Educational Administration: Theory and Practice
2024, 30(5), 12831-12836
ISSN: 2148-2403
https://kuey.net/
Research Article

Comparative Study Of Two Methods For Assessing Leakage Radiation Dose In Digital X-Ray Machine: Regulatory Compliance

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Citation: Meraj Alam, et al (2024), Comparative Study Of Two Methods For Assessing Leakage Radiation Dose In Digital X-Ray Machine: Regulatory Compliance. *Educational Administration: Theory and Practice*, *30*(5), 12831-1236, Doi: 10.53555/kuey.v30i5.5421

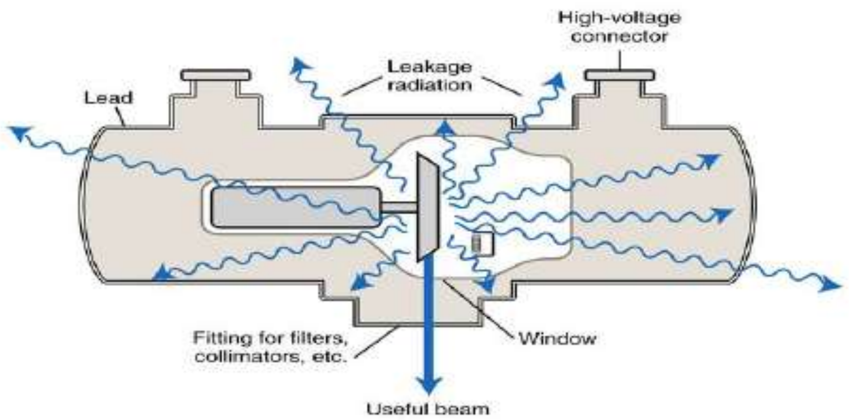
ARTICLE INFO	ABSTRACT

This study aims to evaluate leakage radiation in Digital x-ray equipment through two dosimetry methods: ion chamber and Semiconductor diode dosimeter. The research investigates the feasibility and advantages of employing these methods for the precise assessment of leakage radiation dose in digital x-ray machines. Leakage radiation poses significant risks to patients and healthcare professionals, necessitating accurate assessment techniques. The research is conducted in accordance with established guidelines and standards, with a specific focus on compliance with regulations set forth by the Atomic Energy Regulatory Board (AERB). [1], [2], [3]. Method-1 involves ion chamber dosimetry, while Method-2 employs Semiconductor diode dosimeters. By conducting controlled experiments and comparisons, we assess the precision, reliability, and practicality of each approach. The study's findings elucidate the benefits and challenges associated with these dosimetry methods, contributing to enhanced radiation safety protocols and quality assurance in Digital x-ray imaging. Method-1, employing ion chamber dosimetry, is a conventional approach widely used in radiation measurement applications. It involves the use of a calibrated ion chamber to measure radiation dose accurately. Method-2, utilizing Semiconductor diode dosimeters, represents a newer technology offering advantages such as compactness, portability, and potential for real-time data acquisition. The study involves meticulous experimental setup and data collection procedures. Measurements are conducted under controlled conditions. The permissible limit for radiation leakage from the protective tube housing and collimator in digital x-ray machine is 1.0 mGy (about 114 mR) in one hour at 1.0 meter from the x-ray tube focus point. The measurement of radiation leakage involves employing an ionization chamber and a semiconductor-based radiation survey meter, with the radiation being averaged over a specified area not exceeding 100 cm². Throughout the leakage measurement process, the x-ray machine remains operational with the radiation activated. The collimator of the tube housing is fully closed, and the tube is energized at the maximum rated tube potential and tube current corresponding to that kilovolt peak (kVp). The exposure rate at one meter from the focal spot is measured at various positions, including the anode side, cathode side, front, back, and top of the tube housing and collimator, as illustrated in Figure-1. The study determines the maximum leakage rates for both the tube housing and collimator, accounting for a workload of 180 mA-min per hour for a diagnostic machine (radiography and fluoroscopy). The recorded highest equivalent dose rate is also documented. The measurements values from test method-1 and test method-2 are within the specified limits (114 mR in one hour) of AERB requirement and deviation is within 10%.

Keywords: Digital x-ray machine, Radiation safety, Leakage radiation, Quality Assurance, Regulatory Compliance

I. INTRODUCTION

In present day, diagnostic x-ray examinations are a fundamental aspect of medical practice for diagnosing various medical conditions and being one of the significant contributors of irradiation experienced by the general population. And digital x-ray machines play a crucial role in modern diagnostic radiology, facilitating the rapid acquisition and interpretation of medical images for diagnostic purposes. However, like all x-ray equipment, digital x-ray machines emit radiation, and safeguarding the well-being of patients and healthcare personnel is paramount. Leakage radiation, which refers to radiation that leaks from the x-ray tube (figure 1) and collimator in digital x ray machine, presents a potential hazard if not properly controlled and monitored.



