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## Assessment of Radiation Risk on Healthcare Workers and Public in & around Two Largest Hospital Campuses of Bangladesh

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### ABSTRACT

Ionizing radiation gives tremendous benefit to mankind in the hospital through diagnosis and treatment to patients but unnecessary radiation may cause harm to healthcare workers & the public. The purpose of the study is to continuous radiation monitoring in & around the three largest radiological facilities of Bangladesh such as Atomic Energy Centre Dhaka (AECD), Dhaka Medical College Hospital (DMCH) & Bangabandhu Sheikh Mujib Medical University (BSMMU) campuses, and estimation of radiation risk on healthcare workers & public health. Continuous radiation monitoring was performed in & around the AECD, DMCH, BSMMU campuses from August-October 2020 using the Chemiluminescent Dosimeters. The yearly effective doses to healthcare workers and the public due to radiation released from the facilities were ranged from  $0.606 \pm 0.031$  mSv to  $0.801 \pm 0.042$  mSv with a mean of  $0.707 \pm 0.053$  mSv. The excess lifetime cancer risk (ELCR) on healthcare workers & public health were evaluated based on the yearly effective dose and ranged from  $2.486 \times 10^{-3}$  to  $3.287 \times 10^{-3}$  with a mean of  $2.900 \times 10^{-3}$ . The average yearly effective dose and ELCR on healthcare workers & public health were lower than those of the worldwide permissible values. Continuous radiation monitoring in & around the largest radiological facilities is required for detection of the radiation generating equipment's malfunctions and improper handling of the radioactive materials. The study would help for minimization of radiation risk on healthcare workers & the public and this keeps the hospital's environment free from radiation hazard.

**Keywords:** Hospital radiation, Healthcare workers, Effective dose, ELCR, and Chemiluminescent dosimeters.

### 1. INTRODUCTION:

Ionizing radiation has many beneficial applications to human being but undue radiation may cause harm (Cancer) to healthcare workers & public health. Radiation is widely used in the radiological facility such as hospital for diagnosis & treatment to patients. CT scanner in hospital is contributed most part of radiation absorbed dose to healthcare workers & public (NCRP, 2009; Mettler, 2009). Atomic Energy Centre Dhaka

(AECD) is one of the largest radiological facilities in Bangladesh where one radioactive wastes storage room & various kinds of radioactive substances and radiation generating equipment's are being handled for service, training and Research & Development purposes. BSMMU and DMCH are two largest public hospitals of Bangladesh are located around the AECD campus. Different types of radioactive substances & radiation generating equipment's are routinely used in the

BSMMU & DMCH for diagnosis and treatment to patients. The BSMMU & DMCH are the busiest & largest public hospitals in Bangladesh. National Institute of Nuclear Medicine and Allied Sciences is also situated in the BSMMU campus. Ionizing radiation exists all over the places and healthcare workers & public are exposing natural and artificial radionuclides. Healthcare workers & public used to receive radiation from man-made facilities such as nuclear facility and hospitals. Continuous radiation monitoring in & around the radiological facilities like AECD, BSMMU, DMCH is much needed in order to detect the undue radiation exposure on healthcare workers and public health releasing from the man-made radioactive substances as well as radiation generating equipment's. The annual effective radiation dose on healthcare workers & public health in and around the large radiological facility can be reduced through the continuous radiation monitoring which ensure the safety of healthcare workers & public. Gamma radiation has sufficient energy to ionize the atoms of a matter since it is the highest energetic radiation of the electromagnetic spectrum which is 10,000 times higher than that of visible light (Islamic, 2017; Islamic, 2016).

Gamma radiation is responsible for maximum public exposure that emitting from the naturally occurring radionuclides. The mentionable naturally occurring radionuclides are the primordial radionuclides such as  $^{238}\text{U}$  &  $^{232}\text{Th}$  and their decay products and  $^{40}\text{K}$  that remain small amount in all earth structure. The higher portion of public exposure due to radiation comes from the naturally occurring radionuclides together with cosmic rays and terrestrial radiation (Charles, 2000). Public radiation exposure from the terrestrial gamma radiation depends mostly on geological behavior of the location, e.g., altitude, latitude and solar movement (Agency for Toxic, 1999). Generally, public radiation exposure at indoor location is higher than those of the outdoor radiation exposure because of the building materials. Building materials such as rod, marble, gypsum, concrete, brick, sand, aggregate, granite, limestones and so on, comprise mainly naturally occurring primordial radionuclides including  $^{238}\text{U}$  &  $^{232}\text{Th}$  and their daughter products and  $^{40}\text{K}$ . The perception of the natural radionuclides of the construction materials is crucial for estimation of the public exposure from

radiation since many people spend approximately 80% of their time at indoor location and the remaining 20% of their time at outdoor location (UNSCEAR, 2000; UNSCEAR, 2008; Taskin, 2009).

