

External radiation dose measurement in private nuclear medicine and diagnostic x-ray facilities in Bangladesh

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Abstract: *The application of ionizing radiation in medical sectors for imaging and treatment of patient is expanding day by day. X-ray machines are very common modalities in medical facilities which provide diagnostic information about the human organs. On the other hand, different kinds of radioisotopes are utilized for imaging of patient organ in nuclear medicine. Some isotopes are also used for treatment purposes. However, during handling of radiological devices/radioisotopes radiation professional, patient, public may receive unwanted radiation exposure which can be harmful for them. However, there is an exposure limit for the occupational and public. Usually, there are two kinds of biological effects of radiation, one is deterministic and another stochastic. There is threshold level of radiation dose for the first one to occur but for the second one no limit of radiation dose. Even at small amount of dose stochastic effect may occur in the form of a genetic disorder and cancer disease. Therefore, assessment of radiation dose is always vital in the medical radiation facility. In the current study radiation dose is measured in some x-ray and nuclear medicine facilities by using two GM counters. It has been observed that occupational receive more radiation doses in nuclear medicine facilities compared to x-ray where as public receive fairly less amount of dose from the nuclear medicine activities. On the other hand, public is more vulnerable to radiation in x-ray facilities compared to nuclear medicine. Therefore, from the radiation safety point of view, to limit the exposure level of the concerned personnel is very important hence the adequate shielding arrangements should be in place according to national and international requirements.*

Keywords: Radiation exposure, Threshold dose, Exposure limit, Radiation Safety, Radioisotope.

Introduction:

Radiation and radioactive substances are natural and permanent features of the environment and thus the risk associated with radiation exposure can only be restricted, not eliminated entirely. Additionally, the use of human made radiation is wide spread. Sources of radiation are essential to modern health care: the use of radiation in radiology and nuclear medicine plays vital role particularly in diagnosis of the patient. The small amount of

activity of radioisotope is injected to the patient for diagnosis of the nuclear medicine patient. But for the treatment higher activity of radioisotope (I-131) is delivered to the patient. The acceptance by society of risks associated with radiation is conditional on benefits to be gained from the use made of radiation. Nonetheless, the risks must be restricted and protected against by the application of radiation safety standards developed by national and international organizations [1, 2].

Nuclear medicine is an expanding field in Bangladesh. Nuclear techniques used in this medical sector primarily for the diagnosis of patho-physiological processes of body. In Bangladesh the first nuclear medicine center was set up in 1962 at Dhaka Medical College Campus. Now 19 nuclear medicine facilities are functioning throughout the country. Wide ranges of radioisotopes are used in nuclear medicine such as Tc-99m, I-131, F-18, I-125 etc. Some isotopes are also used calibration of the equipments. The sophisticated and sensitive equipment like gamma camera, single photon emission computed tomography (SPECT), positron emission tomography-computed tomography (PET-CT), bone densitometer, thyroid uptake system are utilized in nuclear medicine. The diagnosis or treatment in nuclear medicine requires team efforts. The technologists have to be careful during delivery of positron-emitting radionuclides to the patients for the PET study. Because there is always chance for having high exposure in the hands of the individual [3]. In the case of diagnostic x-ray facilities, there are about 3500 licensed x-ray facilities running in the country. Most of the facilities do not have trained operator. The design and layout of the facilities are not up to the mark from the radiation shielding point of view according existing nuclear safety and radiation control rules, 1997 [4]. It can be noted that in order to design an x-ray room here in Bangladesh usually the facility owner does not perform shielding assessment to build up the wall, entrance door and control panel barrier [5]. Nonetheless, the qualities of the old x-ray machines are not good too. In most of the cases, the performance tests of the machines are not carried out since its installation in facility. Therefore, the practice causes unwanted radiation exposure. But most people forget or are not aware of radiation effects that may happen even at low doses which known as stochastic effect [6]. Stochastic effect may occur if an irradiated cell is modified rather than killed. Modified cells may turns into a cancer after a long time. It is therefore essential stringent radiation protection requirements to apply in order to ensure safety of the worker, patient, public and the environment as well [7]. In this study, radiation dose for occupational has been assessed in the different location of the nuclear medicine and x-ray facilities during diagnosis of the patient by imaging equipment such as gamma camera, PET-CT, conventional x-ray, etc. Radiation dose is also measured outside the imaging room for estimation of public dose. To reduce the happening of the deterministic effect in the public and the occupational ICRP standards are required to follow and these standards have been incorporated in the existing nuclear safety and radiation control rules (NSRC)'97 in Bangladesh. According to these standards the annual dose limit for occupational worker is 20 mSv and for the public restricted to 1 mSv [4].

