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Measurement of Radiation Exposure of Hands and Fingers of Nuclear Medicine Personnel Using Innovative Low-Cost GM Based System

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Abstract:

Pocket dosimeters are used commonly in Nuclear Medicine or radiology workers for daily dose measurement or during certain high radiation exposure procedures for short periods of time. These are expensive and have many maintenance costs. It may not be feasible to procure many at a time due to cost restraints. We designed a low cost remote dose monitoring device for measurement of radiation for short periods of time. Measuring device was constructed using micro Geiger Muller Counter. The micro-Geiger Counter with model no SBM21 was connected to high voltage circuit and the output signal was obtained. After this, output signal was sent it to Arduino circuit running custom code ESP8266 and readings was made on the mobile/ laptop application after connecting to Arduino circuit running custom code ESP8266 via internet. Readings were taken for short durations during certain periods. Readings were compared to the standard measuring instrument simultaneously. The tube was connected to their hands for hand exposure with a wire. Readings were recorded in the form of µSv/h or mSv/h. RESULT: Total readings were taken during various occasions while preparing (59) and dispensing (45) radioisotopes. During preparation of radiopharmaceuticals, average readings for ^{99m}Tc-Sestamibi[16 SAMPLE] (100mCi to 250mCi), ^{99m}Tc-MDP [21SAMPLE] (150-200mCi) and ^{99m}Tc-DTPA [22SAMPLES] (10-20mCi) were 1115 µSv/h, 3083 µSv/h and 453 µSv/h respectively. During dispensing of radiopharmaceuticals, average readings of total 15 sample each for ^{99m}Tc-Sestamibi (100mCi to 250mCi), ^{99m}Tc-MDP (150-200mCi) and ^{99m}Tc-DTPA (10-20mCi) were 351µSv/h, 209 µSv/h and 235 µSv/h respectively. It was feasible for the worker to fit the measuring device in their pocket while working. Conclusion: Our pilot study revealed accurate readings >95% of the times for short periods of time. Study designing, standardization of readings with more real time accuracy can make this method more reliable and is a low cost means to monitor short periods of radiation exposure for radiation workers.

Keywords: *Pocket dosimeter, micro-Geiger Counter.*

Introduction

All Radiation workers require monitoring of their radiation exposure especially as they are exposed for long years. Specifically, extremities of Nuclear Medicine personnel receive additional exposure while preparing and dispensing radiopharmaceuticals and positioning of patients etc. The radiation exposure of radiation workers is measured most commonly personal monitoring devices like thermos-luminescent dosimeter badges and personal (pocket) dosimeters. All the techniques available are expensive and require regular maintenance of equipment. This may sometimes add to overall functioning in a department especially in developing countries and in smaller departments with limited resources.

Aim & Objectives

To design an instrument with cost effective method for real time dosimetry measurement for radiation workers in Nuclear Medicine

We attempted to fabricate, try and test a GM based system which would be potentially applicable to measure low dose radiation exposure. We tried the device with measurement of hand and fingers exposure in a shielded work environment.

Methodology

Materials Required

- GM tube (SBM 21)
- Microcontroller with display and high voltage generating circuit
- Software code for microcontroller
- Connecting wires
- Power supply
- Standard radioactive source

Construction

GM tube

SBM-21 tube:

- Weight: 0.8grams
- Working range: 350 to 475 Volts
- Start of counting: 260 to 320 Volt
- Plateau length: at least 100 Volts
- Plateau slope: 0.15 %/Volt
- Dead time at 400 Volt power: 64 Roentgen/msec
- Maximum counting: no more than 650 pulses/sec
- Background noise: no more than 0.2 pulses/sec
- Body size: 16 x 6mm
- Pin size: 5 x 2mm
- Total length: 21mm

Microcontroller

It was made in two variants. One with an onboard wifi communication module and another one with an inbuilt display. The microcontroller had circuits for generating high voltage to the GM tube and had an onboard power supply with rechargable battery system.

