Assessment of Radiation Hazard on Public Health at Indoor and Outdoor Environment of DMCH Campus, Dhaka, Bangladesh

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Abstract

Objectives: The purpose of the study is to evaluate the excess life-time cancer risk (ELCR) of public in & around the Dhaka Medical College Hospital (DMCH) campus based on the real-time radiation monitoring data.

Method: A real-time digital portable radiation monitoring device (GAMMA SCOUT) along with a Garmin eTrex Global Positioning System (GPS) device was used for radiation monitoring and location identification respectively. ArcGIS® software (Version 2.3) was used for mapping of the locations.

Result: The measured dose rate in the indoor environment ranged from 0.05-71.21 μSv/hr with an average of 12.709 ± 0.624 μSv/hr and in the outdoor environment ranged from 0.02-0.58 μSv/hr with an average of 0.174 ± 0.038 μSv/hr of the DMCH campus. The annual effective dose in the indoor environment ranged from 84.552- 93.52 mSv with an average of 89.064 ± 47.730 mSv and in the outdoor environment, the value ranged from 0.21-0.43 mSv with an average of 0.306 ± 0.105 mSv. ELCR from indoor gamma radiation ranged from $333×10^{-3}$ - $368 ×10^{-3}$ with an average of $3×10^{-1}$ and in the outdoor, it ranged from $8.377×10^{-4}$ -$1.829×10^{-3}$ with an average value of $1×10^{-3}$ for 32 selected locations in & around DMCH campus.

Conclusion: This type of study is required to minimize the public health risk associated with ionizing radiation. This study also helps for the protection of the environment and the public from unnecessary radiation hazard arising from DMCH.

Keywords

In-Situ, Radiation, Hospital, Environment, ELCR.

INTRODUCTION

Dhaka Medical College Hospital (DMCH) is the oldest and the largest Medical College Hospital in Bangladesh. Ionizing radiation is being used in the hospital for diagnostic and therapeutic procedures of patients worldwide. Ionizing radiation occupies sufficient energy to affect the atoms in living cells and damage the genetic material DNA (US Environmental Protection Agency, 2019). The Absorbed dose of radiation for general population generates from different sources including background

radiation but medical practices such as X-rays, CT scans, nuclear medicine and mammograms, etc. contribute a larger part in this exposure. Different medical tests and treatments use such kind of ionizing radiation at a range of 30% to 50% and are consequently increasing day by day (Sani et al., 2009). Though exposure to low-levels of ionizing radiation does not cause immediate health effects, it increases the risk of cancer over a life-time.

The effects of Radiation on a biological system or ecosystem during an acute, intermediate, or chronic duration of exposure depending on the radiation dose and several variables. Such as, for airborne radioactivity, it includes physical form (gas versus particle), particle solubility and its size, type of radiation (alpha, beta, gamma, or combinations), and the energy of the radiation.

For oral and dermal exposure, toxicity due to radiation related activities is largely influenced by the solubility, metabolism within the body, and the type and energies of the radiation (Agency for Toxic Substances and Disease Registry, 2019). The annual dose limit of radiation for general public and radiation worker are 1mSv and 20 mSv respectively over 5 consecutive years (International Commission for Radiological Protection, 2012).

Crossing this annual dose limit can lead to chronic and acute effects of radiation. Gamma dose rates in various conditions have been characterized both in outdoor and indoor environments due to natural and anthropogenic sources through various international studies (Al-Ghorabie, 2005; Rybach et al., 2002; Sagnatchi et al., 2008; Tavakoli, 2003). But typically, it can be measured under laboratory condition or using In-Situ gamma spectroscopy (Othman and Yassine, 1994).

As radiation exposure from medical sources is increasing day by day (UNSCEAR, 2000), it is necessary to monitor the real-time radiation in & around the large hospital and consequently assess the radiation hazard in both indoor and outdoor environment for the protection of the public as well as the environment. The aim of the present study is to monitor the real-time radiation in & around the DMCH campus in Dhaka city and to evaluate the excess life-time cancer risk (ELCR) of public who are residing nearby DMCH campus.