Materials and Method:

Two private nuclear medicine facilities in Dhaka city and thirteen medical diagnostic x-ray facilities of Gazipur district are randomly selected for the present study. Presently, in nuclear medicine imaging equipment like, gamma camera, single photon emission computed tomography (SPECT), positron emission tomography (PET) etc are being used for the patient study. Among the radioisotopes Tc-99m, I-131, F-18, I-125 are mainly used. Besides this some other radioisotopes Cs-137, Co-60, Co-57 etc. are also used for the quality control of the equipment. The

activity of the isotopes utilized for the imaging of the human organs ranges from 1 mCi to 25 mCi. However, the reference activity of the technetium generator remains up to 400 mCi. Therefore, during collection of Tc-99m from the generator occupational may receive high amount of exposure. During injection of radiopharmaceuticals to the patient, nuclear medicine professional may also be overexposed to radiation. At the same time huge amount of radioactive wastes are generated every day from the nuclear medicine activities. Therefore, becoming contaminated with radioactive substance remains a high probability. In this study, radiation dose is measured in different locations of nuclear medicine department by using two GM counters. Before using GM counters for the dose rate measurement, it has been calibrated at secondary standard dosimetry laboratory (SSDL). On the other hand, ion chamber-type dosimeter could be an ideal device to measure dose rate of x-ray dose. However, during this study dose rates for the x-ray facilities at various locations of interest were measured using G-M tube-type dosimeter meter calibrated against gamma ray. Hence, because of the factors of calibration and response time, there may be a little discrepancy between the measured dose rate and the actual dose rate at the locations of interest [6]. This discrepancy still carries a meaning but have a little influence on the significance of the overall result.

Results and Discussion:

Many radionuclides in nuclear medicine emit penetrating radiation and there is a hazard from external exposure, at a distance from the source. Mostly unsealed radioactive sources are utilized in nuclear medicine. With unsealed sources of radioactive material there is a possibility of an additional hazard. The radioactive contents, usually liquids, are intended to be dispensed from the container. It is possible that leakage and spills during handling of unsealed sources may lead to contamination. In the present study, in one facility (NMC-1) Tc-99m has been found in use which remains in the form of liquid and emits gamma radiation of 140 KeV.

Depending on the patient study the activity of isotope is determined. The reference activity of the Tc-99m generator remains very high from where expected amount of activity is taken into the vial and estimated by dose calibrator according to the demands of patient study. In the facility -1, 10 GBq of Tc-99m isotope is used every day activities. In the process of patient imaging radioisotope is transferred from one location to another location. Radiopharmaceuticals are injected to the patients based on the type of the diagnosis in the isotope dispensing room. Ultimately patient becomes a radioactive source until the radioactivity eliminated from the body by physically decaying or biologically excreted. Table 1 shows the investigation of radiation dose rate at different locations of the facility-1. The radiation dose rate was measured in the hot lab at the Tc-99m generator surface 176 μ Sv/h which is about 18 times higher than the permissible limit of occupational worker [4]. Furthermore, occupational workers receive more radiation doses than their limit near fume hood and waste bin. The maximum dose was recorded in the gamma camera room near patient bed 5.6 μ Sv/h which is lower than the permissible limit for the professional. In

the public area that is in front of the entrance doors of gamma camera room, hot lab radiation dose were recorded in the background level (0.25-0.3 $\mu\text{Sv/h}$). The shielding infrastructure of the room, door etc were developed according to national act and regulations thus the reduced radiation exposure level was recorded in the public area in these sort of facilities [2, 4].