Gamma radiation gives higher part to public radiation exposures from all the ionizing radiation sources because of its superior penetration capability (Al-Saleh, 2007; Awadala *et al.*, 2020). High differences of radiation dose rates were observed in the environment and many international articles were reported the gamma dose rates in and around the nuclear & radiological facilities (Al-Grable, 2005; Arvella, 2002; Rybach, 2002; Sagnatchi, 2008; Tavakoli, 2003; Svoukis, 2007; Rangaswamy, 2005; Ononugbo, 2015; Alasadi, 2016). The subsistence of the naturally occurring & man-made radioisotopes in the hospital's environment may contribute an external & internal radiation effective dose on healthcare workers and public. Calculation of the annual effective dose on healthcare workers & public from the indoor gamma radiation of a radiological facility is very essential, since it is related to the likelihood of getting cancer on healthcare workers & public from the little amount of ionizing radiation during long time. The assessment of the excess life-time cancer risk (ELCR) on healthcare workers & public due to ionizing radiation releasing from the large radiological facilities is essential because those contribute to the collective dose on healthcare workers & public (UNSCEAR, 2008).

AECD, BSMMU, DMCH usage a variety of radioactive substances such as  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$ ,  $^{192}\text{Ir}$ ,  $^{131}\text{I}$ ,  $^{99\text{m}}\text{Tc}$ , etc. and different kinds of radiation generating equipment's such as medical cyclotron, PET-CT, CT scanners, X-ray machines, fluoroscopy, etc. for service, training, diagnosis & treatment purposes to patients. The aim of the study is to continuous radiation monitoring in & around the three largest radiological facilities (AECD, BSMMU, DMCH) of Bangladesh and evaluate the excess life-time cancer risk on healthcare workers & public based on the continuous radiation monitoring data.

## 2. MATERIALS AND METHODS:

**2.1 Thermoluminescent Dosimeter** - The chemiluminescent dosimeters (TLD) consist of LiF: Mg, Ti (TLD-100) which has the effective atomic number of

8.2, comparable to that of the soft tissue of human being. Each TLD card has two chips with size of 3 mm (1/8 inch) square placing between two sheets of Teflon 0.003 inch (10 mg/cm<sup>2</sup>) thick and positioned on an aluminum substrate. Each TLD card (two chips) kept in a holder which protects the TLD card against environmental conditions for long time.

**2.2 TLD Reader & Read out Procedures** - The Harshaw manual TLD Reader of Model 4500 is worldwide very popular for measurement of the two elements TLD card (TLD-100). The manual TLD Reader from the Harshaw Company is widely used for reading out TLD cards & chips for several thermoluminescence (TL) materials in different compositions and dimensions (Harshaw TLD Reader, 2007). The TLD reader has two photo multiplier tube (PMT) in a sliding position for manual read out of the TLD card & chips for whole-body, extremity, eye dosimeters and highly sensitive TL chips for environmental radiation monitoring. Two PMTs & associated electronics make easy for reading out TLD card in two positions at the matching time. PMT consists of photocathode that has the ability to convert the incident light into amplified current which is proportional to the number of generated photons & as a result proportional to the absorbed dose. The two element TLD card is read out through the nitrogen gas heating system using the TLD reader from Harshaw (Model 4500). The nitrogen gas heating system supplies a flow of hot nitrogen gas at perfectly controlled and gradually increased maximum temperature of 300°C. The nitrogen gas heating to the TLD chips were under close loop feedback and the superior electronic system provides stable & repeatable glow curves. The Harshaw TLD reader is connected to a personal computer (PC) and the PC is operated through WinREMS software which is procured from Harshaw Company. The effective dose on healthcare workers & public are evaluated using the Win REMS software.