MATERIALS AND METHODS

Site Description

Dhaka is the capital of Bangladesh and a large number of people visit at DMCH along with the patients daily. Patients diagnosis and treatment use ionizing radiation in hospital and public may get radiation from hospital if radiation safety guidelines are not properly followed by the medical doctors, Medical Physicists, Radiographers, Technician, Nurse, etc. And notably radiation from its surrounding such as Bangabandhu Sheikh Mujib Medical University Hospital and BIRDEM Hospital significantly contributes to add a new dimension of radiation hazard from medical sources in Bangladesh perspective (Faria Hassan et al., 2020).

To mark out the study location, GARMIN eTrex HC series GPS meter (Tzortzis et al., 2003) was used as a personal navigator. Basically it occupies a   very high-sensitivity and high-performance GPS meter and shows full-featured map of the study area .The study area was located from   E 090°22.716' to E090°24.039' and   from   N23°43.550'   to N 23°43.704' .Thirty two locations were selected for monitoring gamma radiation dose rates at indoor and outdoor environment around the DMCH campus. DMCH campus occupies an area of 25 acres with the surroundings of University of Dhaka and Bangladesh University of Engineering and Technology.

The Radiotherapy Department of DMCH marked as a source of radiation exposure is located just north side entrancing the main gate of the outdoor department. Real-time radiation monitoring were performed 28 locations around DMCH campus and 04 indoor locations such as Corridor of Radiotherapy Department and its patients waiting room, X-ray room, Corridor of Department of Radiology and Imaging.

APPARATUS DESCRIPTION

GAMMA SCOUT (User Manual, GAMMA SCOUT, 2014) basically a real-time digital portable radiation monitoring device was successfully used for this study. It is German designed and manufactured with a solid Novadur exterior fitted as an ergonomic shape. A leather body which is totally optional with a tight fitted belt strap has been used as a protector for this device.

This fully featured Geiger counter meets both European CE standards and US FCC 15 where all units come with 2-year manufacturer's warranty and a serialized test certificate (User Manual GAMMA SCOUT, 2014).The unit provides also some facilities with a multiple unit converter, battery indicator, real-time dose rate and cumulative dose display functions and programmable logging and alert functions. It can connect with PC via USB cable for data download and occupies an ultra-low current power circuit for extended battery life of this device.