Entire unit was protected using plexiglass casing and the GM tube was protected using heat shrinked plastic coating:

GM Probe: It is compact with one meter-long cable

Standard radioactive source: 137Cs – Disc sealed source with activity 10μCi and long lived radionuclide with half- life of 30.1yrs

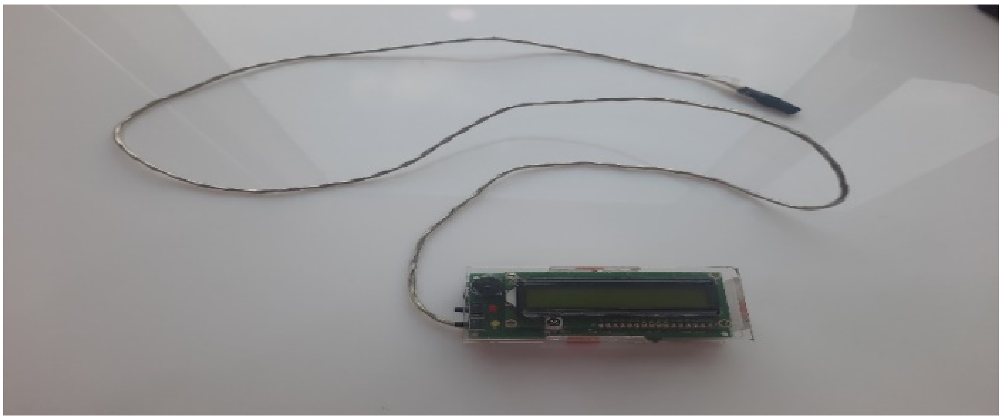


Figure 1. Newly Designed Instrument

Results

The total readings were taken during various occasions while preparing (total 59 readings) and dispensing (total 45 readings) radioisotopes.

Table 1. Exposure Level during Radio-Pharmaceutical Preparation & Dispensing

S. No.	Procedures	^{99m}Tc-Sestamibi		^{99m}Tc-MDP		^{99m}Tc-DTPA	
		Sample	Exposure level (µSv/h)	Sample	Exposure level (µSv/h)	Sample	Exposure level (µSv/h)
1	Radio-pharmaceutical preparation	16	1115	21	3083	22	453
2	Radio-pharmaceutical dispensing	15	351	15	209	15	235

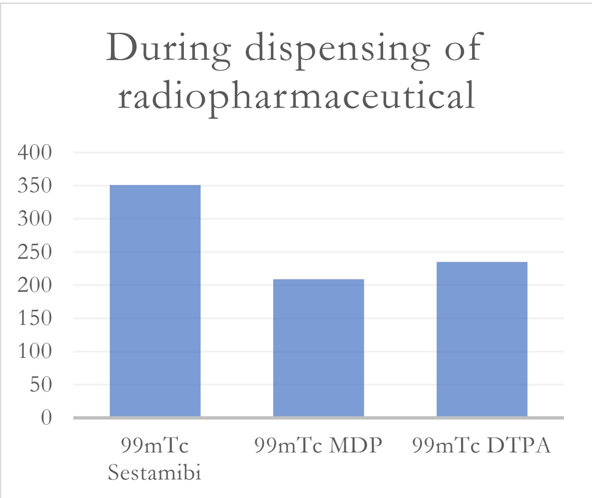


Figure 2. Radiation Exposure Level of Different Radiopharmaceutical (during Dispensing)

Discussion

Working of the instrument

The measuring device was constructed using micro–Geiger Muller Counter. The micro-Geiger Counter with model no SBM21 was connected to high voltage circuit & then connected to the microcontroller using shielded cable and the output signal was obtained. After this, output signal was sent it to Arduino circuit running custom code ESP8266 and the microcontroller display the reading on count basis or can provide exposure readout based on the necessity. The readings were made on the display & also on mobile/ laptop application after connecting to Arduino circuit running custom code ESP8266 via internet. Readings were taken for short durations during certain periods. The GM probe was connected to the main unit using a one meter-long cable which made it more versatile and can be attached to any part of the body where radiation exposure measurements need to be recorded. Readings were recorded in the form of μSv/h or mSv/h. The system can provide real time data about the radiation exposure of the operator.

For standardizing the instrument, this unit was first tested with standard source 137Cs and was calibrated using a standard instrument. Calibration was cross checked with the help of IIT instrument calibration center.

