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Estimation of Radiological Risk on Medical Staff and Public Inside & Outside of Three Large Hospital Campuses in Dhaka, Bangladesh

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ABSTRACT

Ionizing radiation offers great benefit to people in the hospital through diagnostic and therapeutic procedures to patients but undue radiation may create short- and long-term problems for medical staff & public. The goal of the study is to monitor the real-time radiation inside & outside of the three large hospital campuses in Dhaka city of Bangladesh namely National Institute of Cancer Research & Hospital (NICRH), National Heart Foundation Hospital & Research Institute (NHFH), Kidney Foundation Hospital & Research Institute (KFH) and estimation of radiological risk on medical staff& public. The average real-time radiation dose rate & calculated average twelve-monthly effective doses to medical staff and public arising from the NICRH, NHFH, KFH were found to be1.781 ± 0.310 µSv/h, 1.685 ± 0.307µSv/h, 1.735 ± 0.341µSv/hand 3.111 ± 0.556mSv, 2.952 ± 0.437 mSv, 3.039 ± 0.329 mSv respectively. The excess life-time cancer risk (ELCR) on medical staff & public was estimated based on the twelve-monthly effective dose and varied from 8.972 x 10^{-3} to 18.938 x $10^{-3}$with average of 12.071 x 10^{-3}. The average twelve-monthly effective dose and ELCR on medical staff were lower than those of the permissible limit. Real-time radiation monitoring inside & outside of the large hospital campuses is essential for detecting a malfunction of the radiation generating equipment and incorrect handling of the radioactive substances. The study would assist in minimizing radiological risk to medical staff & public and thereby would ensure the environment in the hospital is free from radioactive contamination.

Keywords: Hospital radiation, Medical staff, Public, Monitoring, Risk, Effective dose, and ELCR.

INTRODUCTION:

Ionizing radiation offers great benefit to patients in the hospital but unwanted radiation may detriment to medical staff & public. Radiation is extensively used in the hospital for diagnostic & therapeutic procedures to OL..\= patients. Computed Tomography (CT) scanner in the hospital is responsible maximum part of radiation absorbed dose to medical staff & public (NCRP, 2009; Mettler, 2009). National Institute Cancer Research & Hospital (NICRH) is the largest hospital in Bangladesh for cancer patient management. NICR is the only tertiary level hospital of the country involving in multidisciplinary cancer patient treatment. NICRH has various kinds of radiation generating equipment such as CT scanner, Linac, etc. for diagnosis & treatment to cancer patient. National Heart Foundation Hospital and Research Institute (NHFH) offers all types of advanced non-invasive and invasive examinations including interventional cardiology. NHFH has many types of radiation generating equipment such as CT scan, CT angiogram, digital X-ray, etc., for diagnosis & treatment to patient. Kidney Foundation Hospital and Research Institute (KFH) has radiology and imaging facility in which mobile X-ray unit available. Ionizing radiation subsists everywhere and medical staff & public are getting natural and man-made radionuclide. Medical staff & public are exposing radiation from the radiation generating equipment in the hospital. Real-time radiation monitoring inside & outside of the hospital campus is vital to identify radiation contamination and subsequently to take appropriate measures for minimization of the radiation contamination. Therefore, real-time radiation monitoring is very important for decreasing of the radiation dose for both medical staff and public which ensure the protection against ionizing radiation. Gamma radiation has enough energy to ionize the atoms of a material as it is the most energetic radiation of the electromagnetic spectrum that is 10,000 times higher than that of visible light (Eslami, 2017; Eslami, 2016).