Mapping

Real-time radiation monitoring locations mapping was created using ArcGIS® software (Version 2.3) (Law and Collins, 2015) which is shown in Fig. 1. ArcGIS Pro is the intellectual property of ESRI and used herein under license. All real-time radiation monitoring locations (Both indoor and outdoor environment) are located within the surroundings of DMCH campus.
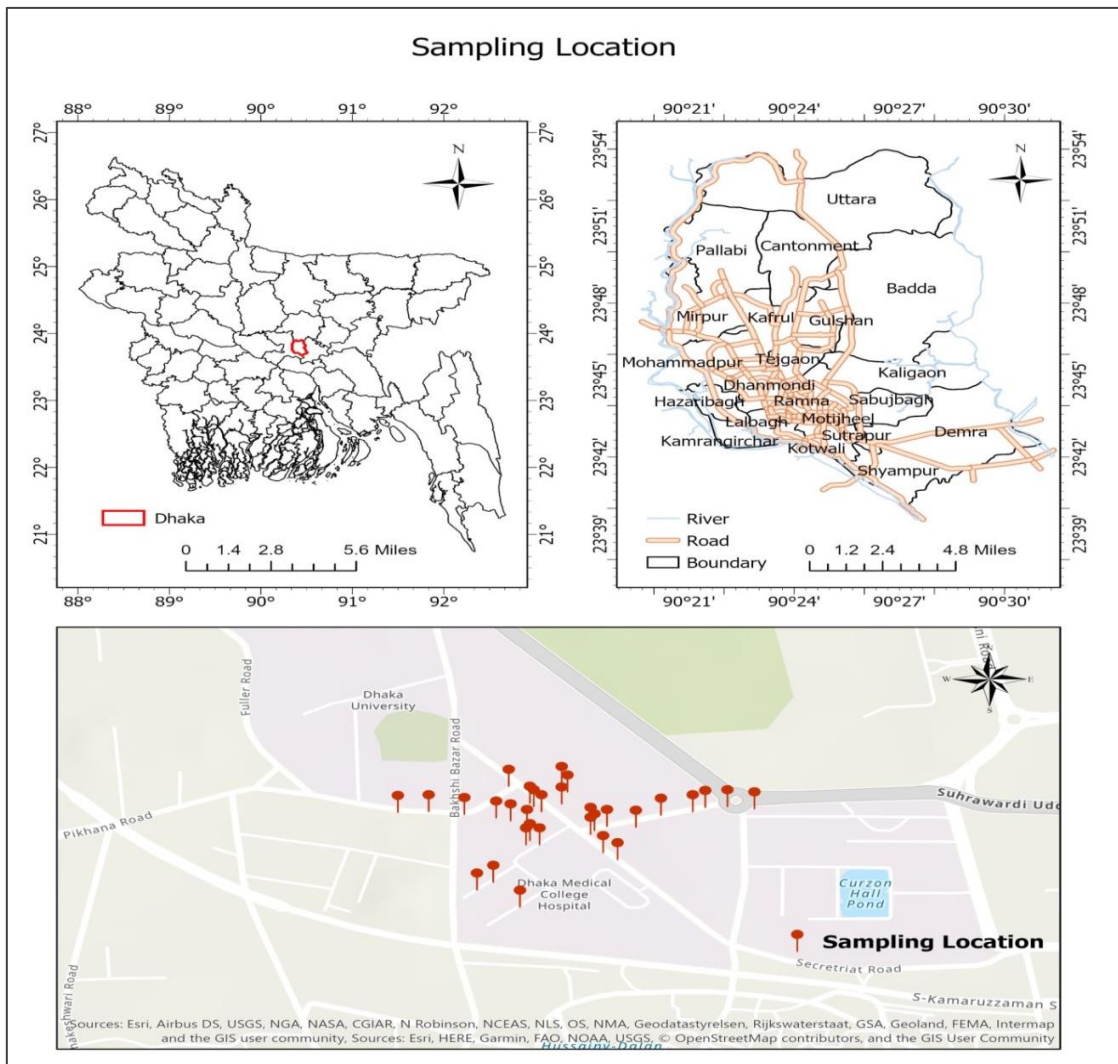
Fig. 1: Location mapping of the real-time radiation monitoring using ArcGIS® software around DMCH campus.

Calibration

The hand held real-time digital gamma radiation monitoring device (GAMMA SCOUT) was calibrated inbuilt by the manufacturer. It was also calibrated using the standard radiation sources at the Secondary Standard Dosimetry Laboratory (SSDL) of Bangladesh Atomic Energy Commission (BAEC). Standard sources such as ^{137}Cs, ^{60}Co, etc. and X-ray Unit available at SSDL of BAEC.

The SSDL of BAEC has been available since 1991, which is traceable to the Primary Standard Dosimetry Laboratory (PSDL) of National Physical Laboratory (NPL), UK. The SSDL of BAEC has X-ray Unit (30 kV-225 kV) for radiation generating equipments calibration.

The performance of BAEC's SSDL is maintained according to the requirements of the International Atomic Energy Agency (IAEA)/World Health Organization (WHO) network of SSDLs. Therefore, the evaluated doses are traceable to the International measurement system. The GAMMA SCOUT accurately measures dose rate in the range of 0.01-5000 μSv/hr (User Manual-GAMMA SCOUT, 2014).

Data taking process and calculation formula

Indoor and outdoor real-time radiation monitoring of the DMCH campus were performed from September-October 2019 using GAMMA SCOUT. The GAMMA SCOUT was placed at 1 m above the ground on tripod and the time for data acquisition in each monitoring point (MP) was 1 h (Mian S. et al., 2019; Wilson, 1994).

Fig. 1 shows the location of DMCH campus and its surroundings where indoor and outdoor environmental gamma radiation was monitored successfully by GAMMA SCOUT under the condition of In-Situ Method. Global Positioning System (GPS) navigation was used for site details and to locate monitoring points.