**2.3 Calibration of TLD Card** - The two element TLD card was calibrated using the standard radioisotopes at the Secondary Standard Dosimetry Laboratory (SSDL) in Bangladesh Atomic Energy Commission (BAEC). Various gamma radiation emitting standard radioisotopes such as <sup>137</sup>Cs, <sup>60</sup>Co, etc. and X-ray Unit are available at SSDL of BAEC in Bangladesh. The SSDL

of BAEC is being operating from 1991 and this laboratory is linked to the Primary Standard Dosimetry Laboratory (PSDL) of National Physical Laboratory (NPL), UK. The SSDL, BAEC in Bangladesh has X-ray Unit (30 kV-225 kV) for radiation generating equipment's & TLD cards calibration. The standard of the SSDL, BAEC in Bangladesh is kept as per conditions of the International Atomic Energy Agency (IAEA)/World Health Organization (WHO) network of SSDLs. Therefore, the correctness of the effective dose calculation is traceable to the international level. Furthermore, the TLD laboratory in the AECD joins regularly worldwide inter-comparison study organized by the IAEA. In 2019 worldwide inter-comparison study, acceptable results were achieved as per the standards trumpet curve criteria (IAEA, 1999; ICRP, 1997).

The two element TLD cards & chips output after reading out using the Harshaw TLD reader is the charges generated by PMT & associated electronics due to the annealing process. Conversion of the output reading of TLD cards & chips from charge (nC) to absorbed dose (Gy) is possible using the equation below:

$$absorbed\ dose = \frac{equivalent\ dose}{quality\ factor} \quad (1)$$

The time between radiation dose given and the readout should be the same to keep the equal fading from one set of two element TLD cards calibration to those of other sets. The calibration factor ( $f_{calibration}$ ) is found using the equation below:

$$f_{calibration} = \frac{D_{ionization\ chamber}(mGy)}{TLD_{reading}(nC)} \quad (2)$$

Absorbed dose of the TLD cards following irradiation is obtained after subtracting background level using the following equation:

$$D_{TLD} = D_{av} - BG \quad (3)$$

Consequently, absorbed dose is assessed for each TLD card through the following equation:

$$D_{TLD} (mGy) = f_{cal} \left( \frac{mGy}{nC} \right) \times TLD_{reading} (nC) \quad (4)$$

**2.4 Calculation of ELCR** - Effective dose is the mostly used factor for calculation of healthcare

workers & public exposure and the possible biological effects connecting with public exposure that is found from the equation below:

$$AED = (D_{out} \times OF_{out} + D_{in} \times OF_{in}) \times T \quad (5)$$

Where, AED is the annual effective dose,  $D_{in}$  and  $D_{out}$  are the average absorbed dose rates in air at indoor & outdoor locations respectively, T is the time in hour,  $OF_{in}$  and  $OF_{out}$  is the indoor and outdoor occupancy factors that is the fraction of time spent of a person. Generally, the value of  $OF_{in}$  and  $OF_{out}$  are 0.8 and 0.2 respectively.

The excess life-time cancer risk (ELCR) is evaluated using the following equation:

$$ELCR = AED \times DL \times RF \quad (6)$$

Where, AED is the annual effective dose to healthcare workers & public, DL is the duration of life of Bangladeshi citizens (<http://en.worldstat.info>, 2020) and RF is risk factor ( $Sv^{-1}$ ) which is a fatal cancer risk per Sievert. For stochastic effects from low-level radiation, ICRP 103 proposed the value of 0.057 per Sievert for the public exposure (ICRP, 2007).

