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Estimation of Radiological Risk on Healthcare Workers and Public in Mymensingh Medical College Hospital Campus, Bangladesh

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ABSTRACT

Ionizing radiation gives immense benefit to patient in the hospital through diagnostic and therapeutic procedures but unnecessary radiation may cause short- and long-term trouble to healthcare workers & public. The purpose of the study is to monitor the real-time radiation in Mymensingh Medical College Hospital (MMCH) Campus of Bangladesh and assessment of radiological risks to healthcare workers & public. Real-time radiation monitoring was accomplished in the MMCH campus from August-September 2022 using digital portable radiation monitoring devices through *In-Situ* technique. The real-time radiation dose rates & calculated annual effective doses to healthcare workers and public ranged from 0.25-4.11 µSv/hr (mean: 1.438 ± 0.331 µSv/h) and 0.438-8.585 mSv (mean: 2.529 ± 0.627 mSv) respectively. The excess life-time cancer risk (ELCR) among healthcare worker & public on MMCH campus were estimated based on the annual effective dose and ranged from 8.436×10^{-3} to 16.572×10^{-3} (mean: 10.667×10^{-3}). Mean ELCR in the MMCH campus is higher than that of the worldwide average value. Real-time radiation monitoring in the big hospital campus is vital for detecting malfunction of the radiation generating equipment and wrong handling of the radioactive substance. The study would help for minimizing the radiological risk to healthcare workers & public in the big hospital campus, thereby would ensure the hospital's environment is free from radioactive contamination.

Keywords: Radiation, Hospital, Healthcare worker, Radiological risk, MMCH, Effective dose, and ELCR.

INTRODUCTION:

Ionizing radiation gives immense benefit to patients in the hospital through diagnosis & therapy practices but intolerable radiation may affliction to healthcare worker & public. Computed Tomography (CT) in the hospital is contributed maximum part of annual effective dose to healthcare worker & public (NCRP, 2009; Mettler F A Jr, 2009). MMCH is a large government hospital that has 39 departments including cardiology, radiology and imaging, radiotherapy, surgery. MMCH has various types of radiation generating equipment such as CT, X-ray, fluoroscopy, etc. Institute of Nuclear Medicine and Allied Sciences (INMAS) was established in the MMCH campus where different types of radioactive materials & radiation generating equipment including SPECT CT used for diagnosis and treatment to patient. Gamma radiation has sufficient energy to ionize the atoms of the material, because it is the most energetic radiation of the electromagnetic spectrum which is 10,000 times higher than that of visible light (Eslami A, 2017; Eslami A, 2016). Gamma radiation gives maximum part of the public exposure that emits from the natural radionuclides.

The leading three natural radionuclides are the primordial radionuclides such as 238U, 232Th & their decay products & 40K that exists trace amount in earth formation. The cosmic rays and terrestrial radiation are responsible for maximum part of the public exposure (Charles M, 2000). Public exposure from the terrestrial radiation stands on originally on geo-logical features of the place such as altitude, latitude & solar system (Agency for Toxic, 1999). Normally, radiation effective dose of the healthcare worker & public at indoor position is higher than that of the outdoor position because building materials contribute few portions of radiation exposure to healthcare worker & public. Building materials, namely rod, brick, concrete, marble, gypsum, sand, granite, lime-stone, aggregate, etc. hold initially natural primordial radionuclides, for example, 238U, 232Th & their decay products and 40K. The know-how of the natural radionuclides of the building materials is important for assessment of the effective dose to healthcare worker & public since human beings spent about 80% time at indoor position and leftover 20% time at outdoor position (UNSCEAR, 2000; UNSCEAR, 2008; UNSCEAR, 1982; Taskin H, 2009). Gamma radiation provides higher part of the effective dose to human beings from all types of the ionizing radiation as it has the longest penetration ability comparing to others (Al-Saleh FS, 2007). Considerable variation of the real-time dose rates was noticed at indoor & outdoor positions of the nuclear installations and hospitals (Al-Ghorable FH, 2005; Arvela H, 2002; Rybach L, 2002; Sagnatchi F, 2008; Tavakoli MB, 2003; Svoukis E, 2007; Rangas-wamy R, 2005; Ononugbo CP, 2015; Alasadi AH, 2016; Ali *et al*., 2022; Biswas *et al*., 2021).

Healthcare worker and public are exposed to radiation externally & internally in the MMCH campus due to the existence of natural and man-made radionuclides. Calculation of the effective dose per year on healthcare worker & public arising from the hospital radiation is very substantial since it is associated with the probability of getting cancer on healthcare worker & public. Estimation of the excess life-time cancer risk (ELCR) on healthcare worker & public due to discharge of ionizing radiation from the large hospital is necessary since those give to collective dose on healthcare worker & public (UNSCEAR, 2008). The objective of the study is to monitor the real-time radiation in the MMCH campus, Bangladesh and to estimate the excess life-time cancer risk on healthcare worker and public based on the annual effective dose.

