ABC Research Alert
Vol 7, Number 3
Published Online: 09 October 2019
http://abcreal.weebly.com/

RADIATION MONITORING AND EVALUATION OF RISK TO POPULATION IN MITFORD HOSPITAL, DHAKA, BANGLADESH

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Abstract

Objective: **Nuclear Medicine workers are getting higher radiation dose because of increasing usage of nuclear medicine for diagnostic and therapeutic procedures. The purpose of the study is to monitor the real-time radiation at the indoor places of the Institute of Nuclear Medicine & Allied Sciences (INMAS) Mitford, Sir Salimullah Medical College and Hospital Campus for minimizing the ionizing radiation hazard to radiation worker and public.**
Methods: **The radiation monitoring was performed using real-time portable digital radiation monitoring device. This real-time digital portable radiation monitoring device meets all European CE standards as well as the American "FCC 15 standard". The portable radiation monitoring device was placed at 1 meter above the ground on tripod and data acquisition time for each monitoring point (MP) was 1 hour. 26 MPs were selected for collection of radiation dose rates at different indoor locations of INMAS, Mitford hospital.**
Results: **The measured dose rates due to natural and man-made radionuclides were ranged from 0.151 ± 0.070 μSv.h^{-1} to 4.313 ± 1.829 μSv.h^{-1} with an average of 0.456 ± 0.227 μSv.h^{-1}. The annual effective dose to the radiation worker and public due to radiation were varied from 0.305 mSv to 8.764 mSv with an average of 0.951 mSv. Excess life-time cancer risk factor based on annual effective dose to radiation worker and public were calculated and varied from 1.213 X 10^{-3} to 3.486 X 10^{-2}.**
Conclusion: **Real-time radiation monitoring at indoor places of nuclear medicine facilities are required for minimizing unnecessary exposure to nuclear medicine workers and public from man-made sources. This kind of study is required for minimizing the radiation hazard in the hospital environment and consequently to keep the radiation dose to worker and public as low as possible.**

Keywords

Indoor; Ionizing Radiation; Nuclear Medicine; In-Situ; Occupational Health; Cancer.

INTRODUCTION

Indoor radiation is higher than outdoor radiation because earth materials are used as construction materials. All kind of building materials such as brick, sand, concrete, limestone, gypsum, aggregate, marble, granite, etc., contain mostly natural radionuclides. The natural radionuclides of building materials contain uranium (^{238}U) and Thorium (^{232}Th) and their decay products and the radioactive potassium (^{40}K). The understanding of the natural radioactivity of building materials is required for the evaluation of public exposure to radiation, because the majority of the people spend about 80% of their time indoors (UNSCEAR, 2008). Nuclear medicine facilities use unsealed radioactive sources for diagnostic and therapeutic procedures. Therefore, the probability of contamination in the indoor environment of the nuclear medicine facilities is high comparing to other departments of the hospital. Therefore, real-time radiation monitoring during working time is crucial for minimizing contamination in the indoor environment and thereby keeping the radiation dose to worker and public as low as possible. The medical use of ionizing radiation, while offering great benefit to patients, also contributes significantly to radiation exposure of workers and populations (UNSCEAR 2000), (EURATOM, 1997), (UNSCEAR, 1993). Occupational exposure to ionizing radiation due to medical activities (both diagnostic and therapeutic procedures) has increased sharply in recent years (UNSCEAR, 2008), (NCRP Report No. 160, 2009). Among the radiation workers in the field of medicine, those mainly concerned by the increasing exposure to ionizing radiation are nuclear medicine workers. Nuclear medicine facility workers used to handle unsealed radioactive materials which can increase to external and internal radiation dose to radiation workers. The amount of radiation dose depends on radionuclide, its activity and type of procedure within a department in which the worker is engaged. Comparatively newer imaging modality that involves use of positron-emitting radionuclides for PET scanning has lead to the higher radiation dose to worker. In case of PET, the reality is that the higher energy (511 keV) gamma radiation used in PET imaging contributing higher radiation dose to the workers comparing to the technicium-99m gamma radiation of lower energy (140 keV) commonly used in imaging procedures. In case of therapeutic application in nuclear medicine, new agents with beta particle emitters of higher therapeutic effectiveness have been used. In connection with growing number of medical procedures involving beta particle emitting radionuclides, extremity such as fingers of hand doses and probable skin contamination of nuclear medicine workers is of great concern. While conducting clinical nuclear medicine procedures, the amount of radiation dose to worker depends on the safe handling of the radioactive materials, for example, the proper wearing of the personnel protective equipments (PPEs) such as lead apron, hand gloves, lead glass, socks, shoes, etc. and the use of syringe shields when administering injections. Workers have to be close to the patient during delivering injections, positioning the patient and the camera. Normally, the imaging process makes the highest contribution to the radiation dose to workers (Barrall R. C. et al., 1976). Internal radiation exposures to worker are significantly lower than external radiation exposures and are controlled by monitoring working surfaces and airborne concentrations (NCRP Report No. 107, 1990). In the nuclear medicine department, because of the possibility of internal radiation exposure, higher values of annual effective dose are expected for personnel involving in the preparation and assay of radiopharmaceuticals than for medical doctors and nurses. The radiation monitoring which is meant to control the dose accumulation pattern of individual (UNSCEAR, 1982) includes a programme of measurements, evaluations and recording of radiation exposure to workers. The objective of the present study is to monitor the real-time radiation at the indoor places of the Institute of Nuclear Medicine & Allied Sciences (INMAS) Mitford, Sir Salimullah Medical College and Hospital Campus by In-Situ Method. Real-time radiation monitoring is essential for minimizing the radiation hazard in the hospital environment and consequently to keep the radiation dose to worker and public as low as possible.