Gamma radiation contributes most public exposure which emits from the natural radionuclide's. The main three naturally occurring radionuclide's are the primordial radionuclide, namely ^{238}U,^{232}Th & their decay products and ^{40}K that exist trace amount in earth formation. The cosmic rays and terrestrial radiation contributed the most part of the public exposure (Charles M, 2000). Public exposure from the terrestrial radiation depends primarily on geological attribution of the place, namely altitude, latitude & solar system (Agency for Toxic, 1999). Usually, radiation exposure of medical staff and public at indoor location is higher than that of the outdoor location due to the building materials. Building materials, for example rod, gypsum, marble, brick, concrete, sand, granite, limestone, aggregate, and so on, contain primarily naturally occurring primordial radionuclide such as ^{238}U, ^{232}Th & their daughter products and ^{40}K.The knowledge of the natural radionuclide of the building materials is vital for assessing the radiation dose to medical staff & public as people spend almost 80% of the time at indoor places and remaining 20% of the time at out-door places (UNSCEAR, 2000; UNSCEAR, 2008; Biswas *et al*., 2021; Taskin H, 2009). Gamma radiation contributes maximum radiation dose to public from all types of the ionizing radiation, because of its greater penetration ability comparing to others (Al-Saleh, 2007). Large variation of the radiation dose rates was observed at indoor & outdoor environments and international articles were reported the radiation dose rates inside and outside of the nuclear facilities & hospitals (Al-Ghorable, 2005; Arvela, 2002; Rybach, 2002; Sagnatchi, 2008; Tavakoli, 2003; Svoukis, 2007; Rangaswamy, 2005; Onon-ugbo, 2015; Alasadi, 2016). The existence of the natural & artificial radionuclide's inside and outside of the hospital campus contribute external & internal radiation dose on medical staff and public. Estimation of the twelve-monthly effective dose on medical staff & public from the indoor radiation of the hospital is very significant, as it is connected to the probability of getting cancer on medical staff & public from the small quantity of radiation during long time. Estimation of the excess life-time cancer risk (ELCR) on medical staff & public from ionizing radiation discharging from the large hospital is vital since those contribute to collective dose on medical staff & public (UNSCEAR, 2008). NICRH, NHFH and KFH usage difference types of the radiation generating equipment such as CT scan, CT angiogram, Linac, X-ray machines, etc. for diagnostic & therapeutic procedures as well as training, research purposes. The goal of the study is to monitor the real-time radiation inside & outside the three large hospital campuses in Dhaka city, Bangladesh and to estimate the excess life-time cancer risk on medical staff & public based on the real-time radiation monitoring data.

MATERIALS AND METHODS:

Radiation Monitoring Equipment

Real-time digital handy radiation monitoring devices were utilized for keeping record of the dose rate at 1 meter in the air from the ground. The monitoring devices were placed on tripod. The radiation monitoring device is designed and made by Germany. A non-compulsory sophisticated leather case with belt fastening can extra protect the monitoring device. The monitoring device is a Geiger counter with a suitable shape so that people can use it most efficiently and safely. The monitoring device contains a battery pointer, manifold unit conversion, real-time radiation dose rate and collective dose exhibition functions and schedule registering and watchful functions. Modern functions contain PC data download through USB cable and very low current power circuit for prolonged battery life. The monitoring device accounts the incidence radiation quickly, consistently, and lastingly. Changing of pulses per minute to dose rate depends on the size of the pulse input. In case of normal environmental input (~ 0.200 µSv/h) the transformation is 142 pulses/minute (User Manual-GAMMA SCOUT, 2014). The monitoring device has the characteristics for audio signal when the dose rate surpasses an exact level. The default audio signal level is 5μSv/h. If this dose rate is surpassed during monitoring of radiation, this will be exhibited with a supplementary sign in the display.

Calibration of the Equipment

The counter tube is not prone to fatigue in normal environmental radiation and thus, it wills not necessitate for re-calibration. However, if the operator has an ISO certification, periodical calibration is necessary. To sub-contract a muster operation, tests would be performed for 72 hours against a primary. The primary is calibrated against a standard reference source, for example Cs-137. A data log is then produced. The monitoring devices were calibrated after manufacturing. The monitoring devices were also calibrated at the Secondary Standard Dosimetry Laboratory (SSDL) of Bangladesh Atomic Energy Commission (BAEC) by gamma-ray standard sources, for example, ^{137}Cs, ^{60}Co, etc. and X-ray Unit. The SSDL of BAEC has been accessible since 1991 that 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 equipment's calibration. The efficiency of BAEC's SSDL is kept up as per requirements of the International Atomic Energy Agency (IAEA)/World Health Organization (WHO) network of SSDLs. Thus, the calculated doses are met the international monitoring system. The monitoring device precisely monitor dose rate within the range 0.01-5000 μSv/hr(User Manual-GAMMA SCOUT, 2014).

Radiation Monitoring Procedures

The real-time radiation monitoring around the NICRH, NHFH & KFH hospital campuses were performed in January-February 2021. The real-time radiation monitoring around the NICRH, NHFH & KFH hospital campuses were carried out to detect the man-made radiation arising from the hospitals. In these hospitals, various kinds of ionizing radiation generating equipment, for example, X-ray Machines, CT scanners, CT angiogram, Linac, etc. used for diagnostic and therapeutic procedures to patients daily.

