Radiation Dose Assessment of Government and Private Nuclear Medicine Facilities in Bangladesh

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Abstract

Nuclear medicine is an important and specialized branch of medical practices which deals with the peaceful application of nuclear energy for diagnosis and treatment of the patient. In nuclear medicine different types of radioisotopes are used for imaging of the patient organ as well as treatment purposes. During handling of radioisotopes the occupational workers, patients and general public may expose to the ionizing radiation which can be harmful for them. As small amount of dose of radiation might cause of cancer. Radiation dose assessment is very important in the nuclear medicine practices for development of radiation protection infrastructure. In present study, radiation dose is measured in some Govt. and private nuclear medicine facilities. The radiation doses at outside the patient injected and waiting areas of the most facilities were measured above the limit set by regulatory body. It has been observed that occupational workers in hot lab receive more radiation doses compared to workers working in control room. Therefore, adequate shielding arrangements should be in place to minimize the radiation dose level according to national and international requirements.

Keywords: Radioisotope, Deterministic effect, Stochastic effect, Threshold dose, Effective dose, Dose limit, Radiopharmaceutical, Permissible limit, Radiation exposure, Control area

1. Introduction

Natural radioactivity is the principal source of radiation exposure. People are constantly exposed to small amount of ionizing radiation from the environment as they carry out their normal daily activities which is called background radiation. An average yearly effective dose from natural background is about of 2.5 mSv [1]. People are also exposed through some medical treatments and through activities involving radioactive material. The most major contributions to man-made ionizing radiation exposure to the public are medical treatments such as diagnostics X-ray, nuclear medicine, and radiation therapy. Medical exposure is the largest human-made source of radiation exposure, accounting for more than 95% of radiation exposure. Worldwide, the total number of nuclear medicine examinations is estimated to be about 35 million per year [2].Nuclear medicine is the use of nuclear energy for diagnosis and therapy in a peaceful manner. Ionizing radiation has many benefits, but it also has the potential to cause harm. Therefore, it is very important to know about radiation mechanisms, the dose from various medical radiation sources, the magnitude and type of risk. In nuclear medicine mostly unsealed sources of short half-lives are used such as Tc-99m, I-131, I-125 etc. F-18 (FDG) is the most common isotope used in PET/CT for which Cyclotron is required to be established near the facility. Positron Emission Tomography (PET) made a real impact with a polyvalent imaging drug called FDG. A new tool combining functional and morphological imaging (PET-CT) is very recently made available to the medical community [3]. The magnitude of risk from radiation is dose-related with higher amounts of radiation being associated with higher risks. The undisputed health benefits of nuclear medicine diagnostics may be accompanied by a generally small risk of harmful effects. For nuclear medicine patients, a low-activity radioisotope is injected for diagnosis, whereas a higher-activity radioisotope is used for treatment. Society accepts radiation risk on the conditional basis as benefit to be gained from the use of radiation. Nevertheless, the risks must be limited and complied against the application of radiation safety standards developed by national and international organizations [4, 5]. In Bangladesh nuclear medicine field is expending day by day. At present more than 20 nuclear medicine centers are functioning at different parts of the country covering almost all the corners for diagnosis and treatment of diseases using radioisotopes and radiopharmaceuticals. In Bangladesh now almost all the centers have sophisticated and sensitive equipment like gamma camera, SPECT, SPECT-CT, BMD, thyroid uptake system for diagnosis and treatment. PET-CT has already been established in few government and private hospitals giving services to the patients. In Bangladesh, the nuclear medicine facility is mainly based on few radioisotopes, Tc-99m, I-131, I-125 and F-18. Team efforts is important for diagnosis and treatment. Medical technologists have to be careful during delivery of radioisotope and radiopharmaceutical to the patient in different study because there is a probability of getting high exposure in the hands of the individual [6]. Most of the people are not concern about the harmful effect of ionizing radiation which may happen even at low doses known as stochastic effect. Irradiated cells with a stochastic effect may become modified by induced mutations. These modifications may lead to clinically significant effects such as cancer and hereditary mutations. Deterministic effects are observed after large absorbed doses of radiation and are mainly a consequence of radiation induced cellular death [1]. In order to ensure safety of worker, patient, public and environment it is essential adamant radiation protection requirements to adopt and should develop proper radiation