### 3. RESULTS AND DISCUSSION:

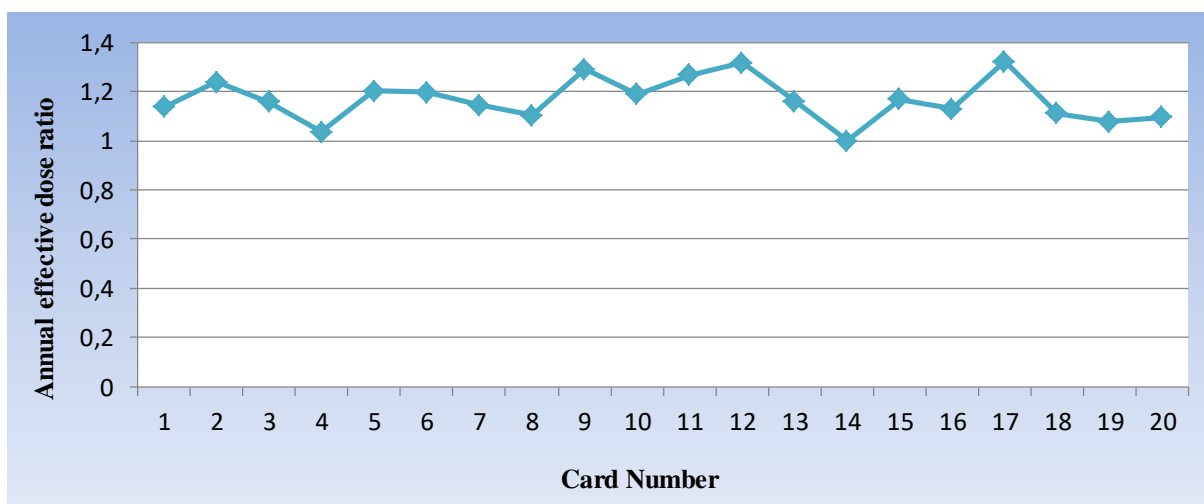
**3.1 Annual effective dose** - Taking into account the international articles (UNSCEAR, 2000; Hashemi, 2019; James, 2015; Zarghani, 2017; Abdullahi, 2019; Monica, 2016), considering that Bangladeshi citizen spends about 20% of their time outdoor location and the remaining 80% of their time indoor location, the yearly effective dose to healthcare workers & public in

and around the three largest radiological facilities (AECD, BSMMU, DMCH) campuses were calculated. **Table 1** depicts the yearly effective dose on healthcare workers & public during the period of August-October 2020. The annual effective dose to healthcare workers & public in & around the three radiological facilities were ranged from  $0.606 \pm 0.031mSv$  to  $0.801 \pm 0.042mSv$  with mean of  $0.707 \pm 0.053 mSv$ . The mean yearly effective dose of healthcare workers& public from the radiological facilities is higher than that of the worldwide average value of 0.48 mSv (ICRP, 2007). The average yearly effective doses were usually high at places nearer to the radioactive waste storage rooms & high activity radioactive substances handling rooms and ranged from  $0.77 \pm 0.03mSv$  to  $0.80 \pm 0.02mSv$  with mean of  $0.79 \pm 0.02mSv$ . Even the mean annual effective doses to healthcare workers& public in & around the three largest radiological facilities in Bangladesh at few locations nearer to the radioactive waste storage rooms and high activity radioactive substances handling rooms were higher than that of the worldwide average value of 0.48 mSv, but those values are below the acceptable limit of 1 mSv for public (ICRP, 2007). Besides, the acceptable limit for public (1 mSv/y) have to be considered from planned exposure situation and is not valid for the existing exposure situation. The minimum yearly effective dose to healthcare workers & public were observed at locations far away from the radioactive waste storage rooms and high activity radioactive substances handling rooms which is  $0.60 \pm 0.04mSv$ .

**Table 1:** Continuous radiation monitoring in & around three largest radiological facilities of Bangladesh from August-October 2020

Sl. No.	Dosimeter ID	Gamma dose rate ( $\mu Sv/month$ )			Annual effective dose due to gamma radiation (mSv) $\pm$ SD
		Range	Mean	SD	
1.	16201	99.99-116.6	106.8	9.8	$0.69 \pm 0.05$
	16202	109.8-128.2	116.2	10.4	$0.75 \pm 0.06$
3.	16203	100.9-117.5	108.67	8.35	$0.70 \pm 0.04$
4.	16204	121.5-164.0	143.17	21.26	$0.63 \pm 0.08$
5.	16205	103.5-124.8	112.77	10.91	$0.73 \pm 0.05$
6.	16206	108.8-117.0	112.47	4.17	$0.72 \pm 0.02$
7.	16207	99.31-117.1	107.54	8.97	$0.69 \pm 0.03$
8.	16208	93.84-118.4	103.68	12.98	$0.67 \pm 0.06$
9.	16209	103.6-135.8	121.2	16.31	$0.78 \pm 0.06$