The study location was marked out using GARMIN eTrex HC series personal navigator. The unit uses the proven performance of Garmin high-sensitivity GPS and full-featured mapping to create an unsurpassed portable GPS receiver (Owner's Manual-GARMIN eTrex HC Series, 2007).

Total 32 monitoring points (MPs) were selected for real-time radiation monitoring data collection in the both indoor and outdoor environment around DMCH campus as shown in Fig. 1. Site details and MPs were fully marked out using Global Positioning System (GPS) navigation noted in the Table 1.

As recommended in international report and paper (UNSCEAR Report, 1988; Arogunjo et al., 2003) the indoor and outdoor occupancy factor of 0.80 and 0.20 respectively for population. Basically, this occupancy factor is direct proportion to the total time during which an individual is exposed to a radiation field whether it is indoor or outdoor.

So, the indoor and outdoor annual effective dose to population due to radiation can be calculated according to the following equations (Sadiq and Agba, 2012; Jibiri and Obarhua, 2013).

For indoor calculation,
Annual Effective Dose (μSv)= dose rate (μSv.h^{-1}) $\times$ 0.8 $\times$ 8760 h. yr^{-1} (1)

For outdoor calculation,
Annual Effective Dose (μSv)= dose rate (μSv.h^{-1}) $\times$ 0.2 $\times$ 8760 h. yr^{-1} (2)

ELCR Calculation:
The term ELCR is defined as the probability that an individual will develop cancer over his life-time of exposure to radiation.

$$ELCR = AED \times DL \times RF \qquad\qquad (3)$$

Where,

DL refers to the average duration of life in Bangladeshi people (http://en.worldstat.info/Asia/Bangladesh, 2019) and RF refers to risk factor (Sv−1), indicating the fatal cancer risk expressed in per Sievert.

AED is Annual Effective Dose of public. For stochastic effects due to low dose background radiation, ICRP 103 suggested the value is 0.05 Sv or 0.000057 mSv for the public exposure (ICRP, 2007).

RESULTS AND DISCUSSION

The measured dose rate in the indoor environment ranged from 0.05-71.21 µSv/hr with an average of 12.709 ± 0.624 µSv/hr and in the outdoor environment ranged from 0.02-0.58 µSv/hr with an average of 0.174 ± 0.038 µSv/hr of the DMCH campus.

The annual effective dose in the indoor environment ranged from 84.552- 93.52 mSv with an average of 89.064 ± 47.730 mSv and in the outdoor environment, the value ranged from 0.21-0.43 mSv with an average of 0.306 ± 0.105 mSv.

ELCR from indoor gamma radiation ranged from 333×10^{-3} - 368×10^{-3} with an average of 3×10^{-1} and in the outdoor, it ranged from 8.377×10^{-4} -1.829×10^{-3} with an average value of 1×10^{-3} for 32 selected locations in & around DMCH campus.

Real-time radiation monitoring is required to minimize the radiation hazard on public health and the surrounding environment in & around the hospital campus. Real-time radiation monitoring also important to ensure the protection of the radiation workers, patients and the general public from undue radiation arising from the diagnostic and therapeutic procedures of patients in the hospitals.

This type of study is crucial for calculation of appropriate amount of shielding of the radiation generating equipments as well as requirement of the personal protective equipments of the radiation workers and detection of the radiation generating equipments malfunction. Table-1 shows radiation dose rate monitoring at indoor locations of DMCH campus from September-October, 2019.

MP No.	Latitude/ Longitude	Location	Radiation dose rate (µSv/hr)			Annual effective dose due to radiation (mSv) ± SD
			Range	Mean	SD	
1	N23°43.578' E090°22.716'	X-ray room, Dept of Radiology	0.05-71.21	13.345	27.086	93.525 ± 189.816
2	N23°43.617' E090°23.816'	Corridor of Dept of Radiology and Imaging	12.00-12.13	12.065	0.042	84.552 ± 0.293
3	N23°43.675' E090°23.839'	Corridor of Radiotherapy Department	12.20-12.39	12.295	0.059	86.163 ± 0.415
4	N23°43.643' E090°23.803'	Radiotherapy Department	13.04-13.22	13.13	0.056	92.015 ± 0.394

Table. 1: Radiation dose rate monitoring at indoor locations of the DMCH campus from September-October, 2019.