Floor	0.3
Fume Hood	14.32
Waste Bin Surface	32

Table 1: Dose Rate Measurement in Nuclear Medicine Facility 1

Facility	Location 1 (Gamma Camera Room)	Dose Rate in $\mu\text{Sv/h}$	Location 2 (Hot lab)	Dose Rate in $\mu\text{Sv/h}$
LABAID Ltd (Facility ID NMC-1)	Console Area	0.3	Entrance Door	0.3
	Entrance Door	0.3	Sink	0.5
	Floor	0.3	Lead Block Top	7.5
	Patient Bed (Without Patient)	0.3	Dose Calibrator Surface	0.5
	Patient Bed (With Patient)	5.6	Tc-99m Generator Surface	176

In the facility-2 F-18(FDG) fluoro-de-oxyglucose radiopharmaceutical is utilized for the PET-CT imaging system. The reference activity of F-18 isotope generator is 220 mCi from which 10 mCi is injected to the patient for whole body scan. Dose rate at different locations of the facility-2 have been represented in the table 2. Maximum amount of radiation level 80 $\mu\text{Sv/h}$ was estimated at the F-18 generator surface in the hot lab. Apart from this, significant amount of radiation exposure was recorded at the waste bin and the basin in the same area (hot lab) and in the patient waiting place 50 $\mu\text{Sv/h}$ was measured. In the PET-CT room radiation exposure were recorded in the background level. On the other hand the radiation levels were recorded at the background level in the public area that is in front of the entrance doors of the different room in the department. Therefore, it is a matter of great concern for the occupational involved in nuclear medicine practice from the radiation dose receiving point of view rather than the public. The public those who are not patient or occupational are receiving less amount of exposure from the nuclear medicine facilities which complies with their permissible limit. Because the shielding conditions of nuclear medicine facilities are ample to protect the radiation from penetration to the public area.

Table 2: Dose Rate Measurement in Nuclear Medicine Facility 2

Facility	Location 1 (PET-CT Room)	Dose Rate in $\mu\text{Sv/h}$	Location 2 Administration Room (Hot Lab)	Dose Rate in $\mu\text{Sv/h}$	Location 3 (Patient Waiting Place)	Dose Rate in $\mu\text{Sv/h}$
Medinova Medical Services Ltd (Facility ID NMC-2)	Console Area	0.3	Basin	15	Entrance Door	0.8
	Entrance Door 1	0.5	Waste Bin	47	At 1 meter from door	0.25
	Entrance Door 2	0.35	F-18 (FDG) Generator Surface	80	Around Patient	50
	Entrance Door 3	0.3	Floor	1.8		
	Patient Bed	0.3	Dose Calibrator Surface	2		
	Floor	0.3	Outside Lead Block	2.2		

An occupational exposure record for the nuclear medicine department has been presented in the table 3. According to table 3 one physicist, two technologists and two attendants who receive considerable amount of radiation dose from the work. The exposure has been assessed for the 6 months considering 3 months records separately. Among the professional nuclear medicine physicist has received reasonably large amount of exposure total of 2.471 mSv in 6 months because his vast involvement in the many areas of the department including dose calculation, patient imaging, quality control of equipment, waste management etc which might have contributed to that amount of exposure. One technologist also receives considerable amount of radiation dose of 2.019 mSv in 6 months. On the other hand, among the other group of professional, the x-ray technologists receive less than 0.05 mSv in 6 months [8]. The cause of receiving less amount of exposure in the x-ray facilities due to less operating time of a machine, good shielding condition of operator position and the use of personal protective equipment particularly lead apron. In addition, the present study was carried out only for the conventional radiological examinations (x-ray, dental x-ray) in the x-ray facilities. During conventional radiological examination not only the occupational but also the patient receives less amount of radiation dose [9].