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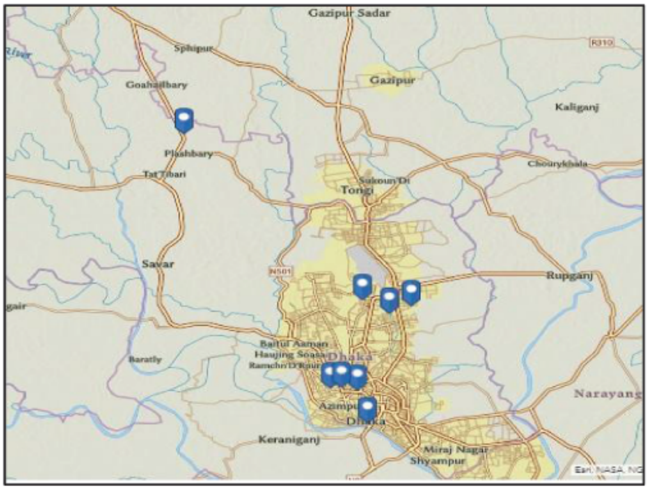
protection infrastructure accordingly in every radiation related facility in Bangladesh [7]. In the present study, radiation dose has been measured in different locations of nuclear medicine facilities during diagnosis of the patients by PET-CT, SPECT-CT, SPECT, Gamma camera etc. Radiation dose is also measured outside the imaging room for estimation of public dose. Occupational worker effective dose is also assessed from their routine monitoring report to find out their dose received status. According to national regulation [8]. The annual dose limit for occupational worker and public is 2o mSv and 1 mSv respectively. According to national regulation [8], occupational worker annual dose limit is 20 mSv and for public it is 1 mSv.

2. Materials and Method

A comprehensive inspection was carried out in nine (09) private and government nuclear medicine facilities of Bangladesh for the present study. Among them seven (07) are located in Dhaka city and the other two (02) are located in Dhaka and Mymensingh district.



The above maps show the locations of the nuclear medicine facilities in Bangladesh where the inspections were performed.

GPS Location of the nuclear medicine facilities using Google map are as follows

No.	Facility ID	Latitude	Altitude
1	NMC-1	N23° 42' 44.4924"	E90° 24' 2.2284"
2	NMC-2	N23° 57' 11.2392"	E90° 16' 27.2748"
3	NMC-3	N23° 48' 36.1224"	E90° 25' 51.8052"
4	NMC-4	N23° 44' 29.7888"	E90° 22' 30.4644"
5	NMC-5	N23° 48' 17.11174"	E90° 24' 56.5092"
6	NMC-6	N23° 48' 53.5032"	E90° 23' 50.2152"
7	NMC-7	N23° 44' 21.84"	E90° 23' 38.8536"
8	NMC-8	N24° 44' 39.0588"	E90° 24' 38.0412"
9	NMC-9	N23° 44' 31.4952"	E90° 22' 58.9152"

Present nuclear medicine technique uses various imaging equipment such as gamma camera, single photon emission computed tomography (SPECT), SPECT-CT, positron emission tomography (PET), PET-CT, Thyroid gamma camera etc. for diagnostic purposes of the patients. Tc-99m, I-131, F-18, I-125, Sr-90 are the most commonly used radioisotopes in nuclear medicine facility. Co-60, Co-57, Cs-137, Na-22 etc. are also used for quality control purposes of the imaging equipment. Tc-99m is collected from Technetium generator of different suppliers which contains up to 400 mCi. Tc-99m is used for diagnostic purposes and is administered in the patient's body in small amounts that vary from 1 to 20 mCi [9]. The activity is measured using the dose calibrator before dose administration to the patient. In the current study, TC-99m was found in use at four facilities in a liquid form and I-131 has also been found in three nuclear medicine facilities for therapeutic uses. As Occupational radiation worker handle diagnostic and therapeutic patient, they are likely to receive high amount of radiation dose and may also be over exposed to radiation. At the same time, nuclear medicine activities produce a large amount of radioactive waste regularly. As a result, the possibility of becoming contaminated with a radioactive substance remains high.

A regulatory inspection checklist was prepared including various types of regulatory information from the design and layout of the facility to the measurement of radiation dose rates. The safety parameters were assessed, with a focus on the specification of radioactive source/radiation generating equipment, room size, console area's shielding condition, shielding material at entrance door, thickness of side walls of imaging room and surroundings of the facilities and were recorded in the check list. With these safety parameters, a comprehensive layout of the whole facility was portrayed on the spot. The check list also covers a wide range of relevant elements, from personal protective equipment to the facility's shielding structure. Radiation dose rate meters were used to assess the radiation exposure emitted by radioisotopes in this study. Radiation dose rates were measured at different locations in and around the facilities to evaluate the occupational and public exposure.