MATERIALS AND METHODS:

Radiation Monitoring Equipment

Real-time digital movable radiation monitoring instruments were utilized to collect the dose rates at 1 meter over the ground level. The monitoring instruments were set up on the tripod. The radiation monitoring instruments were designed and fabricated by Germany. A non-mandatory intensified leather case including belt connection can redundant protection the monitoring instrument. The monitoring instrument is a Geiger counter with competent form so that human beings can utilize it most effortlessly and safely. The monitoring instrument holds a battery gauge, different unit conversion, real-time radiation dose rate and collective dose demonstration positions and timetable for registering and aware functions. Revolutionary guides hold PC data download via USB cable and extremely small electric power circuit for lengthening battery life. The monitoring instrument registers the prevalence radiation promptly, continually, and steadily. Alteration of pulses per minute to dose rate based on the magnitude of the pulse input. For typical environmental condition, input usually (~ 0.200 µSv/h) the changeover is 142 pulses/minute (User Manual, 2014). The monitoring instrument has the quality for voice signal when the dose rate exceeds the precise level. The default voice signal level is 5µSv/h. If the radiation level in any area beyond the 5 µSv/h, the dose rate will be showed including an additional sign in the display.

Calibration of the Equipment

The monitoring instrument was calibrated in a laboratory with ISO certificate after fabricating. The counter tube is not tending to fatigue in usual environmental condition and hence, it will not obligatory for re-calibration. Nevertheless, if the user country has an ISO certification laboratory, regular calibration is essential. To deal a muster handling, tests should be accomplished for 72 hours against a primary standard. The primary is calibrated against a standard reference source, namely Cs-137. A data log is then created. The monitoring instrument was calibrated after manufacturing. The monitoring instrument was also calibrated in the calibration laboratory, namely the Secondary Standard Dosimetry Laboratory (SSDL) of Bangladesh Atomic Energy

Commission (BAEC) by the gamma-ray standard sources (^{137}Cs, ^{60}Co, etc.) and X-ray Unit. The SSDL under BAEC has been operating since 1991. The SSDL under BAEC is traceable to the Primary Standard Dosimetry Laboratory (PSDL) of the National Physical Laboratory (NPL), United Kingdom. The SSDL under BAEC has X-ray Unit (30 kV-225 kV) for calibration of radiation generating equipment. The management of SSDL under BAEC is protected fulfilling the requirement of the Inter-national Atomic Energy Agency (IAEA)/ World Health Organization (WHO) network of the SSDLs. Hence, the real-time dose rates of the monitoring instrument have been achieved to meet the inter-national monitoring system. The monitoring instrument has the capacity to exactly monitor the dose rates in the range of 0.01-5000 µSv/hr (User Manual, 2014).

Radiation Monitoring Procedure

The real-time radiation monitoring in the MMCH campus was accomplished in August-September 2022 following In-Situ method. The real-time radiation monitoring in the MMCH campus was performed at various outdoor places such as nearby positions of the radiation generating equipment rooms, for example, X-ray Machines, CT scan machines, CT angiogram, etc. & outside of the INMAS building where different types of radioactive substances were stored. The real-time radiation monitoring was completed at 32 choosing locations in the MMCH campus and data acquiring time for one monitoring point (MP) was almost 1 hour. The digital movable monitoring instrument was positioned on tripod at 1meter over the ground level. The MP was recorded using a GARMIN eTrex HC Series Personal Navigator. The instrument shows the aceptable effectiveness of Garmin high-detectable GPS and the outermost distance mapping to make an unparallel handy GPS receiver (Owner's Manual-GARMIN eTrex HC Series, 2007).

Radiation Monitoring Site

32 MPs were selected in the MMCH campus and those MPs are marked out using Garmin HC series Personal Navigator. The longitude/latitude of the study is varied from N: 24.44669 to N: 24.44503 and from E: 90.24678 to E: 90.24483. MMCH has 39 departments, namely, radiology & imaging, radiotherapy, cardiology, anatomy, physiology, biochemistry, pathology, microbiology, pharmacology, forensic medicine, community medicine, medicine, respiratory medicine, neurology, physical medicine, nephrology, gastroenterology, endocrinology, heaptology, hematology, surgery, urology, ortho-surgery, burn & plastic surgery, ortho-tromatology, neurosurgery, paediatrics surgery, gynae & obs., paediatrics, paediatrics nephrology, paediatrics hematology & oncology, neonatology, ophthalmology, ENT & head neck surgery, anesthesiology, dermatology, psychiatry, blood transfusion medicine, dental unit. The MPs were chosen at outdoors adjacent to the radiation generating equipment rooms and radioactive material handling & storage rooms.