The annual effective dose of the indoor environment of the selected locations were calculated which varied from 84.552±0.293 mSv to 93.525±189.816 mSv.

The mean annual effective dose was found to be 89.064 ± 47.730 mSv. In Table 1, it may be mentioned here that the radiation dose rate and consequently the calculated annual effective dose are very high, because radiation data was taken when the radiation generating equipments was on conditions. The average annual effective dose limit for radiation worker for 5 consecutive years is 20 mSv (ICRP, 2007).

Therefore, medical staff (Medical doctors, Physicists, Radiographers, Technician, Nurses, etc.) have to wear personal protective equipments (PPEs) during their daily office working time in order to minimize their annual effective dose while working with radioactive sources and radiation generating equipments in the hospitals.

This study is really helpful to identify the artificial radionuclides sources such as from medical activities as well as to ensure the safety of the public as well as radiation workers in the hospitals.

It is observed from Table 2 that the annual effective dose of the public who are residing nearby DMCH campus ranged from 0.213 ± 0.102 mSv to 0.427± 0.211 mSv with an average of 0.306 ± 0.105 mSv. It may be mentioned from Table 2 that 06 locations of the outdoor dose rate anround DMCH campus

were higher than the worldwide average dose rate 0.274 µSv/hr due to natural radiation (UNSCEAR, 2000).

| MP No.	Latitude	Longitude	Radiation dose rate (µSv/hr)			Annual effective dose due to radiation (mSv) ± SD
			Range	Mean	SD	
1	N23°43.564'	E090°23.768'	0.05-0.23	0.14	0.056	0.245±0.099
2	N23°43.550'	E090°22.817'	0.02-0.19	0.164	0.202	0.288±0.354
3	N23°43.623'	E090°23.806'	0.07-0.25	0.16	0.056	0.280±0.099
4	N23°43.676'	E090°23.806'	0.05-0.26	0.159	0.059	0.278±0.103
5	N23°43.692'	E 090°23.845'	0.12-0.29	0.212	0.049	0.371±0.086
6	N23°43.704'	E090°23.839'	0.17-0.36	0.265	0.061	0.465±0.108
7	N23°43.637'	E090°23.873'	0.11-0.25	0.177	0.043	0.309±0.076
8	N23°43.643'	E090°23.886'	0.11-0.27	0.203	0.047	0.372±0.090
9	N23°43.642'	E090°23.916'	0.12-0.39	0.216	0.062	0.378±0.109
10	N23°43.659'	E 090°23.942'	0.15-0.27	0.208	0.037	0.364±0.066
11	N23°43.664'	E090°23.975'	0.11-0.25	0.183	0.043	0.320±0.076
12	N23°43.670'	E090°23.988'	0.05-0.58	0.244	0.121	0.427±0.211
13	N23°43.671'	E090°24.011'	0.07-0.23	0.148	0.046	0.26±0.080
14	N23°43.668'	E 090°24.039'	0.13-0.25	0.195	0.048	0.342±0.084
15	N23°43.671'	E 090°23.810'	0.1-0.2	0.15	0.033	0.263±0.058
16	N23°43.651'	E 090°23.786'	0.05-0.2	0.129	0.046	0.227±0.080
17	N23°43.655'	E 090°23.771'	0.07-0.18	0.125	0.036	0.219±0.063
18	N23°43.660'	E 090°23.738'	0.07-0.2	0.135	0.042	0.236±0.073
19	N23°43.637'	E 090°23.873'	0.05-0.2	0.125	0.048	0.219±0.083
20	N23°43.700'	E 090°23.784'	0.16-0.23	0.194	0.024	0.340±0.041
21	N23°43.664'	E 090°23.701'	0.05-0.25	0.168	0.053	0.294±0.093
22	N23°43.663'	E 090°23.669'	0.05-0.31	0.213	0.065	0.372±0.115
23	N23°43.664'	E090°23.818'	0.04-0.27	0.132	0.065	0.231±0.114
24	N23°43.646'	E 090°23.869'	0.07-0.25	0.16	0.056	0.280±0.098
25	N23°43.632'	E 090°23.869'	0.14-0.32	0.214	0.053	0.375±0.093
26	N23°43.606'	E 090°23.882'	0.05-0.26	0.159	0.050	0.278±0.088
27	N23°43.596'	E 090°23.897'	0.06-0.27	0.121	0.059	0.213±0.102
28	N23°43.617'	E090°23.802'	0.05-0.47	0.177	0.108	0.309±0.189

Table. 2: Radiation dose rate monitoring around the DMCH campus from September-October, 2019.