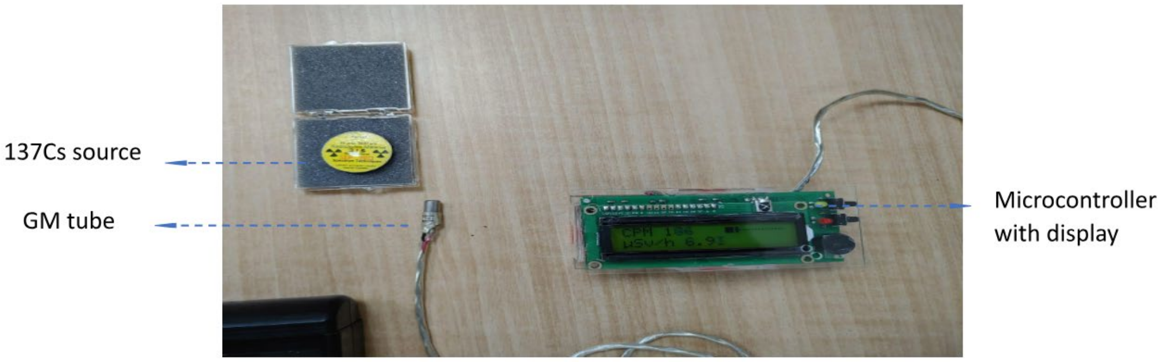


Figure 3. Front View

Figure 4. Back Side View

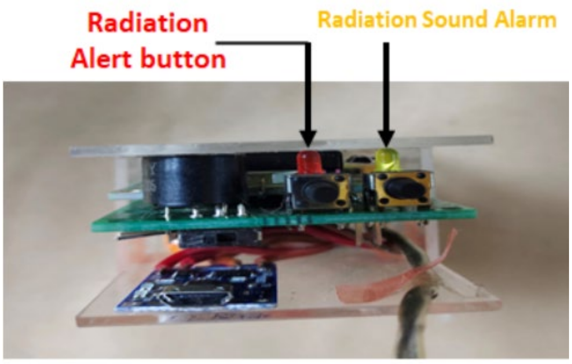


Figure 5. Side View

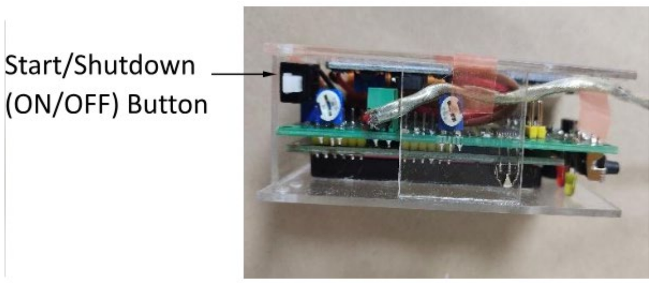


Figure 6. Top View

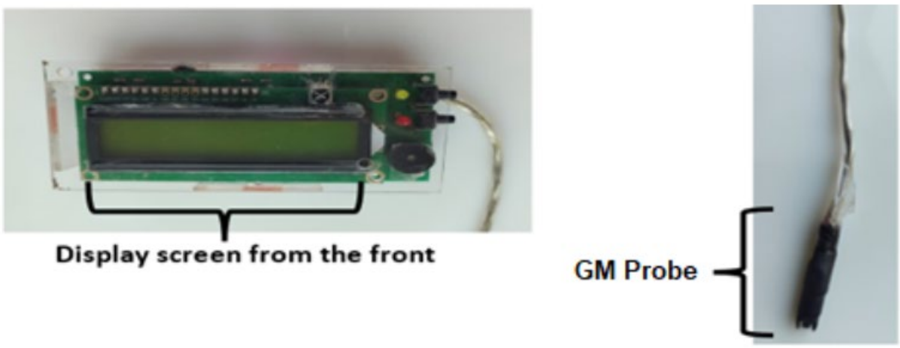


Figure 7. Display Screen and GM Probe

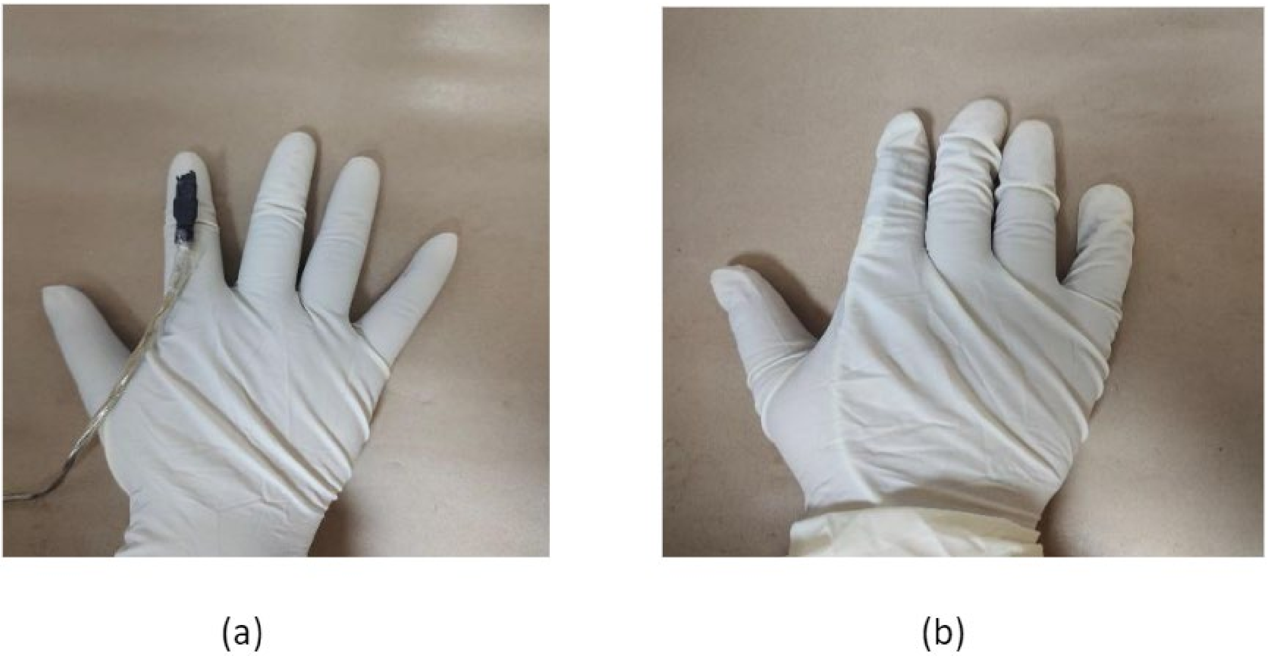


Figure 8 (a & b). Position of the GM Probe (Radiation Detector) while Handling the Radioisotope

Handling of Radiopharmaceutical with GM Probe

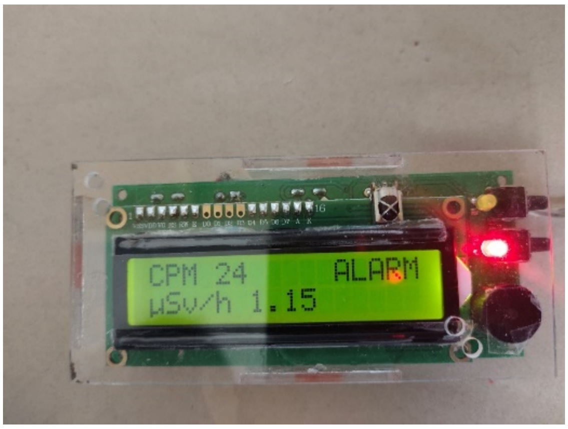
GM based counters can be used for measuring lower rates of radiation. Even while working in a shielded environment like an L-bench or lead pots there is added radiation exposure to the hands and fingers. Good work practices can reduce this radiation exposure and minimize the rates to a lower level (Pant, 2008; Saha, 2012).

For measuring the ionizing radiation, radiation monitoring detectors are commonly used. Like for high radiation, ionization-based detector (survey meter) is used and for lower radiation, GM based detector (contamination cum survey meter) is used. In Nuclear Medicine facility, we mainly deal with unsealed form of radionuclides which need more radiation protection to the radiation worker as well as public while handling the radioisotope (during