Estimation of Radiological Risk

Effective dose is generally applied for calculation of the healthcare worker & public exposure and possible biological effects in regard to public exposure that is achieved from the equation underneath:

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

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

Here, AED is the annual effective dose, D_{in} and D_{out} are the mean absorbed dose rates in air at indoor & outdoor positions respectively, T is the time in hour, OF_{in} and OF_{out} is the indoor and outdoor positions occupancy factors that is the part of time (%) exhausting of human beings. Generally, the value of OF_{in} and OF_{out} are 80% and 20% respectively (UNSCEAR, 1988).

The excess life-time cancer risk (ELCR) is estimated based on the equation underneath:

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

Here, AED is the annual effective dose to healthcare worker & public, DL is the duration of life of Bangladeshi inhabitant (http://en.worldstat.info, 2023) and RF is risk factor (Sv^{-1}) which is a fatal cancer risk per Sievert. For stochastic effects yielding from low-level radiation, ICRP 103 recom-mended the value of 0.057 per Sievert to public (ICRP, 2007).

RESULTS AND DISCUSSION:

Annual effective dose

Annual effective dose on healthcare worker and public in the MMCH campus in Bangladesh (where radiation generating equipment and radioactive substances were being used for diagnosis & treatment to patient) were calculated based on the international reputation studies (UNSCEAR, 2000; Hashemi M, 2019; James IU 2015; Zarghani H, 2017; Abdullahi

S, 2019; Monica S, 2016). It is supposing that Bangladeshi populace exhausts about 20% time at outdoor position and leftover 80% time at indoor position, then annual effective dose on healthcare worker and public in the MMCH campus of Bangladesh were calculated. Table 1 demonstrates the annual effective dose on healthcare worker and public from August-September 2022. The yearly effective dose to healthcare worker and public in the MMCH campus were ranged from 0.438-8.585 mSv (mean: 2.529 ± 0.627 mSv). The average yearly effective dose on healthcare worker & public due to the presence of radiation generating equipment and radioactive materials in the MMCH campus is five-fold higher than that of the global average of 0.48 mSv (ICRP, 2007). The average yearly effective doses were usually upmost at positions next to the CT rooms, CT angiogram rooms, X-ray rooms, SPECT-CT rooms and radioactive material handling, storage & dispensing rooms of the INMAS. Notwithstanding, the average yearly effective doses on healthcare worker & public next to the CT rooms, CT angiogram rooms, X-ray rooms, SPECT-CT rooms at several positions were considerably large, yet those values are smaller than the authorized limit of 20 mSv for healthcare worker (ICRP, 2007). Additionally, the yearly authorized limit to public (1 mSv) ought to be taken into consideration from planned exposure situation and is not relevant to the existing exposure situation. The aforementioned yearly effective doses on healthcare worker & public were summation of the planned exposure and existing exposure. The minimum yearly effective dose on healthcare worker & public were found out at position far apart from the CT rooms, CT angiogram rooms, X-ray rooms, SPECT-CT rooms and radioactive substances handling, storage and dispensing rooms. When the utmost number of radiations generating equipment (CT, X-ray, SPECT-CT, etc.) in the hospital were kept in "on-state", that moment high radiation dose rates were found out at positions next to radiation generating rooms. **Table 1** Demonstrates the real-time radiation monitoring dose rates at 32 positions in the MMCH from August-September 2022. It is observed from the Table 1 that real-time radiation dose rates & yearly effective dose on healthcare worker and public in the MMCH campus is fairly higher than those of the green field.

Table 1: Real-time radiation monitoring in the MMCH campus from August-September 2022.