The excess dose rate of the 06 locations around DMCH campus is due to the man-made radioactive sources and radiation generating equipments such as CT, X-ray, etc. widely used in the DMCH for diagnostic and theraputic procedures of patients. Howerver, the average annual effective dose limit from man-made sources for public and radiation workers for 5 consecutive years are 1 mSv and 20 mSv respectively.
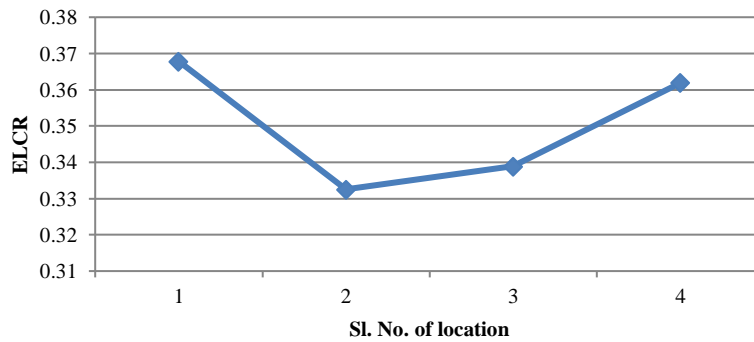
The frequency distribution of the indoor and outdoor radiation dose rates in air are shown in Fig. 2 and Fig. 3 respectively:
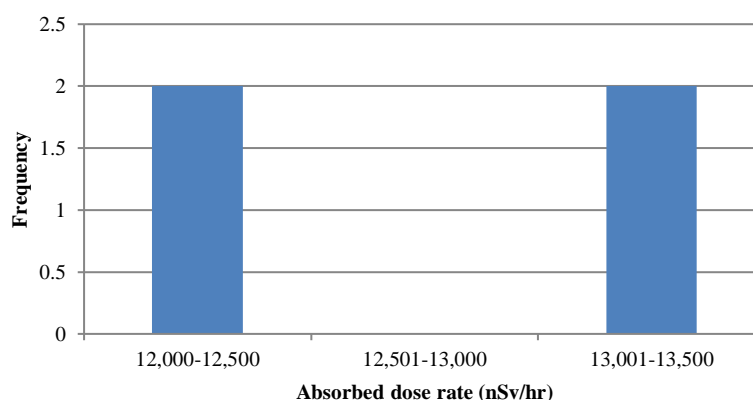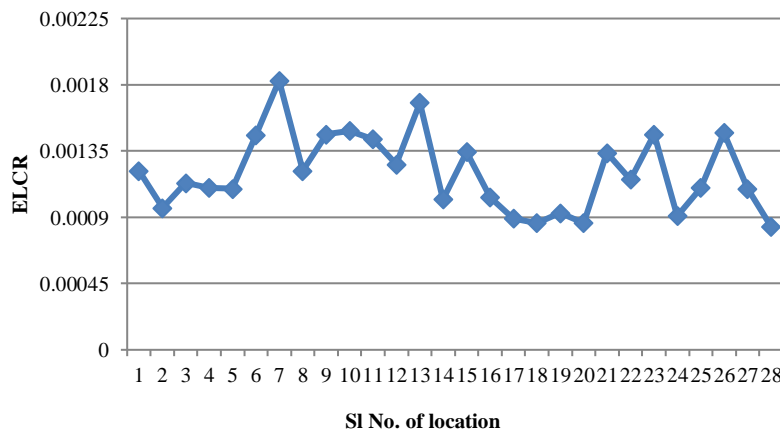