Radioactive source inventory logbook, radioisotope injected patient inventory, area monitoring records, personal monitoring and health surveillance reports of radiation worker was checked to evaluate the radiation safety status on the spot during inspection. With all regulatory data an inspection report was produced with necessary recommendations for improving radiation safety infrastructure. Inspection is a significant regulatory function and a continuous procedure in accordance with the law to monitor radiation related activities, which ultimately helps to improve the facility's overall radiation safety scenario. In the present study, inspection findings related to radiation dose levels in different nuclear medicine facilities and other regulatory aspects are recorded and compared with each other. The findings of the present study are tabulated and graphically represented in terms of shielding construction, radiation dose levels and other regulatory factors.

3. Results and Discussion

Table 1 shows the radiation dose rate assessment at different locations of PET-CT machine room and its adjacent area of 7 nuclear medicine facilities. The radiation dose rate was measured in entrance door, control console, post injection waiting room door, FDG preparation room and waste storage place. The radiation dose rate at entrance door (PET-CT room) of NMC-1 was 31.0 µSv/hr which is about 3 times higher than the permissible limit of occupational worker [8]. Occupational workers also receive six/seven times higher dose than acceptable limit (10 µSv/hr) at FDG preparation room of NMC-2 and NMC-3. The maximum dose was recorded 100 µSv/hr at waste storage place of NMC-2 and NMC-5 which is 10 times higher than the permissible limit (10 µSv/hr) of the occupational radiation worker.

Table 1: Radiation dose rate (µSv/hr) measurement for PET-CT machines in seven nuclear medicine facilities

Facility identification number	Location 1	Location 2	Location 3	Location 4	Location 5
	Main entrance door (ED)	Control console (CC)	Entrance door (outside) of post injection waiting room (with patient)	FDG preparation room (Hot lab)	Waste storage place (WSP)
NMC-1	31.0	0.43	2.32	3.0	1.57
NMC-2	5.00	0.50	10.00	70.00	100.00
NMC-3	0.80	0.60	7.00	60.00	8.00
NMC-4	0.40	0.60	10.00	1.00	0.30
NMC-5	0.40	0.50	8.0	1.5	100.00
NMC-6	4.12	0.28	0.17	2.0	6.50
NMC-7	7.96	5.85	0.88	0.18	5.0

Fig 1shows the dose rate at different locations such as entrance door (ED), control console (CC), post injection waiting room (PIWR), hot lab, waste storage place (WSP) of seven nuclear medicine facilities which are the part of controlled area in nuclear medicine facilities. Due to the inadequate shielding, the dose level in waste storage areas of two facilities is relatively high. In NMC-2 and NMC-3,

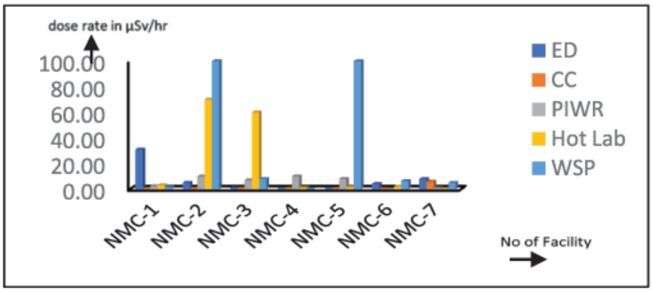


Fig. 1: Radiation dose rate in and around PET-CT room

due to high radiation exposure radiation workers receive high amount of radiation dose in hot lab compare to other places in controlled area. In NMC-1, shielding material is not found at required level [7, 10] in the entrance door and radiation dose exceeds regulatory limit [8]. It has also been observed that radiation workers at NMC-1 and NMC-2 do not wear a lead apron or a TLD-badge to protect themselves while handling patients. But personal safety is

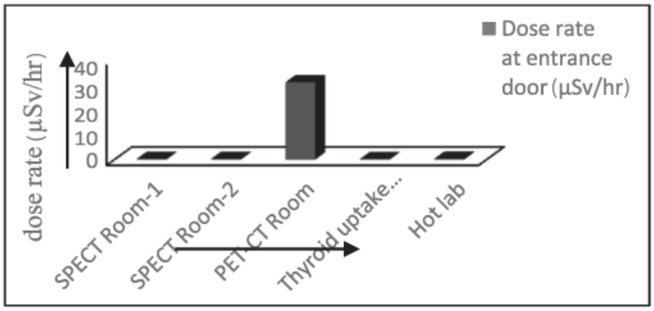


Fig. 2 : Dose assessment at EDs of imaging rooms and hot lab in NMC-1

required during handling of radioactive source as well as isotope injected patient.