MATERIALS AND METHODS

Description of the apparatus

A real-time digital portable radiation monitoring device which is known as GAMMA SCOUT was used for this study. GAMMA SCOUT is German designed and manufactured, built with a solid Novadur exterior. An optional stylish leather holster with belt strap can further protect the GAMMA SCOUT from the elements. The GAMMA SCOUT meets all European CE standards as well as US FCC 15. All units come with an industry leading 2-year manufacturer's warranty and a serialized test certificate. The GAMMA SCOUT is a fully featured Geiger counter with a form fitting ergonomic shape. The unit has a battery indicator, multiple unit conversion, real-time dose rate and cumulative dose display functions and programmable logging and alert functions. Advanced functions include PC data download via USB cable and an ultra low current power circuit for extended battery life (User Manual-GAMMA SCOUT, 2014).

Calibration of the apparatus

The GAMMA SCOUT was calibrated inbuilt by the manufacturer. The GAMMA SCOUT is also calibrated at the Secondary Standard Dosimetry Laboratory (SSDL) under the Bangladesh Atomic Energy Commission (BAEC) using gamma-ray standard sources such as ^{137}Cs, ^{60}Co, etc. and X-ray Unit. The SSDL of BAEC has been available since 1991, which is traceable to the Primary Standard Dosimetry Laboratory (PSDL) of National Physical Laboratory (NPL), UK. The SSDL of BAEC has X-ray Unit (30 kV-225 kV) for radiation generating equipments calibration. The performance of BAEC's SSDL is maintained according to the requirements of the International Atomic Energy Agency (IAEA)/World Health Organization (WHO) network of SSDLs. Therefore, the evaluated doses are traceable to the International measurement system. The GAMMA SCOUT accurately measure dose rate in the range of 0.01-5000 µSv/hr (User Manual-GAMMA SCOUT, 2014).

Description of the Site

The study location was marked out using GARMIN eTrex HC series personal navigator. The unit uses the proven performance of Garmin high-sensitivity GPS and full-featured mapping to create an unsurpassed portable GPS receiver (Owner's Manual-GARMIN eTrex HC Series, 2007). The GPS reading of the monitoring locations were varied from E: 90º40.022′ to E: 090º40.108′ and from N: 23º71.206′ to N: 23º71.283′. Twenty six locations were selected for monitoring of indoor radiation dose rates at the Institute of Nuclear Medicine & Allied Sciences (INMAS) Mitford, Sir Salimullah Medical College and Hospital Campus by In-Situ Method. The monitoring locations include hot lab, thyroid lab, gamma camera lab/SPECT-CT lab, RIA lab, patient waiting room, visitor waiting room, common spaces, corridor, etc. The monitoring was performed from April-June 2018. For each location, the real-time digital portable radiation monitoring device (GAMMA SCOUT) was placed on tripod at 1 m height and time for dose rate monitoring was 1 hour. Table 1 gives the description of monitoring points (MPs). This site was marked out using Global Positioning System (GPS) navigation. is an es-tablishment of nuclear medicine activities in Dhaka city of Bangladesh. is an institute of Bangladesh Atomic Energy Commission (BAEC) under the Ministry of Science & Technology, Government of the People's Republic of Bangladesh. The INMAS Mitford hospital is located in the campus of Sir Salimullah Medical College and Mitford Hospital which is the oldest medical hospital in Dhaka as well in the country.