The real-time radiation monitoring was con-ducted at 96 selected locations around the NICRH, NHFH & KFH hospital campuses and data collection time at each monitoring point (MP) was about 1 hour. The digital handy monitoring device was set upon tripod at 1meter in the air from the ground. The MP was indicated by a mark using a GARMIN eTre-xHC Series Personal Navigator. The device uses the demonstrate efficiency of Garmin high-delicacy GPS and the outmost extent mapping to form an income-parable portable GPS receiver (Owner's Manual-GARMIN eTrex HC Series, 2007).

Radiation Monitoring Site

32 MPs around the NICRH are located from N: 23.46570 to N: 23.46817 and from E: 90.24534 to E: 90.24672. The 32 MPs around the NHFH are located from N: 23.48198 to N: 23.48252 and from E: 90.21697 to E: 90.21762. The 32 MPs around the KFH are located from N: 23.48571 to N: 23.48835 and from E: 90.21435 to E: 90.21573.NICRH has many departments such as radiation oncology, medical oncology, surgical oncology, gynecological oncology, hematology, cancer epidemiology, radiology & imaging, genitourinary oncology, histopathology, cytopathology, pediatric haematology & oncology, plastic & reconstructive surgery, microbiology, immunology & molecular biology, blood transfusion medicine, palliative care, orthopedic surgical oncology, anaesthesiology, physical medicine & rehabilitation, psychotherapy, emergency oncology, dental and faciom axillary surgical oncology, ENT oncology, laboratory medicine. The NHFH has various types of facilities, for example, cardiac catheterization, coronary angiogram, CT angiogram, digital X-rays of all types, portable X-rays, CT scan, etc. The KFH has different types of facilities such as mobile X-rays unit in the radiology and imaging department.

Estimation of Radiological Risk

Effective dose is the typically used term for calculation of medical staff & public exposure and the probable biological effects concerning with public exposure which is obtained from the equation below:

For outdoor, $AED = D_{out} \times OF_{out} \times T$ (1)

For indoor, $AED = D_{in} \times OF_{in} \times T$ (2)

Here, AED is the annual effective dose, D_{in} and D_{out} are the mean absorbed dose rates in air at indoor & outdoor places respectively, T is the time in hour, OF_{in} and OF_{out} is the indoor and outdoor occupancy factors which is the portion of time spending of an individual. Mostly, the value of OF_{in} and OF_{out} are 0.8 and 0.2 respectively (UNSCEAR, 1988).

The excess life-time cancer risk (ELCR) is estimated following equation below:

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

Here, AED is the annual effective dose to medical staff & public, DL is the duration of life of Bangladeshi citizens (http://en.worldstat.info, 2022) and RF is risk factor (Sv^{-1}) that is a fatal cancer risk per Sievert. For stochastic effects arising from low-level radiation, ICRP 103 recommended the value of 0.057 per Sievert for the public (ICRP, 2007).

RESULTS AND DISCUSSION:

Annual effective dose

Twelve-monthly effective dose on medical staff & public at inside and outside of three large hospital campuses of Dhaka city were calculated on the basis of international articles (UNSCEAR, 2000; Hashemi, 2019; James, 2015; Zarghani, 2017; Abdullahi, 2019; Monica, 2016). Assuming that Bangladeshi resident spends approximately 20% of time at outdoor places and remaining 80% of time at indoor places, the twelve-monthly effective dose on medical staff & public inside and outside the three large hospital campuses (NICRH, NHFH, KFH) in Dhaka city were calculated. **Table 1** shows the twelve-monthly effective dose on medical staff & public in the period of January-February 2021.The twelve-mothly effective dose to medical staff & public inside and outside the three large hospital campuses were ranged from 2.952 ± 0.437mSv to 3.111 ± 0.556mSv with mean of 3.034± 0.441 mSv. The mean twelve-mothly effective dose of medical staff & public from the three large hospital campuses is six times higher than that of the worldwide mean of 0.48 mSv (ICRP, 2007). The mean twelve-monthly effective doses were generally high at places nearer to the CT scan rooms, CT angiogram rooms, X-ray machines rooms. Though, the average twelve-monthly effective doses to medical staff inside & around the CT scan rooms, CT angiogram rooms, X-ray machines roost few places were higher, but those values are lower than the permissible limit of 20 mSv for medical staff (ICRP, 2007). In addition to that, the twelve-monthly permissible limit for public (1 mSv) would be taken into consideration from planned exposure situation and is not applicable for the existing exosure situation. The above mentioned twelve-monthly effective doses were sum of the planned exposure and existing exposure. The lowest twelve-monthly effecttive dose to medical staff & public were found at places far away from the CT scan rooms, CT angiogram rooms, X-ray machines rooms. When the maximum number of radiations generating equipment in the hospital was in "on-state", then high radiation dose rates were found at inside & outside places. **Table 1** Shows real-time radiation monitoring data at 96 locations inside & outside of three large hospitals from January-February 2021. It is observed from **Table 1** that real-time radiation data as well as twelve-monthly effective dose of the NICRH are relatively higher than those of the other two hospitals (NHFH & KFH) in Dhaka city.