radiopharmaceutical preparation and radiopharmaceutical injection). For personnel radiation monitoring, TLD and pocket dosimeters are used to measure radiation dose received by the radiation worker who is working in radiation field. The basic principle of TLD is thermoluminescence which don't give instant result. It takes time but it is cheaper than pocket dosimeter (Pant, 2008; Saha, 2012).

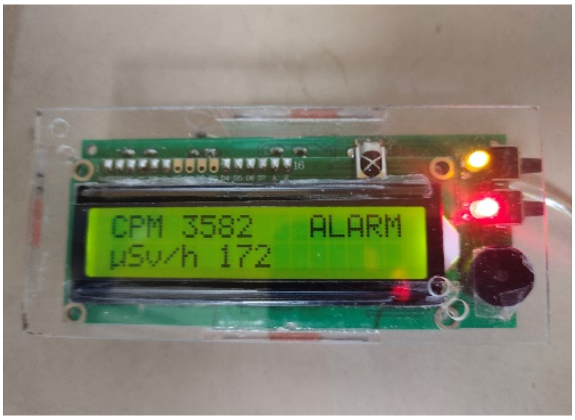
Figure 9. Handling of Radiopharmaceutical in Nuclear Medicine Facility behind L – Bench with proper Radiation Safety Protocol

Pocket dosimeters are used commonly in Nuclear Medicine or radiology workers for daily dose measurement or during certain high radiation exposure procedures for short periods of time. It shows an instant result and need less time but it's expensive which need high maintenance costs. It may not be feasible to procure many at a time due to cost restraints. So, we designed a low-cost remote dose monitoring device for measurement of radiation for short periods of time. It measures the finger's exposure while working in radiation area. It is feasible for the worker to fit the measuring device in their pocket while working. With this innovative detector, a single device is used for different occupational worker (Pant, 2008; Saha, 2012).