Fig.2 indicates the dose levels at entrance door of different imaging room and hot lab in NMC-1. Radiation dose at entrance door of PET-CT room is higher than the regulatory limit, on the other hand, the observed radiation dose at the entrance door of other imaging room (in absence of patient) was comparable with background radiation level. As the PET-CT entrance door is near to control console, occupational radiation worker working in control console may receive an extra dose which can have detrimental effects on health.

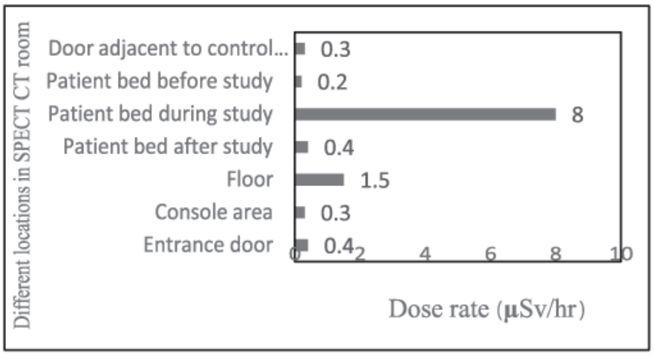


Fig. 3: Dose rate measurement at different locations of SPECT-CT Gamma Camera room in NMC-8

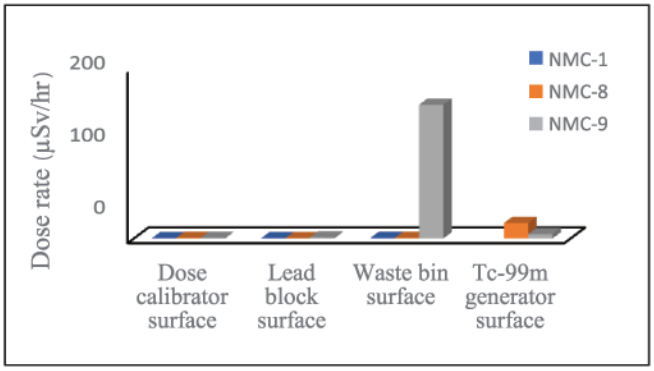


Fig. 4:Radiation dose assessment at different locations in hot lab of three facilities (NMC-1, NMC-8, NMC-9)

In the present study, radiation doses at different locations in another two facilities (NMC-8 and NMC-9) has also been measured. In NMC-8, Tc-99m generator has been found in use and reference activity of the Tc-99m generator is 333 mCi from which 3-20 mCi activity is used per patient in regular work. The maximum dose rate of 18.0 µSv/hr was recorded on the surface of Tc-99m generator which is slightly above the permissible limit for occupational worker. Further more, radiation dose levels in the SPECT-CT gamma camera room were found to be slightly higher than background radiation levels (0.2-0.3 Sv/hr). The shielding infrastructure of NMC-8 was improved according to national act and regulations, resulting in lower radiation exposures in both the occupational worker and public areas.

Fig.3 reflects the dose level at different locations of SPECT-CT Gamma Camera room in NMC-8. As the radiation dose is not much higher, occupational worker receive less amount of exposure in SPECT-CT gamma camera room. Besides, the radiation dose rates in controlled areas of the facility are found to be below the regulatory limit indicate that the shielding arrangement is well enough complying with regulatory requirements.

Dose rate at different locations of NMC-9 have been measured during inspection. Maximum amount of radiation dose rate157 µSv/hr was estimated at the waste bin surface in the hot lab. Apart from that, significant amount of radiation exposure of 78.0 µSv/hr was recorded at the sink in the same area and other places no significant amount of radiation was found. Radiation dose was recorded at the background level in the public area adjacent to the facility.

Fig. 4 exhibits the dose rate assessment at dose calibrator, lead block, waste bin and Tc-99m generator surface in hot lab of three nuclear medicine facilities (NMC-1, NMC-8, NMC-9). It has been observed that the dose rate at waste bin surface of NMC-9 was significantly higher than the permissible limit. Because the waste bin sits inside the hot lab room, occupational workers are exposed to additional radiation, which may have an impact on their health. However, a considerable amount of radiation exposure is not found in any of the three facilities' hot labs.