Table 1: Real-time radiation monitoring at 96 locations inside & outside of three large hospitals from January-February 2021.

Name of hospital	Gamma dose rate (μSv/h)			Annual effective dose due to gamma radiation (mSv ± SD)
	Range	Mean	SD	
National Institute of Cancer Research and Hospital	1.15-4.05	1.781	0.310	3.111 ± 0.556
National Heart Foundation Hospital & Research Institute	1.23-3.15	1.685	0.307	2.952 ± 0.437
Kidney Foundation Hospital & Research Institute	1.24-2.85	1.735	0.341	3.039 ± 0.329

Fig. 1 shows the mean twelve-monthly effective dose value for each location to medical staff & public normalized to the minimum twelve-monthly effective dose value. It may be mentioned here that Serial No. 1-32 for NICRH, Serial No. 33-64 for NHFH and Serial No. 65-96 for KFH. It is observed from **Fig. 1**, average twelve-monthly effective dose for four places (serial numbers 9, 14, 21 & 27) in NICRH, one place (serial no. 53) in NHFH & four places (serial no. 67, 74, 80 & 95) in KFH are fairly higher than those of the other places. The reason is that places for serial numbers9, 14, 21, 27, 53, 67, 74, 80 & 95 are adjacent to radiation generating equipment rooms such as CT scan rooms, CT angiogram rooms, X-ray machines rooms, etc. **Fig. 1** & **Table 1** show the difference of dose rates inside & outside of the three large hospital campuses contribute from the natural and man-made sources. The natural radiation originates from the construction materials of the building, soil & water. The man-made radiation originates from the radiation generating equipment & radioactive substances in the hospitals which is being used for diagnosis & treatment to patient.

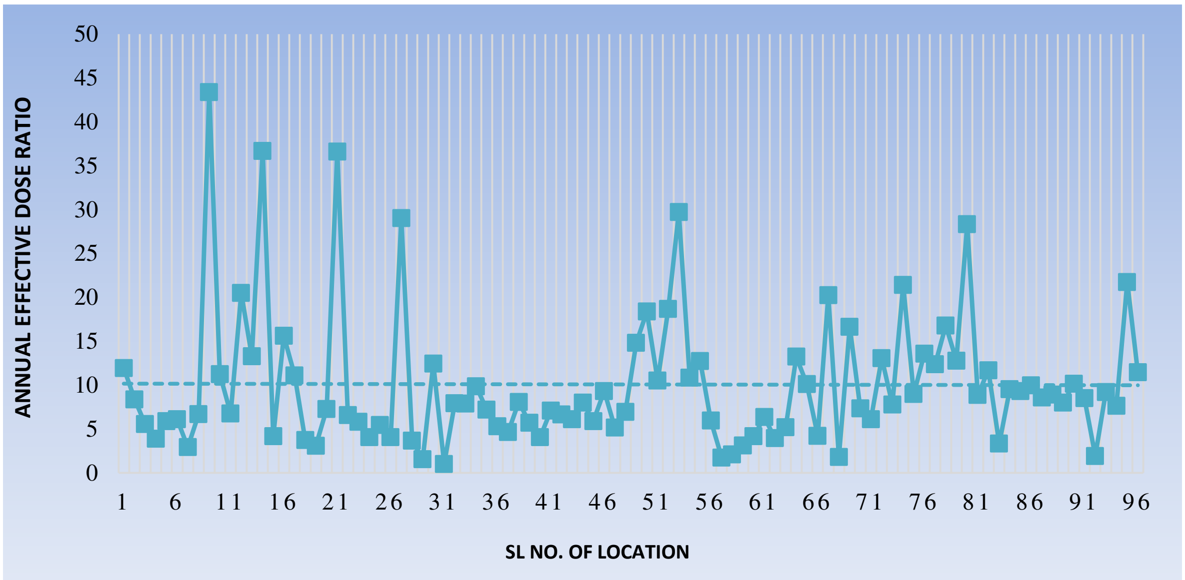

Fig. 1: Average twelve-monthly effective dose value for each place normalized to the minimum twelve-monthly effective dose.