Zuckier L.S., Boardman B., Zhao Q.H. (1998) developed a remotely portable system using software and telephone lines for continuous radiation monitoring of 131I therapy in patients which revealed that the patient monitoring with this newly developed portable GM detector showed the accuracy and easy technique which reduced the hospital stay of patient after radioiodine therapy.



a



b

Figure 10. (a) Background Radiation Level; (b) Radiation Level is Shown while Handling the Radioactivity

Dean et al. (2022) assessed the extremities and whole-body exposure radiation exposure of radiation workers. In this study, they assessed that the extremities exposure is higher than whole body exposure. They also revealed that the dose level also varied from the work place like in Radio-pharmacy laboratory, dose level to extremities is 5 times more than the whole-body dose level and in cyclotron operation, the medial dose level to extremities is 100 times more than whole body median dose level which resulted that there is an underassessment of exposure level of radiation worker in medical applications.

Askounis et al. (2022) conducted an experiment in which various methods developed for the assessment of the effective dose and eye lens dose.

Gbetchedji et al. (2020) assessed the effective dose of occupational healthcare workers exposed in South Africa. In this study, the annual mean annual effective doses ranged from 0.44 to 8.20 mSv in all specialities of medical sectors, while diagnostic radiology ranged from 0.07 to 4.37 mSv. For the nuclear medicine and radiotherapy from medical groups, the mean annual effective dose varied between 0.56 and 6.30 mSv. Industrial and research/teaching sectors data varied between 0.38 to 19.40 mSv. They concluded that more data are required to give the exact value of effective dose of radiation workers in South Africa.

Wang et al. (2017) determined the personal dose level of radiation workers in medical institutions at the municipal level and below in a city from 2011 to 2014. The result was that the annual effective dose of the radiation workers was 0-4.76 mSv (mean 0.31±0.40 mSv), and the collective annual effective dose was 351.96 mSv. The annual effective dose was significantly different between radiation workers with different times of permit application, hospital levels, and types of occupational radiation. It was also varied with different length of radiation work.

Jain P., Fleming P., Mehta A.C. (1999) explained the radiation safety procedures for radiation workers in bronchoscopy study as the radiation worker received maximum radiation burden in this procedure. So, there is a need to explain the whole radiation safety procedures to the radiation workers. For this procedure, standard safety precautions are to be followed to prevent the health risk of radiation workers.

Ittimani et al. (2007) determined the radiation exposure level to trauma team members. The result was that total dose ranged from 1.2 to 20.5μSv for a single trauma patient. Only 15 trauma patients per year for a team member were taken without the radiation safety accessories based on department data. They demonstrated the possibility of significant radiation exposure for unprotected trauma team members.

Sethole K.M., Ahrens, E. and Kruger, U. (2019) determined the level of compliance with the use of personal radiation monitoring devices by qualified radiographers at 5 provincial hospitals in the Tshwane District Area. Health Physics. 2019. Total 96 questionnaires sent out to the provincial hospitals in the Tshwane district area, 61 were returned with a response rate of 63.5%. The result showed compliance of radiographers in wearing radiation monitoring devices but inconsistency in the placement of radiation monitoring device. In this study, lack of awareness about policies from the Radiation Board was also noted.

Feng, H.T. & Sun, Z. (2019) analyzed the personal dose of radiation exposure of radiation workers in some medical institutions in Tianjin from 2014 to 2018. The Result was that a total of 8718 persons were monitored in this study. Out of which 14 persons (0.2%) whose annual effective dose was higher than 5 mSv 8661 persons (99.3%) whose annual effective dose was lower than 2 mSv; 43 persons (0.5%) whose annual effective dose was 0.22 mSv. The annual effective dose per capita of radiation workers in primary and secondary hospitals was higher than that in tertiary hospitals; and the abnormal rate of individual dose monitoring was 73. They concluded that personal dosage of radiation workers in some medical institutions in Tianjin is at a low level.

Conclusion

This is our pilot study which revealed accurate hand/finger exposure readings >95% of the times for short periods of time. The study designing and standardization of readings with more real time accuracy can make this method more reliable and is a low cost means to monitor short periods of radiation exposure for radiation worker. It is feasible for the worker to fit the measuring device in their pocket while working in radiation area.

The entire system was built to keep the construction cost as low as possible with an aim of building the entire system indigenously. Each unit costed approximately 10,000 to build which make it one of the cheapest GM counting systems. This helps institutes and industries to save cost significantly in procuring radiation protection instruments and also will help them to effectively monitor radiation exposure in radiation workers.

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