Table 2: Occupational radiation dose assessment in nuclear medicine facilities

Facility identification no	Occupational worker identification no	Reporting period	Effective dose (mSv}
NMC-3	All Occupational worker	July- Sept., 2019	0.00
NMC-4	TS-MA	Feb.-June, 2018	0.171
NMC-5	FH-RC	Dec.-Mar. 2018	0.553
		Jan.- Mar., 2019	0.492
NMC-6	SM- PTT	Oct. 2018– Jan. 2019	0.349
	BH-MT	Jan.- Feb. 2019	4.787
NMC-7	SI-EO	Sept.– Nov., 2019	0.111
	MK-SA-1	-	0.183
	JI-SA-II	-	0.123

In table 2, an occupational effective dose has been recorded for 5 nuclear medicine facilities. According to the data, various occupational workers have been received different levels of radiation dose for periods ranging from 2 to 5 months. One medical technician received a considerable amount of radiation dose of 4.787 mSv in two months among the occupational workers. Due to the involvement of many areas, including radiology and imaging, and nuclear medicine activities, medical technician received a significant quantity of radiation doses. Other radiation workers, with the exception of medical technician, did not receive considerable amounts of radiation due to the facilities' strong shielding conditions and the use of personal protective equipment, particularly lead apron.

4. Conclusion

Occupational radiation workers are receiving higher radiation dose due to usage of radioisotopes in nuclear medicine for diagnostic and therapeutic purposes. As radiation exposure carries health risks namely cancer and genetic risks for the exposed person, the occupational workers involved in the use of ionizing radiation sources are at risk. As a result, radiation safety is essential for both occupational workers and patients, as well as the general public and the environment. Radiation protection of workers is an important issue in nuclear medicine as high radionuclide activities are needed for diagnosis and treatment, the procedures require the handling of radiopharmaceuticals in contact with, or very close to the extremities, pure beta emitters and mixed photon/beta emitters are often used in nuclear medicine. Thus, Nuclear medicine workers are potentially exposed to external radiation and to internal contamination in case of accidental intake. It is essential to make sure that the investigation is justified and that the radiation absorbed dose to the patients as well as to radiation workers and other individuals involved is kept as low as reasonably achievable. In medical radiation protection, improving patient dosimetry and reducing unnecessary exposures, particularly in unusual and novel applications, are important goals. Radiation protection is concerned with the prevention or limitation of possible harmful effects of radiation exposure of workers, patient as well as general public. Routine radiation monitoring at work place of nuclear medicine facilities is required for minimizing unnecessary exposure to radiation worker, patient and public. In this assessment the design or layout of nuclear medicine facilities has been found to be quite up to standard. But attitude of wearing personal protective clothing such as lead apron, personal monitoring device TLD badge, as well as a lack of contamination monitor, extremity dosimeter, etc. and long working hours with close contact to the patient, may have contributed to the radiation dose to the occupational workers. All workers must wear a TLD badge to assess their personal accumulated dose and protect themselves against the harmful effects of ionizing radiation. As there is a lack of proper waste disposal arrangement in few facilities, various accessories (hand gloves, syringe, needles, tissue etc.) used by the radiation worker should be stored in the radioactive waste container with correct identification in every facility. It has been observed that some radioisotope injected patients move here and there inside the facility, exposing general workers to harmful radiation. In that situation, a special type of identification badge for all isotope injected patients should be used to increase awareness among all workers of nuclear medicine facilities. PET-CT facilities bring up a bit different design requirement than traditional nuclear medicine facilities and are more likely to require additional radiation shielding to fulfill the requirements of radiation safety. By using appropriate design and shielding and maintaining proper operating practices, radiation doses to worker, public and environment can be kept to permissible limits. Based on the findings of this study, more activities should be performed both by regulators and operators in order to implement national and international standards to ensure the safe use of ionizing radiation. This study has been conducted with a small number of nuclear medicine facilities; therefore, in order to accurately complete all findings related to radiation safety and protection in all areas, a comprehensive study with a large number of nuclear medicine facilities is required. The Bangladesh Atomic Energy Regulatory Authority is enforcing the rules and regulations in the country effectively and efficiently to protect people and the environment from the harmful effects of ionizing radiation.

Acknowledgement

The authors gratefully acknowledge the support and cooperation of Bangladesh Atomic Energy Regulatory Authority for providing logistics during the study. The authors also like to thank the employer of facilities for their assistance during inspection of the nuclear medicine facilities.

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