10	16210	103.3-121.7	111.5	9.36	0.72 ± 0.05
11	16211	107.8-135.5	118.93	14.62	0.77 ± 0.06
12	16212	109.2-135.2	123.67	13.24	0.80 ± 0.06
13	16213	99.05-124.1	108.82	13.4	0.70 ± 0.05
14	16214	85.79-100.9	93.89	7.61	0.60 ± 0.04
15	16215	104.2-118.5	109.67	7.72	0.71 ± 0.03
16	16216	99.74-110.2	105.91	5.48	0.68 ± 0.02
17	16217	120.1-132.1	124.1	6.93	0.80 ± 0.03
18	16218	95.54-109.8	104.35	7.69	0.67 ± 0.04
19	16219	89.09-113.5	101.16	12.21	0.65 ± 0.05
20	16220	89.34-117.4	102.71	14.07	0.66 ± 0.06



**Fig 1:** Average yearly effective dose values normalized to the minimum annual effective dose for each place.

**Fig 1** depicts the mean annual effective dose values of healthcare worker & public normalized to the minimum annual effective dose value for each location. It is observed from **Fig 1** that average yearly effective dose for two locations (location numbers 17 & 12) are comparatively higher than those of the other locations. The reason is that location numbers 17 & 12 are the nearest positions to the radioactive waste storage rooms & high activity radioactive substances handling rooms.

**Fig 2** depicts the background dose rate ( $\mu\text{Sv}/\text{month}$ ) in & around the three largest radiological facilities (AECD, BSMMU, DMCH) campuses contributes from the construction materials of the building, natural radionuclides containing in soil and probable small number of man-made radionuclides from the radiological facilities. The differences of the monthly background level dose rate in & around the radiological facilities were observed due to the weather conditions.

From **Fig 2**, it is found that the background radiation dose rate ( $\mu\text{Sv}/\text{month}$ ) in August was higher than that in September & October 2020. It is described in the international articles (Bellia, 2001) that the outdoor background radiation absorbed dose rate in spring and autumn are higher than those of other seasons. Adding more radon gas close to ground level at outdoor locations during the winter and spring season's gives high gamma absorbed dose rate during the winter and spring seasons. Another reason, the radon exhalation rate from soil surface is reduced due to the filling up of pore spaces on the soil in rainy season. Furthermore, radon and its daughter products will be washed out directly to decrease its concentration in the lower atmosphere in rainy season (Stranden, 1985; Chandra-shekhara, 2006).

The frequency distribution of the gamma absorbed dose rates in & around the three largest radiological facilities are shown in **Fig 3**.

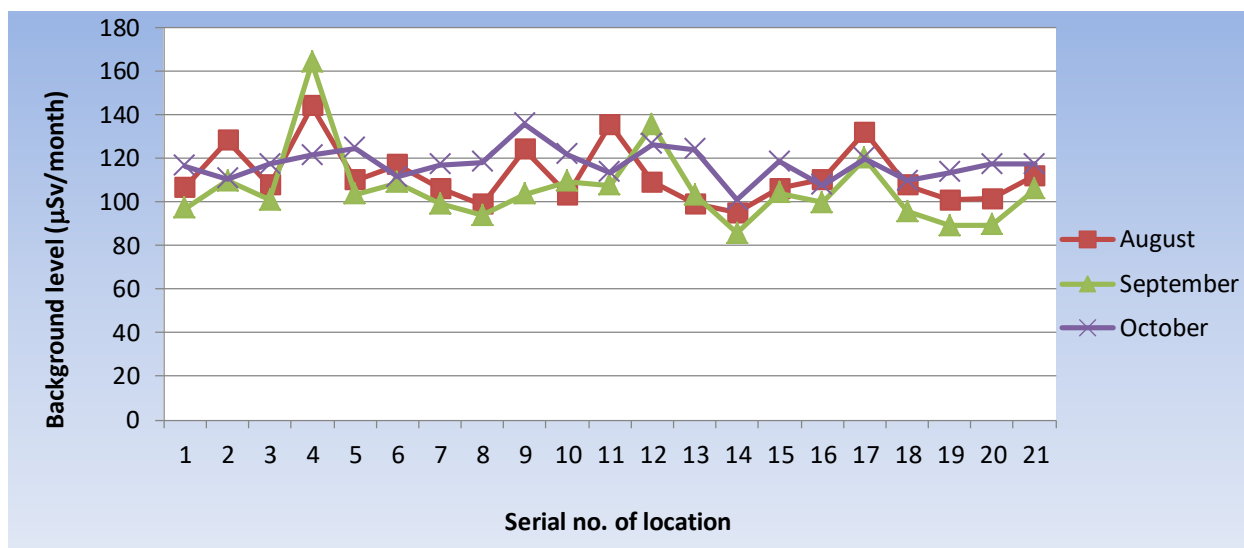


Fig 2: Background radiation level (µSv/month) in & around the three largest radiological facilities of Bangladesh.