The variation of the twelve-monthly effective dose rates inside & outside the three large hospital campuses were observed due to the weather conditions during data collection period. It is explained in the international articles (Bellia, 2001) that the outdoor radiation dose rate in spring and autumn are moderately higher than those of other seasons. Accumulation of more radon gas adjacent to ground at outdoor places during the winter and spring seasons contributes more gamma dose rate during the winter and spring seasons.

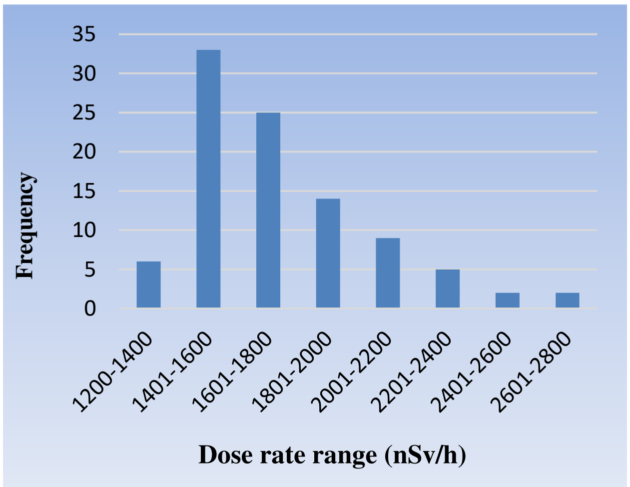

Fig. 2: The frequency distribution of the gamma dose rates at 96 locations inside & outside places of the three large hospital campuses of Dhaka city.

In addition to that radon exhalation rate from soil surface is lowered due to the filling up of pore spaces in the soil in rainy season. Moreover, radon and its daughter products are usually washed out directly for reduction of its concentration in the lower atmosphere in the rainy season (Stranden, 1985; Chandrashekara, 2006). The frequency distribution of the gamma dose rates inside & outside of the three large hospital campuses in Dhaka city is shown in **Fig. 2**.

Excess life-time cancer risk (ELCR)

The ionizing radiation risk on medical staff & public which originates from the natural & man-made sources in the hospital campus should be estimated for assessment of medical hazard. It was found in the international articles that the evaluation of the twelve-monthly effective dose and subsequently ELCR on medical staff & public at indoor places of the hospital is limited numbers comparing to those found at the outdoor places. It is seen in **Table 2** that the estimated ELCR on medical staff & public inside & outside the three large hospital campuses is comparable to Iran. It is seen from **Table 2** mean ELCR on medical staff & public in some parts of Iran, Iraq, Pakistan, India, Malaysia, Nigeria and Morocco are lower than that of the three large hospitals in Bangladesh. However, mean ELCR in some parts of India are quite higher than that of the three large hospital campuses in Bangladesh. The relatively high ELCR on medical staff & public inside & outside the three large hospital campuses in Dhaka city are mostly contributed from the CT scanners, CT angiogram, X-ray machines, etc. used in the hospitals for diagnosis & treatment to patient. Besides, the relatively high ELCR on medical staff & public at indoor places of the building existing due to the instruments of the laboratory in the hospitals, extra decorative stones for the structure of walls & floor tiles and due to the lack of proper ventilation system in the laboratory, wards, working rooms of the hospital buildings that increase the radon concentration level.