Table 3: Occupational Exposure Assessment in Nuclear Medicine

Facility	Occupational	Period of Report (First Segment)	Period of Report (Second Segment)	Effective Dose in mSv
Lab Aid Limited	Dr.Kazi Nusrat Razia	August to November 2014	February to April 2014	0
	Sk.Md.Diadarul Alam, Physicist	do	do	1.656, 0.815
	Md.Kamrul Hasan, Tech.	do	do	0,0
	Mrs.Morjina Akhter, Tech.	do	do	0.998, 1.021
	Mrs.Marina Akhter, Attendant.	do	do	0.422,0

Shiule Begum, do do 0, 0.781
 Attendant

Table 4 represents the dose rate measurement findings in and around the x-ray facilities of Gazipur district. From the dose rate measurement, it has been observed that the shielding conditions of entrance door of 80% facilities are not sufficient to protect the radiation from emitting to the public area. Public are becoming exposed to radiation dose which do not comply with the permissible limit. The maximum radiation dose rate was recorded 40µSv/h at the entrance door of a facility (Gazi-P-01). On the other side, the shielding conditions of the control panel (CP) barrier are appropriate for the operator safety in the 60 % facilities which has reduced the occupational exposure level considerably. But the condition of other facilities still requires improving the quality of CP barrier. However, according to personal exposure record all the occupational involved in the diagnostic x-ray facilities are receiving same amount of exposure (less than 0.05 mSv per six months) this could be due to the less operating hour of the machine. The reasonable room size of the facilities can also reduce the occupational exposure at minimum level. Therefore, to reduce the occupational exposure level in the nuclear medicine facilities personal protective equipment such as lead apron, hand gloves, respiratory mask, and shoes cover etc should be in place. On the other hand, to limit the public dose in the x-ray facilities good shielding infrastructure particularly for the entrance door should be devolved.

Table 4: Dose Rate Measurement in Diagnostic x-ray Facilities

Facility	Facility Identification Number	Location 1	Location 2	Dose Rate in $\mu\text{Sv/h}$
Shandani Complex, Gazipur	Diagnostic Joydebpur, Gazi-P-01	Entrance Door (ED)	Control Panel (CP)	40, 10
Shandani Masimpur, Gazipur	Diagnostic, Gazi-P-02	ED	CP	0.5, 0.3
Radium Center, Gazipur	Diagnostic Gazi-P-03	ED	CP	1.5, 80
Doctors Foundation and Diagnostic Center, Gazipur	Diagnostic Center, Gazi-P-04	ED	CP	1.5, 0.3
Sumona Center, Gazipur	Diagnostic Gazi-P-05	ED	CP	10, 0.3
Alpha Medical Lab, Gazipur	Lab, Gazi-P-06	ED	CP	2, 0.3
Aichi Medical Center, Gazipur	Center, Gazi-P-07	ED	CP	5, 0.3
Shareef General Hospital, Gazipur	Hospital, Gazi-P-08	ED	CP	15, 50
New Al-Hera Hospital, Gazipur	Hospital, Gazi-P-09	ED	CP	0.3, 0.3
Al-Raj Medical and Diagnostic Lab, Gazipur	and Diagnostic Lab, Gazi-P-10	ED	CP	0.3, 20
Dr. Azhar-Halima Hospital, Gazipur	Gazi-P-11	ED	CP	01, 03
City Diagnostic Complex, Gazipur	Complex, Gazi-P-12	ED	CP	1.5, 0.3
Hasan Diagnostic Center, Gazipur	Center, Gazi-P-13	ED	CP	0.7, 40
M.M Clinic and Diagnostic Center, Gazipur	and Diagnostic Center, Gazi-P-14	ED	CP	2, 90
Jamuna Diagnostic Center, Gazipur	Center, Gazi-P-15	ED	CP	1, 200