SL No.	Latitude	Altitude	Radiation dose rate (µSv/hr)			Annual effective dose due to radiation (mSv) ± SD
			Mean	Range	SD	
1	N24.44509	E090.24609	1.4325	1.33 -1.54	0.0677	2.5097±0.1185
2	N24.44527	E090.24483	1.4165	1.31-1.53	0.0636	2.4817±0.1108
3	N24.44635	E090.24536	1.3775	1.28 -1.49	0.0637	2.409±0.1116
4	N24.44650	E090.24549	1.5235	1.2 – 2.07	0.2314	2.6691±0.4419
5	N24.44660	E090.24550	1.5385	1.43 -1.67	0.0744	2.6954±0.1295
6	N24.44674	E090.24553	1.3275	1.21 -1.47	0.0838	2.3257±0.1462
7	N24.44667	E090.24587	1.255	1.16 -1.35	0.0593	2.1987±0.1036
8	N24.44669	E090.24600	2.234	0.99 -4.11	1.0871	3.9139±1.9045
9	N24.44650	E090.24640	1.5965	1.51 -1.71	0.0621	2.797±0.1081
10	N24.44647	E090.24677	1.4055	1.31 -1.51	0.0603	2.4633±0.1059
11	N24.44528	E090.24572	1.3245	0.49 -1.75	0.4022	2.2951±0.7238
12	N24.44523	E090.24599	1.3635	1.18 -1.62	0.1158	2.3888±0.2029
13	N24.44520	E090.24585	1.5335	1.42 -1.64	0.0713	2.6867±0.1248
14	N24.44522	E090.24498	1.356	1.26 -1.47	0.0613	2.3757±1.375
15	N24.44645	E090.24523	1.1965	1.10 -1.31	0.0621	2.0963±0.1082
16	N24.44599	E090.24556	1.4315	1.35 -1.53	0.0529	2.5079±0.0927
17	N24.44508	E090.24637	1.404	1.30 -1.50	0.0609	2.7585±1.375
18	N24.44503	E090.24623	1.365	1.27 -1.46	0.0593	2.3915±0.1036
19	N24.44513	E090.24568	1.4695	1.21 -1.69	0.1447	2.5745±0.2531
20	N24.44517	E090.24546	2.0135	1.42 -2.91	0.4551	3.5276±0.7975
21	N24.44532	E090.24554	1.5385	1.34 -1.75	0.1265	2.6954±0.2211
22	N24.44519	E090.24537	1.3555	1.26 -1.46	0.0611	2.3748±0.1065
23	N24.44661	E090.24596	1.3865	1.28 -1.49	0.0645	2.4291±0.1124
24	N24.44662	E090.24608	1.4745	1.23 -1.81	0.1767	2.5929±0.3155
25	N24.44609	E090.24678	1.369	1.05 -1.69	0.1714	2.3985±0.2998
26	N24.44562	E090.24671	1.1375	1.01 -1.26	0.2608	1.9929±0.1296
27	N24.44540	E090.24668	1.1565	1.05 -1.27	0.0637	2.0262±0.1111

28	N24.44511	E090.24662	1.1615	0.25 -1.56	0.3125	2.0349±0.5476
29	N24.44506	E090.24658	1.4955	1.31 -1.72	0.1167	2.6201±0.2043
30	N24.44510	E090.24582	1.4625	0.49 -2.39	0.4785	2.5623±0.8384
31	N24.44518	E090.24611	1.475	1.38 -1.57	0.0593	2.5842±0.1036
32	N24.44637	E090.24524	1.4495	1.33 -1.56	0.0753	2.5395±0.1309

Fig. 1 demonstrates the average yearly effective dose for each position on healthcare worker & public normalized to the smallest yearly effective dose. It is noticed from **Fig. 1**, average yearly effective dose for two positions (serial numbers 8 & 20) in the MMCH campus are practically greater than those of the other positions. The motive for greater real-time dose rates at two positions (serial numbers 8 & 20) is that these two positions are next to the CT rooms. Conversely, it is marked from **Fig. 1**, average yearly effective dose for two positions (serial numbers 15 & 26) in the MMCH campus are practically lesser than those of the other positions. The motive for lesser real-time dose rates at two positions (serial numbers 15 & 26) is that these two positions are very far apart from the CT rooms.

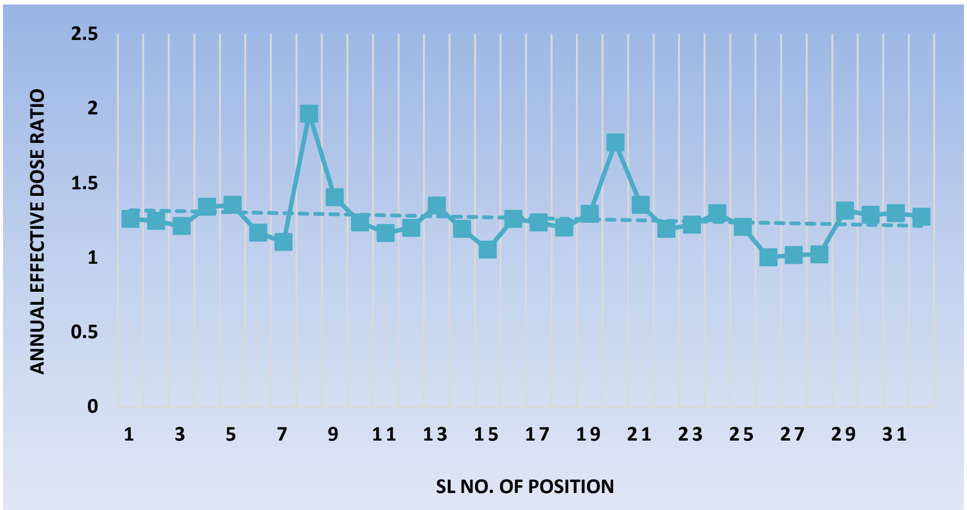

Fig. 1: Average yearly effective dose for each position normalized to the lowest yearly effective dose.