Calculation of Annual effective dose and ELCR

UNCEAR 1988 recommended the indoor occupancy factor of 0.80 to population. This occupancy factor is the proportion of the total time during which an individual is exposed to a radiation field at indoor. The indoor annual effective dose to population due to radiation is calculated according to the following equation:

$$Annual\ effective\ dose\ (\mu Sv) = dose\ rate\ (\mu Sv.\text{hr}^{-1})\ \times 0.8\ \times\ 8760\ hr.yr^{-1} \qquad (1)$$

Excess life-time cancer risk factor (ELCR) is calculated by using the following equation:

$$ELCR = AED \times DL \times RF \qquad (1)$$

Where AED is annual effective dose to radiation worker, DL is the duration of life of Bangladeshi people (http://en.worldstat.info/Asia/Bangladesh, 2019) and RF is the risk factor (Sv^{-1}), it is a fatal cancer risk per Sievert. For stochastic effects from low dose radiation, ICRP 103 suggested the value of 0.057 for the public exposure (ICRP, 2007).

RESULTS AND DISCUSSION

The measured average annual effective dose for radiation worker was 0.951 mSv which is lower than the worldwide average annual effective dose (1.4 mSv) for radiation worker in nuclear medicine (UNSCEAR, 2008). The maximum dose for one day in SPECT-CT room at INMAS Mitford hospital was 34.48 μSv which is lower than the maximum allowable dose for one day (55 μSv) in nuclear medicine department (ICRP, 2008). The average annual effective dose for radiation workers at nuclear medicine departments in Greece during the period 2000-2002 was varied from 0.75-1.49 mSv (UNSCEAR, 2008). The average annual effective dose to radiation worker for various indoor places of INMAS Mitford hospital was found to be within the dose range of nuclear medicine departments in Greece except SPECT-CT Lab. Using the conversion factor of 0.7 Sv Gy^{-1} as recommended by UNSCEAR 2000 and considering that people in Bangladesh spend approximately 20 % of their time outdoor and remaining 80% of time indoor; the annual effective dose received by people in Dhaka city due to the radiation is given in Table 1.Table 1 shows annual effective dose received by the radiation workers of INMAS Mitford Hospital.

Name of Place	Latitude/ Altitude	Radiation dose rate (μSv/hr)			Annual effective dose due to radiation (mSv) ± SD
		Range	Mean	SD	
SPECT/CT lab	N 23⁰ 71.221' E 90⁰40.09'	0.38-5.87	4.313	1.829	8.764 ± 3.717
Thyroid lab	-	0.20-0.38	0.289	0.056	0.559 ± 0.095
RIA lab	N 23⁰ 71.235' E 90⁰40.073'	0.11-0.30	0.201	0.067	0.409 ± 0.137
Visitor/patient waiting room-1	N 23⁰ 71.208' E 90⁰40.048'	0.16-0.57	0.338	0.093	0.687 ± 0.189
Visitor/patient waiting room-2	N 23⁰ 71.228' E 90⁰40.027'	0.12-0.24	0.173	0.038	0.351 ± 0.077
Visitor/patient waiting room-3	N 23⁰ 71.235' E 90⁰40.064'	0.10-0.20	0.153	0.033	0.311 ± 0.068
Common Space-1	N 23⁰ 71.251' E 90⁰40.072'	0.52-4.50	1.204	1.206	2.446 ± 2.450
Common Space-2	N 23⁰ 71.232' E 90⁰40.054'	0.19-0.31	0.245	0.039	0.497 ± 0.081
Common Space-3	N 23⁰ 71.235' E 90⁰40.108'	0.11-0.23	0.165	0.036	0.345 ± 0.079
Common Space-4	N 23⁰ 71.250' E 90⁰40.035'	0.12-0.23	0.175	0.036	0.356 ± 0.073
Common Space-5	N 23⁰ 71.255' E 90⁰40.043'	0.07-0.27	0.174	0.059	0.355 ± 0.121
Common Space-6	-	0.12-0.23	0.176	0.037	0.358 ± 0.076
Common Space-7	-	0.18-0.34	0.248	0.051	0.489 ± 0.129
Common Space-8	N 23⁰ 71.220' E 90⁰40.051'	0.10-0.27	0.201	0.049	0.419 ± 0.099
Common Space-9	N 23⁰ 71.236' E 90⁰40.036'	0.12-0.28	0.183	0.045	0.372 ± 0.092
Common Space-10	N 23⁰ 71.281' E 90⁰40.052'	0.07-0.27	0.177	0.061	0.359 ± 0.123
Corridor-1 (north side)1st floor	N 23⁰ 71.282' E 90⁰40.074'	0.14-0.35	0.232	0.070	0.471 ± 0.143