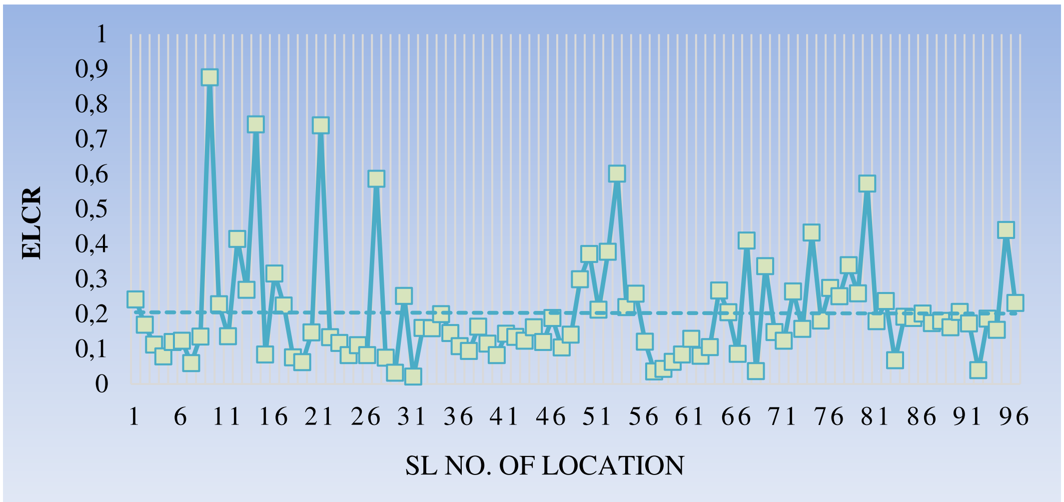

Fig. 3: Excess life-time cancer risk (ELCR) on medical staff & public inside and outside the three large hospital campuses in Dhaka city.

Table 2: Twelve-monthly effective dose and ELCR of some countries are compared with the present study.

Country	Twelve-monthly effective dose range (mean) in mSv	ELCR	Reference
Iran	1.68	10.7 X10^{-3}	Hashemi *et al.*, 2019 [25]
Malaysia	0.782	3.22 X10^{-3}	Abdullahi *et al.*, 2019 [28]
Nigeria	0.54-0.949 (1.06)	3.71 X10^{-3}	Ononugbo *et al.*, 2015 [33]
Nigeria	0.645	2.26 X10^{-3}	Etuk *et al.*, 2017 [34]
India	7.56	20.56 X10^{-3}	Monica *et al.*, 2016 [29]
Iran	0.49	1.715 X10^{-3}	Zarghani *et al.*, 2017 [27]
Pakistan	0.92	3.21 X10^{-3}	Qureshi *et al.*, 2014 [35]
Iraq	0.56	1.64 X10^{-3}	Mohammed *et al.*, 2017[36]
Pakistan	0.49	1.629 X10^{-3}	Rafique et *al.*, 2014 [37]
India	0.522	1.83 X10^{-3}	Murugesan *et al.*, 2016 [38]
Nigeria	0.14-0.19 (0.16)	0.56 X10^{-3}	Avwiri *et al.*, 2019 [39]
Pakistan	1.0	3.4 X10^{-3}	Ali *et al.*, 2019 [40]
Morocco	0.05-0.56	0.19-1.96X10^{-3}	Kassi *et al.*, 2018 [41]
World	0.3-0.6 (0.48)	1.16 X10^{-3}	UNSCEAR, 2000 [5], Murugesan *et al.*, 2016 [38], and Hashemi *et al.*, 2019 [25]
Bangladesh	2.952-3.111 (3.034)	12.071 X10^{-3}	present study

The estimated mean twelve-monthly effective dose of 3.034 mSv may not be expected to add substantial risk on medical staff from the radiological risk analysis. The reason is that mean twelve-monthly dose limit for the medical staff as per ICRP 103 (ICRP, 2007) is 20 mSv for five consecutive years and the limit is relevant to the planned exposure situations and is not connected to radiation contributing from the existing exposure situations.

CONCLUSION:

CT scan and nuclear cardiology is responsible more ionizing radiation dose on medical staff & public in the hospital. Real-time radiation monitoring inside & outside of the three large hospital campuses would facilitate to minimize the ionizing radiation dose on medical staff and public through correction of the radiation generating equipment's errors and inappropriate handling of radioactive materials in the hospital campuses. The mean twelve-monthly effective dose and mean ELCR on medical staff & public inside and outside the three large hospital campuses in Dhaka city are higher than those of the worldwide average values. This type of study should be conducted regularly inside & outside of the large hospital campus for minimization of the ELCR on medical staff & public that ensure the safety of their daily work in the hospital campus against undue radiation hazard. Moreover, medical staff should be more aware during handling the radiation generating equipment & radioactive substances in the hospital and must follow the national regulations related to the radiation protection & international recommend-dations (especially IAEA & ICRP) in order to reduce the unnecessary radiation hazard on medical staff & public in the environment of the hospital.

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CONFLICTS OF INTERESTS:

The authors declare no conflict of interest.

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