Fig. 1 & **Table 1** demonstrate the fluctuation of the dose rates in the MMCH campus were contributed from the natural & man-made sources. The natural radiation is emerging from the construction materials of the building, soil and water. The man-made radiation is arising from the radiation generating equipment & radioactive material in the hospital that is being used to diagnosis and treatment to patients. The alteration of the yearly effective dose in the MMCH campus at different positions were depended on many reasons: (1) number of radiation generating equipment were remained in "on" or "off" conditions during the real-time radiation monitoring period; (2) real-time radiation monitoring positions are next-door or far away from the radiation generating equipment or radioactive substances handling, storage or dispensing rooms; (3) weather conditions during the real-time radiation monitoring period. It was attributed in the international article (Bellia S, 2001) that radiation dose rates at outdoor positions in the spring and autumn were moderately higher than those of other seasons. Aggregation of extra radon gas adjoining to the ground at outdoor positions throughout the winter and spring seasons were provided additional gamma dose rates amid the winter and spring seasons. Again, radon emanation rates from the soil surface are reduced due to the infusing of cavity spaces in soil in the rainy season. Furthermore, radon and its by-products are generally washed out straightway for declining of its concentration in the lesser atmosphere in rainy season (Stranden E, 1985; Chandrashekara MS, 2006). The frequency distribution of the real-time radiation dose rates in the MMCH campus in Bangladesh is demonstrated in below **Fig. 2**.

Excess life-time cancer risk (ELCR)

Excess life-time cancer risk (ELCR) on healthcare worker & public in the MMCH campus should be estimated in order to investigate the medical radiation hazard. The medical radiation hazard is appeared from the natural and man-made radiation sources in the hospital. It was viewed in the international papers that calculation of yearly effective dose and afterward ELCR on healthcare worker and public at indoor positions of the hospital is the modest numbers comparing to those seen at the outdoor positions.

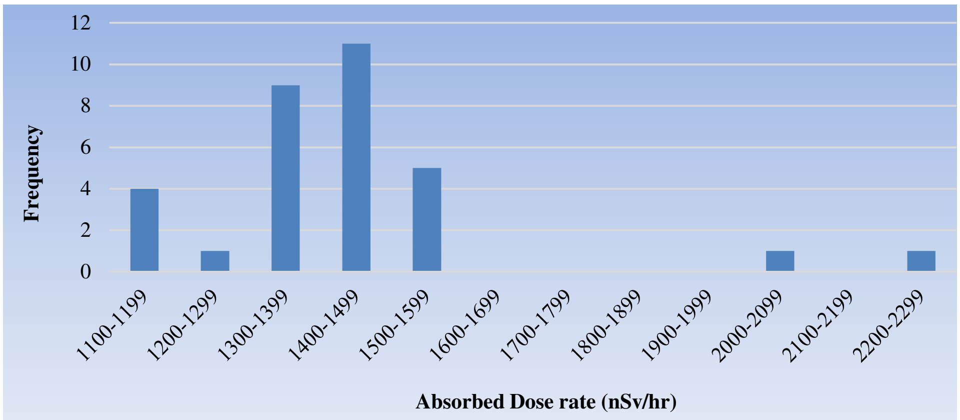

Fig. 2: The frequency distribution of the real-time radiation dose rates at 32 positions in the MMCH campus.

It is viewed in **Table 2** that the estimated ELCR on healthcare worker & public in the MMCH campus is consistent to Iran. It is perceived from **Table 2**, average ELCR on health-care worker & public at few areas of Iraq, Iran, India, Malaysia, Pakistan, Nigeria & Morocco are slighter than that of the MMCH campus in Bangladesh. On the other hand, average ELCR at few areas of India are greater than that of the MMCH campus in Bangladesh. Somewhat high ELCR on healthcare worker & public in the MMCH campus of Bangladesh are primarily given from the CT, CT angiogram, X-ray machine, etc. operated in the hospital to diagnosis & treatment to patients. In addition to that, the quite high ELCR on healthcare worker & public at indoor positions of the building persist due to the apparatus (electronics) in the laboratory of the hospital, surplus gorgeous stones on the structure of the walls & floor tiles & due to the nonexistence of right ventilation system in the laboratory, working rooms, patient wards of the hospital building that enhancing the radon concentration.