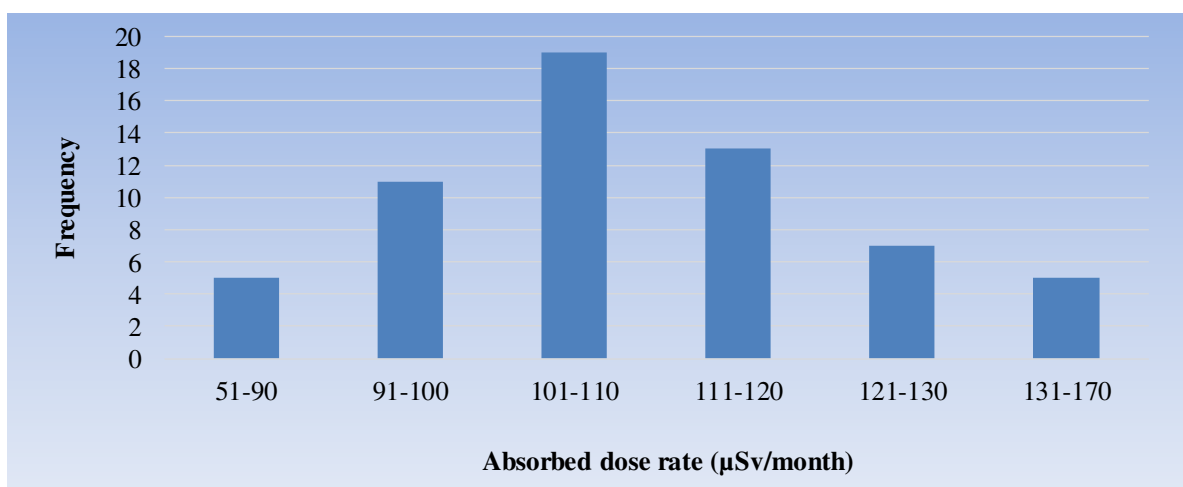
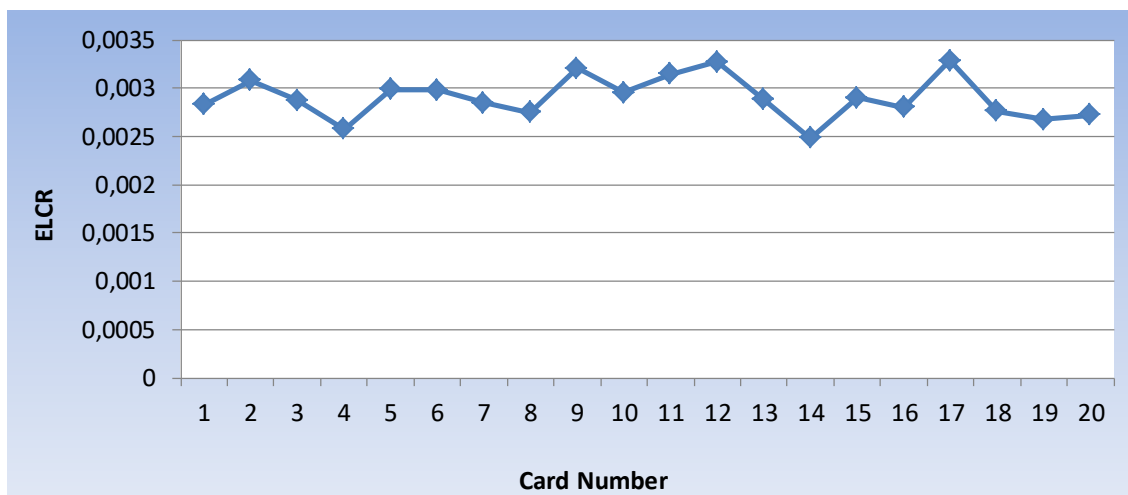


Fig 3: The frequency distribution of the gamma absorbed dose rates in & around the three largest radiological facilities.