Corridor-2 (north side)2nd floor	N 23^{0}71.265' E 90^{0}40.060'	0.09-0.23	0.168	0.042	0.342 ± 0.085
Corridor-3 (north side)3rd floor	N 23^{0}71.265' E 90^{0}40.074'	0.08-0.27	0.181	0.061	0.368 ± 0.124
Corridor-4 (north side)4th floor	N 23^{0}71.257' E 90^{0}40.065'	0.10-0.28	0.193	0.050	0.392 ± 0.102
Corridor-1 (south side)1st floor	N 23^{0}71.220' E 90^{0}40.028'	0.10-0.37	0.26	0.079	0.528 ± 0.161
Corridor-2 (south side)2nd floor	N 23^{0}71.206' E 90^{0}40.040'	0.02-0.23	0.15	0.071	0.305 ± 0.145
Corridor-3 (south side)3rd floor	N 23^{0}71.210' E 90^{0}40.022'	0.05-0.25	0.151	0.070	0.306 ± 0.143
Corridor-4 (east side)4th floor	N 23^{0}71.206' E 90^{0}40.055'	0.14-0.26	0.20	0.039	0.406 ± 0.079
Corridor-1 (middle)	N 23^{0}72.31' E 90^{0}40.057'	0.07-0.25	0.168	0.056	0.343 ± 0.113
Corridor-2 (middle)	N 23^{0}71.226' E 90^{0}40.074'	0.44-6.06	1.741	1.625	3.537 ± 3.302

Table 1: Annual effective dose due to radiation at indoor places of INMAS Mitford Hospital

Figure 1 shows the frequency distribution of radiation dose rate at indoor places of INMAS Mitford Hospital.