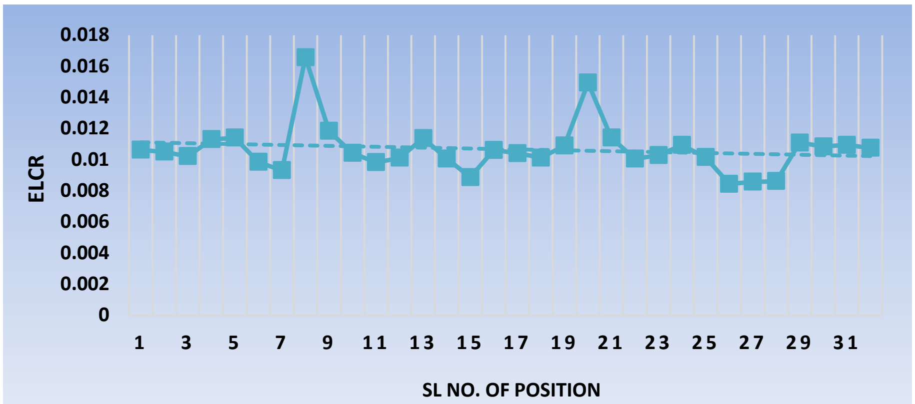

Fig. 3: Excess life-time cancer risk (ELCR) on healthcare worker & public in the MMCH campus of Bangladesh.

Table 2: Yearly effective dose & ELCR on healthcare worker and Public in the MMCH campus are compared to other countries.

Country	Yearly 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	0.19-1.96 X10^{-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	**0.438-8.585 (2.529)**	**10.667 ×10^{-3}**	**present study**

The estimated average effective dose of 2.529 mSv may not be presumed to introduce weighty risk on healthcare worker from the radiological risk perspective. The motive is that average yearly effective dose limit to healthcare worker as per ICRP 103 (ICRP, 2007) is 20 mSv for 5 consecutive years & the limit is pertinent to the planned exposure practice and is not related to radiation arising from the existing exposure practice.

CONCLUSION:

CT and nuclear cardiology are liable for additional ionizing radiation effective dose on healthcare worker and public in the hospital. Real-time radiation monitoring in the large hospital campus would promote to minimize the ionizing radiation risk on healthcare worker & public by means of assessment of the radiation generating equipment's faults and incorrect management of radioactive material in the hospital campus. The mean yearly effective dose and mean ELCR on healthcare worker & public in the MMCH campus of Bangladesh are much greater than those of the global mean values. Study should be carried out routinely in the large hospital campus for diminishing the ELCR on healthcare worker & public which confirm the safety of their everyday work in the hospital campus against intolerable radiation risk. Besides, healthcare worker must be attentive during operation of the radiation generating equipment and handling of the radioactive substances in the hospital. Additionally, healthcare worker has to comply with the national rules relevant to the radiation protection and international recommendations (particularly IAEA and ICRP) for reduction of the intolerable radiation risk throughout their daily work in the environment of the hospital.

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CONFLICTS OF INTEREST:

The authors declare no conflict of interest.

REFERENCES:

1) Abdullahi S, Ismail AF, and Samat S. (2019). Determination of indoor doses and excess lifetime cancer risks caused by building materials containing natural radionuclides in Malaysia. *Nuclear Engineering & Technology,* **51**, 325-336.https://doi.org/10.1016/j.net.2018.09.017
2) Agency for Toxic Substances and Disease Registry (ATSDR), (1999). Toxicological profile for ionizing radiation. Atlanta, GA: US, *Dept. of Health and Human Services, Public Health Service*.
3) Alasadi AH, Alaboodi AS, and Abojassim AA. (2016). Survey of absorbed dose rates in air of Buildings Agriculture and Sciences in University of Kufa at Al-Najaf Governorate, Iraq. *J. of Chemical & Pharmaceutical Research*, **8**(4), 1388-1392.https://www.jocpr.com
4) Al-Ghorable FH. (2005). Measurement of environmental terrestrial gamma radiation dose rate in three mountainous locations in western region of Saudi Arabia. *Environ. Res.*, **98**,160-166. https://doi.org/10.1016/j.envres.2004.06.004
5) Ali M, Bano S, and Alam M. (2019). Indoor and outdoor gamma radiation level in mud and concrete houses and the annual effective dose and excess lifetime cancer risk in Gahkuch Ghizer valley of Hindukush Range. *J. of Him. Earth Sci.*, **52**(2), 177-184.
6) Ali MA, Rahman MS, & Sikder MKU. (2022). Estimation of radiological risk on medical staff and public inside & outside of three large hospital campuses in Dhaka, Bangladesh. *Eur. J. Med. Health Sci*., **4**(3), 70-78. https://doi.org/10.34104/ejmhs.022.070078