Fig.1 Dose assessment at EDs of nuclear medicine and x-ray facilities

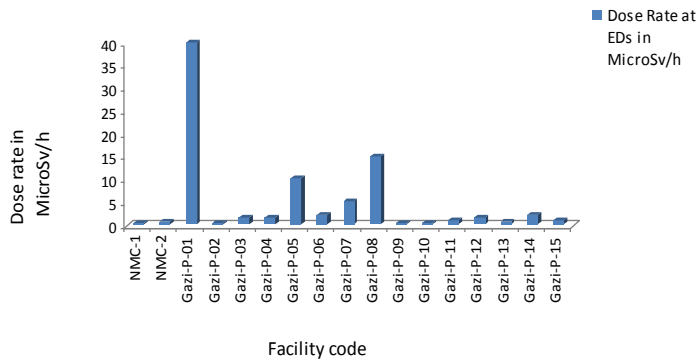
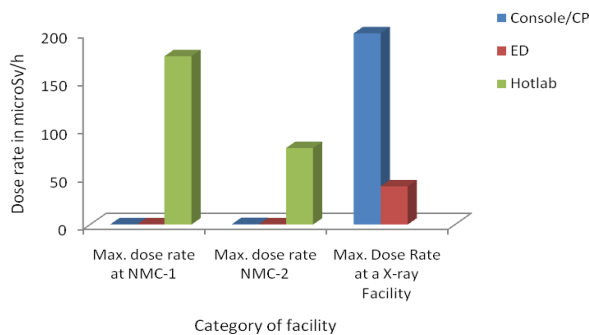


Fig 1 shows the dose rates at the entrance doors of the nuclear medicine and x-ray facilities. In some x-ray facilities the shielding condition of the entrance is very poor which do not provide

any kind of protection to the radiation. The thicknesses of the shielding materials are not found in the required level [10]. Fig2. reflects the dose level at the gamma camera room, PET-CT room, hot lab and x-ray room which are the part of the controlled area in the nuclear medicine and x-ray facilities where public access is restricted. In nuclear medicine facilities occupational receive more radiation dose in hot lab comparatively less

Fig. 2 Dose levels at controlled areas of NMC/X-ray facilities



amount of exposure receive working in gamma camera/PET-CT room even though these places demarked as controlled areas. On the other hand in one control panel of a x-ray room occupational being exposed to very high amount of radiation dose which is 200 μ Sv/h. But the average exposure in the control panels of x-ray room is very much less than this amounting.

Conclusion

As far as the occupational exposure is concerned the nuclear medicine people should be alert regards to their safety during

working with the radiopharmaceutical injected patient or handling of the radioisopes particularly in the hot lab. In this study it has been revealed that the design or layout of the nuclear medicine facilities is quite up to standard but lacking or attitude of wearing of personal protective clothing such as lead apron and the in deficiency of radiation monitor, contamination monitor and extremity dosimeter etc as well as long working hour with close contact to the patient might have contributed to the radiation dose to the professional. On the other hand, due to good shielding infrastructure of nuclear medicine department public are relatively safer in this domain than the x-ray facility. In the x-ray facilities, the infrastructures of the x-ray room were not good in particular the entrance door shielding. Consequently public are becoming more exposed to radiation than that of their limit. But inside the room the operator position was built up with proper shielding and the operators were also wearing lead apron during operating the machine which could reduce their exposure considerably compared to nuclear medicine professional. However, this study has been carried out not including large number of facilities particularly the number of nuclear medicines therefore in order to conclude the findings of the occupational or public exposure more precisely it still requires to perform a comprehensive study including large number of nuclear medicine and x-ray facilities as well.

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