Fig. 2: The frequency distribution of the indoor dose rate of the DMCH campus.
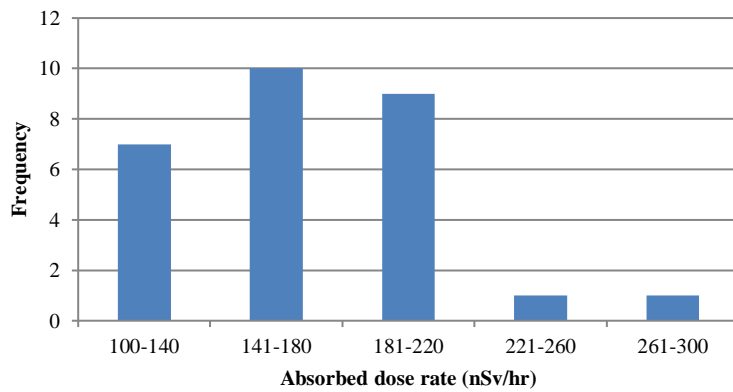
Fig. 3: The frequency distribution of the outdoor dose rate of the DMCH campus.

Fig. 4: The excess life-time cancer risk (ELCR) of medical staff in the selected indoor locations of the DMCH, if Personal Protective Equipments (PPEs) were not used.

Fig. 5: The excess life-time cancer risk (ELCR) of public around the DMCH campus.

HEALTH RISK ASSESSMENT

The health risk from absorption by scattered radiation among general public were assessed based on target hazard quotient (THQ) which is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected. It is primarily used by US EPA to assess the health risks of radiation.

If,

THQ>1, the exposed public will likely experience a detrimental effect.

THQ<1, A hazard quotient less than or equal to 1 indicates that adverse effects are not likely to occur, and thus can be considered to have negligible hazard.

This type of study is required to assess the radiation hazard arising from nuclear and radiological facilities, e.g., hospitals in the country or from the neighbor countries. From this study, it can be concluded that radiation due to man-made sources such as medical exposure plays a vital role in the environmental radiation in and around the DMCH campus and the corresponding public health risks. Radioactive sources and radiation generating equipments should be properly handled and operated as per national radiation safety regulations and international guidelines.

The average annual effective dose is found to be 0.43 mSv in outdoor environment of DMCH campus which is not very significant but for indoor environment, that value is 93 mSv which is very alarming and hazardous both for radiation workers and general public and its surrounding ecosystem. It indicates a serious health threat. Though geographical, geological, and altitude of cities put a great significance for high radiation exposure but from the indoor data, it can assume that medical tests and treatments play a vital role of this radiation hazard around DMCH campus. The average levels of annual effective dose to populations for countries are mostly in the range of 0.30-0.60 mSv, except the indoor study. The annual effective dose to population due to outdoor environmental radiation in Dhaka city ranged from 0.121-0.244 mSv/yr which is within the range of worldwide average. But in indoor calculation, DMCH has lower environmental gamma radiation than a hospital of Egypt (Harb, S. 2016) where annual effective dose was found to be 2449 mSv (when the device is on) much greater than the observed value of Bangladesh that is 93 mSv.

CONCLUSION

This study estimated the public health risk arising from the largest and the busiest medical college hospital (DMCH) in Bangladesh based on radiation monitoring data. The radiation dose rate and the corresponding annual effective dose of public who are residing nearby DMCH campus are higher than the green field of Dhaka city. The reason is that different kind of radioactive materials as well as radiation generating equipments are being used for diagnostic and therapeutic procedures of patients in DMCH that contribute additional radiation dose to public who are living nearby DMCH campus. Therefore, it is essential to properly follow the national radiation protection and safety regulations and international guidelines while handling radioactive materials and radiation generating equipments in the hospitals in order to reduce the radiation hazard in the surrounding environment of the DMCH campus. Therefore, the real-time radiation monitoring is very essential around DMCH campus through regular workplace monitoring, quality control of radiation generating equipments as well as ensuring that acceptable limit is not exceeded. Radiation workers in this sector should be more conscious in using their personal protective equipment on a regular basis and keep dosimeters along with them for proper personnel monitoring.

ACKNOWLEDGEMENT

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