7) Al-Saleh FS. (2007). Measurement of indoor gamma radiation and radon concentrations in dwellings of Riyadh City, Saudi Arabia. *Appl. Radiat. Isot.,* **65**,843-848. https://doi.org/10.1016/j.apradiso.2007.01.021
8) Arvela H. (2002). Population distribution of doses from natural radiation in Finland. *Int. Congr. Ser.*, **1225**, 9-14.
9) Avwiri GO, Ekpo J, and Chad-Umoren YE. (2019). Occupational hazards from outdoor and indoor radiation in oil fields facilities in Rivers State, Nigeria. *Asian of Physical & Chemical Sciences,* **7**(4), 1-7. https://doi.org/10.9734/AJOPACS/2019/v7i430099
10) Bellia S, Basile S, and Rizzio S. (2001). Seasonal variation of air karma in the Vulcano Porto area (Aeolian Islands, Italy). *Appl. Radiat. Isot.*, **54**,701-706.
11) Biswas A, Rahman MS, Yeasmin S, Sikder MKU. (2021). Assessment of radiation risk on healthcare workers and public in & around two largest hospital campuses of Bangladesh, *Eur. J. Med. Health Sci*., **3**(3), 48-57. https://doi.org/10.34104/ejmhs.021.048057
12) Charles M. (2001). UNSCEAR Report, Sources and Effects of Ionizing Radiation. *J. Radiol. Prot.,* **21**(1), 83-86. https://iopscience.iop.org/article/10.1088/0952-4746/21/1/609
13) Chandrashekara MS, Sannappa J, and Paramesh I. (2006). Studies on atmospheric electrical conductivity related to radon its progeny in the lower atmosphere at Mysore. *Atoms Environ.*, **40**, 87-95. https://doi.org/10.1016/j.atmosenv.2005.09.026
14) Etuk S E, Antia A D, Agbasi OE. (2017). Assessment and evaluation of excess lifetime cancer risk for occupants of university of Uyo permanent campus, Nigeria. *Inter J. of Physical Research*, **5**(1), 28-35. https://doi.org/10.14419/ijpr.v5i1.7564
15) Eslami A, Akhoondi L, and Goorani A. (2017). Outdoor gamma radiation measurement in order to estimate the annual effective dose and excess lifetime cancer risk for residents of Tehran, Iran. *J. Air Pollut. Health*, **1**(4), 243-250.
16) Eslami A, Saghi MH, and Rastegar A. (2016). Assessment of background gamma radiation and determination of excess lifetime cancer risk in Sabzebar city, Iran in 2014. *Tehran Univ. Med. J.*, **73**(10), 751-755.
17) Hashemi M, Akhoondi L, and Eslami A. (2019). Assessment of indoor gamma radiation and determination of excess lifetime cancer risk in Tehran in winter and spring 2017. *Radiat. Prot. Dosim.*, **184**(2), 148-154. https://doi.org/10.1093/rpd/ncy193
18) Harshaw Model 4500, Manual TLD Workstation Operator's Manual. (2007). (Cochran Road, Solon, Ohio) (Pub. No. 4500-0-O-0598-002, 6801).
19) IAEA-International Atomic Energy Agency. (1999). Assessment of occupational exposures due to external sources of radiation. Safety Guides Series No. RS-G-1.3, Vienna, Austria.
20) ICRP-International Commission on Radiological Protection. (1997). General Principles for the radiation protection of workers, First edn. Annals of the ICRP, **27**(1), *Pergamon Press, Oxford and New York*.
21) ICRP. (2007). Recommendations of the ICRP: Annals of the ICRP (International Commission on Radiological Protection), **37**, pp.2-4. https://www.icrp.org/
22) James IU, Moses IF, and Ikoh UE. (2015). Measurement of indoor and outdoor back-ground ionising radiation levels of Kwali Gene-ral Hospital, Abuja. *J. Appl. Sci. Env.. Manag.* **19** (1), 89-93. https://doi.org/10.4314/jasem.v19i1.12
23) Kassi B, Boukhair A, and Benjelloun M. (2018). Assessment of exposure due to technologically enhanced natural radioactivity in various samples of Moroccan building materials. *World J. of Nucl. Sci. & Technol.*, **8**, 176-189. https://doi.org/10.4236/wjnst.2018.84015
24) Mettler F.A. Jr., Bhargavan M., and Faulkner K. (2009). Radiologic and nuclear medicine studies in the United States and worldwide: frequency, radiation dose, and comparison with other radiation sources-1950-2007. *Radiology,* **253**(2), 520-531.
25) Mohammed RS, Ahmed RS. (2017). Estimation of excess lifetime cancer risk and radiation hazard indices in Southern Iraq. *Environ. Earth. Sci.*, **76**, 303. https://doi.org/10.1007/s12665-017-6616-7
26) Monica S, Visnu PAK, and Jojo PJ. (2016). Estimation of indoor and outdoor effective doses and lifetime cancer risk from gamma dose rates along the coastal regions of Kollam