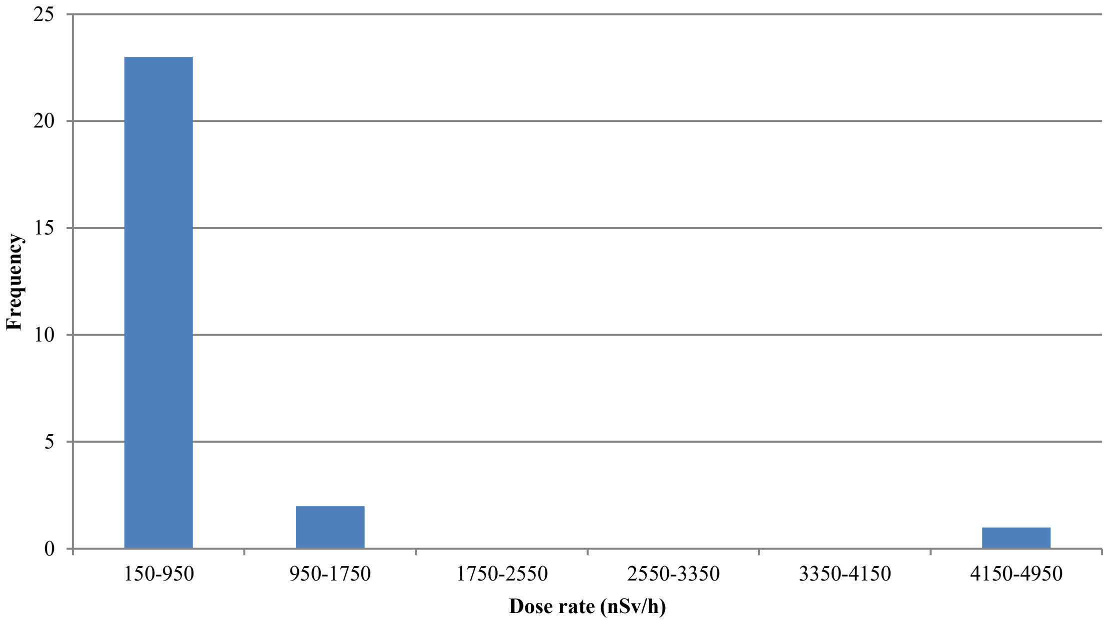

Fig. 1: Frequency distribution of radiation dose rate at indoor places of INMAS Mitford Hospital.

In general, effective dose for CT examinations can be higher than most other diagnostic imaging modalities (Wall B.F. et al., 1997). According to the Swedish Radiation Safety Authority report, CT and nuclear medicine made 16% of all radiological investigations except mammography and contributed to 64% of the collective radiation dose in Sweden in 2005 (Almen A et al., 2008). According to the National Council on Radiological Protection and Measurement in USA, CT and nuclear medicine made 22% of all radiological investigations but contributed to 75% of the collective radiation dose in US in 2006 (NCRP, 2009). However, the doses are dependent on the number of manipulations, the type of radioisotope and the amount of activity handled.

To assess the radiological risk, life-time cancer risk was calculated based on annual effective dose to radiation worker and it was varied from 1.213 X 10^{-3} to 3.486 X 10^{-2} with an average of 3.783 X 10^{-3}. The average cancer risk factor is lower than the world average value of 5.57 X 10^{-3} (UNSCEAR, 2008) that need more similar studies for confirmation. Although the annual effective dose and ELCR values at indoor locations of INMAS Mitford hospital are lower than the world average values except SPECT-CT lab but all the values are well below the dose limit prescribed for the radiation workers in the Nuclear Safety and Radiation Control Rules-1997 of Bangladesh (NSRC Rules, 1997). The estimated average annual effective dose of 0.951 mSv is not anticipated to contribute significant extra hazard from the radiological health point of view. Due to comparison purposes, the annual dose limit for members of the public according to ICRP 103 (ICRP, 2007 recommendation) is 1 mSv/year and this limit is applicable to practices from planned exposure situation such as nuclear or radiological facilities and is not applicable to radiation doses receiving from existing exposure situations such as natural sources of radiation. The real-time radiation monitoring in the indoor places of the hospital especially nuclear medicine departments are required for safety of the worker, public and the environment and keeping the indoor places free from unnecessary radiation.

CONCLUSION

Nuclear medicine facilities use unsealed radioactive materials. That's why the probability of getting contamination in the indoor environment of the nuclear medicine facilities is high comparing to other departments of the hospital. Therefore, real-time radiation monitoring during working time is crucial for minimizing contamination in the indoor environment and thereby keeping the radiation dose to worker and public as low as possible. The measured dose rates due to natural and man-made radionuclides were ranged from 0.151 ± 0.071 $\mu Sv.h^{-1}$ to 4.313 ± 1.829 $\mu Sv.h^{-1}$ with an average of 0.456 ± 0.227 $\mu Sv.h^{-1}$. The annual effective dose to the radiation worker and public due to radiation were varied from 0.305 mSv to 8.764 mSv with an average of 0.951 mSv. Medical application of CT has drastic changed in medical imaging and plays a huge role in regular medical care, but CT is still a leading source of radiation exposure to the population. Although significant additional information about physiology, cellular and molecular events are given by SPECT/CT and PET/CT investigations, these types of procedures considered worldwide as high dose investigations. Cooperation between nuclear medicine and radiology department's worker is required for optimum use of CT, PET/CT and SPECT/CT investigations.

Acknowledgement

The authors would like to thank concerned personnel of Health Physics Division, Atomic Energy Center, Dhaka for their support.

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