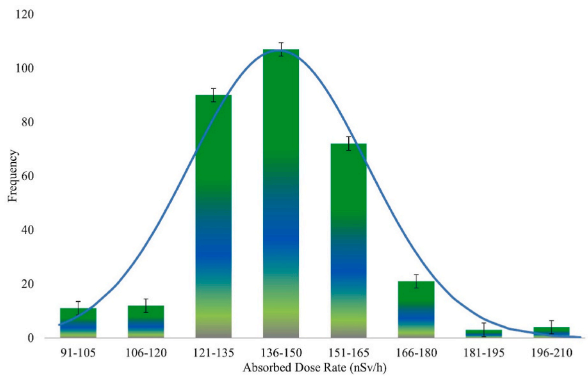

Fig. 2. Frequency distribution curve for radiation dose rate.

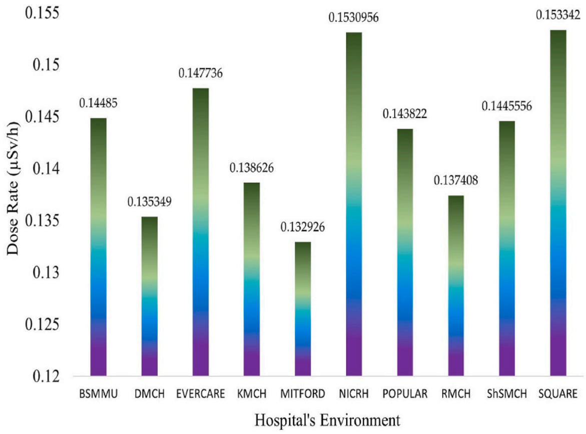

Fig. 3. Average dose rate around hospitals.

Table 3
Estimated ELCR based on ICRP & BEIR recommendations.

Hospital	ICRP ELCR		BEIR ELCR	
	Range	Mean	Range	Mean
BSMMU	3.55×10^{-4}-2.09×10^{-3}	1.05×10^{-3}	3.99×10^{-4}-2.34×10^{-3}	1.18×10^{-3}
DMCH	8.70×10^{-5}-2.57×10^{-3}	9.83×10^{-4}	9.77×10^{-5}-2.89×10^{-3}	1.10×10^{-3}
EVERCARE	4.06×10^{-4}-1.64×10^{-3}	1.07×10^{-3}	4.56×10^{-4}-1.84×10^{-3}	1.20×10^{-3}
KMCH	3.55×10^{-4}-2.20×10^{-3}	1.00×10^{-3}	3.99×10^{-5}-2.47×10^{-3}	1.12×10^{-3}
MITFORD	6.45×10^{-4}-1.93×10^{-3}	9.64×10^{-4}	7.24×10^{-4}-2.17×10^{-3}	1.08×10^{-3}
NICRH	3.55×10^{-4}-1.83×10^{-3}	1.08×10^{-3}	3.99×10^{-4}-2.05×10^{-3}	1.22×10^{-3}
POPULAR	3.55×10^{-4}-1.88×10^{-3}	1.04×10^{-3}	3.99×10^{-4}-2.11×10^{-3}	1.17×10^{-3}
RMCH	3.55×10^{-4}-2.01×10^{-3}	9.96×10^{-4}	3.99×10^{-4}-2.26×10^{-3}	1.12×10^{-3}
ShSMCH	0.181×10^{-3}-1.83×10^{-3}	1.05×10^{-3}	0.203×10^{-3}-2.05×10^{-3}	1.18×10^{-3}
SQUARE	0.681×10^{-3}-1.83×10^{-3}	1.11×10^{-3}	0.765×10^{-3}-2.05×10^{-3}	1.25×10^{-3}

Most of those values from the present study are higher than the worldwide average value of 0.29×10^{-3} and the recommended limit of 1.45×10^{-3} [46].

Table 4
Comparison of present study with others performed outside Bangladesh.

Name of Institution/ Location	Country	Absorbed Dose Rate Range (µSv/h)	Mean Dose Rate (µSv/h)	Annual Effective Dose (mSv)	Mean Annual Effective Dose (mSv)	Reference
Ijebu-Ife, Ogun State	Nigeria	0.02–0.10	0.05	0.07–0.350	0.182	[47]
Kashmir	India	0.042–0.127	0.08	0.07–0.22	0.140	[48]
Jammu		0.048–0.110	0.073	0.08–0.19	0.130	
Ladakh		0.056–0.257	0.113	0.10–0.45	0.190	
Gahkuch Ghizer Valley	Pakistan	0.132–0.189	0.154	0.3–0.5	0.4	[49]
Abu Rusheid	Egypt	0.175–0.84	0.518	0.31–1.47	0.9	[50]
Um Naggat		0.137–0.574	0.30	0.24–1.01	0.5	
Nationwide Survey	Switzerland	0.052–0.146	0.085	0.091–0.256	0.15	[51]
-	Worldwide Average	–	0.274	0.3–0.6	0.48	[3], [41], [42]
Central and western region	Bangladesh	0.133–0.153	0.143	0.021–0.622	0.250	Present study

being used for the diagnosis and treatment of patients. Proper management of the radioactive substances in the nuclear medicine departments is very important for minimization of the radiation dose rates in and around the hospital campus. It is observed that radioactive substances were not handled properly in the nuclear medicine departments due to a lack of qualified medical physicists. Deficiencies of shielding arrangements were detected in the rooms where radioactive substances were dispensed, storage, handling, etc. Hospital authorities have to get the license for operation of the radiation generating equipment and radioactive substances in

Bangladesh from the Bangladesh Atomic Energy Regulatory Authority (BAERA) as per the Nuclear Safety and Radiation Control (NSRC) Rules-1997. BAERA gives a license for one year after sending inspectors to the hospital and every year license to be renewed based on inspector reports. However, BAERA could not send inspectors to the hospitals for providing recommendations related to radiation protection due to the shortage of inspectors. This is the first extensive study of the largest central and western regions of Bangladesh. Therefore, the study would aware the public who are residing nearby large hospitals.

5. Conclusion

Bangladesh is a small country in the world (ranked 94th) and the most populated country in the world (ranked 8th). So, many people reside adjacent to the large hospitals where different kinds of radiation-generating equipment and radioactive substances are being used for the diagnosis and treatment of patients. The radiation dose rates around the ten large hospitals in the central and western regions of Bangladesh are higher than that of the green field. The annual effective dose ranged from 0.021 mSv to 0.622 mSv around ten major hospitals in central and western Bangladesh. Several calculated data are higher but the mean values in all monitoring points are lower than the worldwide average value. So, there is no acute radiation threat, and the radiation dose present around those hospitals is not incredibly harmful to public health. But if the radiation dose rises, it will be a warning sign. ELCR on public based on ICRP recommendations varied from 8.70×10^{-5} to 2.57×10^{-3}. The estimated average ELCR is more than three times higher than the worldwide average value. The present study shows that out of every thousand people, one is at risk of cancer from hospital-scattered radiation without any knowledge of ionizing radiation exposure. Further studies will be required for a better explanation of recorded high dose rates and to take necessary steps to protect against leakage radiation from the hospital for minimizing the radiation risk to public health and keeping the hospital environment free from radiation hazards.

Author contribution statement

Md. Mostafizur Rahman: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Mohammad Sohelur Rahman: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Md. Harunor Rashid Khan: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data. Selina Yeasmin: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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