District, Kerala. *Radiat. Prot. Environ.,* **39**, 38-43. https://doi.org/10.4103/0972-0464.185180

27) Murugesan S, Mullainathan S, and Meenakshisundaram V. (2016). Environmental radioactivity, magnetic measurements and mineral analysis of major south Indian river sediments. *J. Mater. Environ. Sci.*, **7**(7), 2375-2388.
28) NCRP, (2009). The National Council on Radiation Protection & Measurements. Report No. 160, *Bethesda, MD 20814-3095, USA.* https://ncrponline.org/
29) Ononugbo CP, Avwiri GO, and Tutumeni G. (2015). Estimation of indoor and outdoor effective doses from gamma dose rates of residential building in emelogu village in rivers state, Nigeria. *Inter Res J. of Pure & Appl Phy*, **3**(2), 18-27. https://www.eajournals.org/
30) Qureshi A A, Calligaris C, and Waheed A. (2014). Evaluation of excess lifetime cancer risk due to natural radioactivity in the rivers sediments of northern Pakistan. *J. Radiat. Res. & Appl. Sci.*, **7**, 438-447. https://doi.org/10.1016/j.jrras.2014.07.008
31) Rafique M, Rahman S, and Matiullah.(2014). Evaluation of excess lifetime cancer risk from gamma dose rates Jhelum Valley. *J. Radiat. Res. and Appl. Sci.*, **7**, 29-35.
32) Rangaswamy DR, Srilatha MC, and Sannappa J. (2015). Measurement of terrestrial gamma radiation dose and evaluation of annual effective dose in Shimoga District of Karnataka State, India. *Radiation Protection & Environment,* **38**(4), 154-159. https://doi.org/10.4103/0972-0464.176152
33) Rybach L, Bucher B, and Schwarz G. (2002). Radiation doses of Swiss population from external sources. *J. Environ. Radiat.,* **62**, 277-286. https://doi.org/10.1016/s0265-931x(0)00169-2
34) Sagnatchi F, Salouti M, Eslami A. (2008). Assessment of annual effective dose due to natural gamma radiation in Zanjan (Iran). *Radiat. Prot. Dosim.*, **132**, 346-349.
35) Stranden E, Kolstad AK, and Lind B. (1985). The influence of moisture & temperature on radon exhalation. *Rad. Prot. Dosim.*, **7**, 55-58.
36) Svoukis E, Tsertos H. (2007). Indoor and outdoor In-situ high-resolution gamma radiation measurements in urban area of Cyprus. *Radiat. Prot. Dosim.*, **123**(3), 384-390. https://doi.org/10.1093/rpd/ncl159
37) Tavakoli MB. (2003). Annual background radiation in the city of Isfahan. *Med. Sci. Monit.*, **9**, 7-10.
38) Taskin H, Karavus M, Ay P, and Karahan G. (2009). Radionuclides concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey. *J. Env. Radi.* **100**(1), 49-53. https://doi.org/10.1016/j.jenvrad.2008.10.012
39) United Nations Scientific Committee on the effects of atomic radiation (UNSCEAR), (2000). Sources and Effects of Ionizing Radiation. *Annex A: Dose assessment methodologies, New York, USA*, **1**. https://www.unscear.org/unscear/en/publications/2000_1.html
40) United Nations Scientific Committee on the effects of atomic radiation (UNSCEAR), Report to the General Assembly, (2008). New York, USA, **1**. pp.260.
41) United Nations Scientific Committee on the effects of atomic radiation (UNSCEAR), Report to the General Assembly, (1982). Ionizing radiation: sources and biological effects, *USA*. https://www.unscear.org/unscear/en/publications/1982.html
42) Zarghani H, Jafari R. (2017). Assessment of outdoor and indoor background gamma radiation, the annual effective dose and excess lifetime cancer risk in Birjand, Iran. *Jundishapur J. Health. Sci.*, **9**(3), 1-4. https://doi.org/10.5812/jjhs.40791

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