**3.2 Excess life-time cancer risk (ELCR) -** The ionizing radiation risk on healthcare workers & public which may arise from the natural & artificial sources need to be evaluated for assessment of medical hazard. It was seen in the international articles that the calculation of the yearly effective dose and the corresponding ELCR on healthcare workers & public at indoor locations of a radiological facility is few numbers comparing to those found at the outdoor locations. It is found in **Table 2** that the evaluated ELCR on healthcare workers & public in & around the radiological facilities is comparable to Malaysia & Nigeria. It is observed from **Table 2**, average ELCR value on healthcare workers & public in some parts of Iran, Iraq, Pakistan, India and Morocco are lower than that

of the radiological facility in Bangladesh. On the other hand, the average ELCR value on healthcare workers & public in Iran, Malaysia, India and Pakistan are higher than Bangladesh. The higher ELCR value on healthcare workers & public in & around the radiological facilities in Bangladesh are mainly contributed from the CT scanners & other nuclear imaging devices used in the hospitals. Moreover, the higher ELCR value on healthcare workers & public at indoor locations of a building can present because of the laboratory equipment's in the hospitals, other decorative stones for the construction of walls & floor tiles and due to the poor ventilation system in the working room's of a hospital building which raise the radon concentration level.



**Fig 4:** Excess life-time cancer risk (ELCR) on healthcare workers & public in and around the three largest radiological facilities of Bangladesh.

**Table 2:** Annual effective dose and ELCR values of selected countries are compared with this study.

Country	Annual effective dose range (mean) in mSv	ELCR	Reference
Iran	1.68	$10.7 \times 10^{-3}$	Hashemi, 2019
Malaysia	0.782	$3.22 \times 10^{-3}$	Abdullahi, 2019
Nigeria	0.54-0.949 (1.06)	$3.71 \times 10^{-3}$	Ononugbo, 2015
Nigeria	0.645	$2.26 \times 10^{-3}$	Etuk, 2017
India	7.56	$20.56 \times 10^{-3}$	Monica, 2016
Iran	0.49	$1.715 \times 10^{-3}$	Zarghani, 2017
Pakistan	0.92	$3.21 \times 10^{-3}$	Qureshi, 2014
Iraq	0.56	$1.64 \times 10^{-3}$	Mohammed, 2017
Pakistan	0.49	$1.629 \times 10^{-3}$	Rafique, 2014
India	0.522	$1.83 \times 10^{-3}$	Murugesan, 2016
Nigeria	0.14-0.19 (0.16)	$0.56 \times 10^{-3}$	Avwiri, 2019
Pakistan	1.0	$3.4 \times 10^{-3}$	Ali, 2019
Morocco	0.05-0.56	$0.19-1.96 \times 10^{-3}$	Kassi, 2018
World	0.3-0.6 (0.48)	$1.16 \times 10^{-3}$	UNSCEAR, 2000, Murugesan, 2016, and Hashemi, 2019
Bangladesh	0.60-0.80 (0.70)	$2.9 \times 10^{-3}$	This study

The calculated average annual effective dose of 0.70 mSv is not expected to add significant risk on healthcare workers & public from the radiological risks study. The reason is that average yearly dose limit for the public as per ICRP 103 (ICRP, 2007) is 1 mSv and the limit is applied for the planned exposure situations and is not related to radiation giving from the existing exposure situations.

**4. CONCLUSION:**

CT scanners and nuclear cardiology contributed more ionizing radiation dose on healthcare workers & public

in medical field. Continuous radiation monitoring in & around of a radiological facility (hospital) would help to control the ionizing radiation exposure on healthcare workers & public through corrections of the radiation generating equipment’s malfunctions as well as improper handling of radioactive substances in the hospitals. The average yearly effective dose and average ELCR on healthcare workers & public in and around the three largest radiological facilities are higher than that of the worldwide average values. The study should be performed routinely in & around a radiological facility to minimize the ELCR on healthcare workers

& public which ensure the safety of their daily work at hospital environment against unnecessary radiation hazard. However, healthcare workers should be more conscious during handling the radiation generating equipments in the hospital and maintain strictly the radiation protection principles of national regulations as well as international recommendations in order to minimize the radiological hazard on healthcare workers & public.

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## 6. CONFLICTS OF INTEREST:

The authors declare no conflict of interest.

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