(Figure 1)

To mitigate risks associated with leakage radiation, regulatory bodies such as the Atomic Energy Regulatory Board (AERB) have established guidelines and standards for radiation safety in medical facilities [1]. These regulations mandate the regular assessment of leakage radiation dose to ensure compliance with permissible limits and safeguard the health and well-being of individuals exposed to x-ray radiation. Traditionally, ion chamber dosimetry has been the preferred method for assessing leakage radiation dose in x-ray machines. Ion chambers offer high accuracy and reliability in radiation measurement and have been extensively used in medical physics applications. However, advancements in semiconductor technology have led to the development of Semiconductor diode dosimeters, which offer potential advantages such as compactness, portability, and real-time data acquisition.
The research is conducted in accordance with AERB guidelines to ensure alignment with regulatory requirements and standards [1]. By providing insights into the strengths and limitations of each dosimetry method, this study aims to inform healthcare facilities, medical physicists, and regulatory bodies about the most appropriate dosimetry techniques for ensuring radiation safety in digital x-ray imaging.
Through this comparative study, we aim to contribute to the advancement of radiation safety practices in diagnostic radiology and the optimization of patient and staff protection in medical imaging environments.

X-ray leakage measurements are performed to find potential leakage of ionizing radiation from x-ray tubes housing in the x-ray machine. It is part of the type testing and QA at manufacturers of x-ray machines and radiation safety procedures at hospitals.
A key aspect of this study is the comparison between Method-1, which utilizes ion chamber dosimetry, and Method-2, which employs Semiconductor diode dosimeters. While ion chamber dosimetry is a well-established and widely used method in radiation measurement applications, Semiconductor diode dosimeters represent a newer technology with potential advantages such as compactness, portability, and the ability for real-time data acquisition.

II. METHODS AND MATERIAL

The experimental setup involves the use of a Digital x-ray machine, dosimetry equipment including ion chamber dosimeters and Semiconductor diode dosimeters, and calibration procedures according to manufacturer specifications and regulatory standards.
The Radiation leakage measurements are conducted using an ionization chamber and a semiconductor-based radiation survey meter. during a leakage measurement, the x-ray machine is operated with the radiation ON, while the collimator of the x-ray tube housing in digital x-ray machine remains fully closed. The tube is powered up to its maximum rated tube potential and tube current at the specified kilovolt peak (kVp). Exposure rates are then measured at 1 meter from the focal point to six different locations, each spaced at

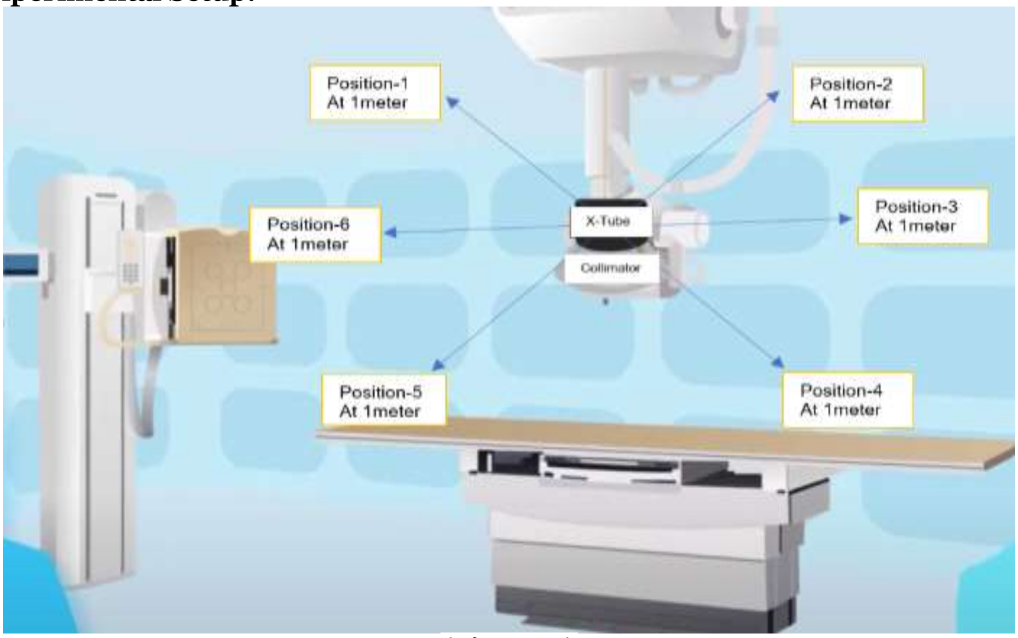
60° intervals, including the anode side, cathode side, front, back, and top, relative to both the tube housing and collimator.
The maximum leakage rates (measured in mR/h) from both the tube housing and collimator are used to compute the leakage radiation over a one-hour period, considering the workload of the unit.
Measurements are taken at regular intervals with both dosimetry devices to ensure comprehensive coverage of leakage radiation levels.

Leakage Radiation Limits: Compliance with leakage radiation dose limits specified by AERB guidelines is verified to ensure safety standards are met.

Formula to calculate radiation leakage in mR in hour.

$$\text{mR in one hr} = \frac{\text{Highest Dose rate (mR/Hr)}}{mA * 60} * 180 \qquad (1)$$

Experimental Setup:



(Figure 2)

Dosimetry Equipment:
Raysafe X2 Survey meter is based on Semiconductor diode dosimeter shown in figure-3a and RGD 27091 Survey meter is based Ion-chamber dosimeter as shown in figure-3b are employed for measuring leakage radiation dose. Both dosimetry devices are calibrated according to manufacturer specifications and regulatory standards. And the correction factor 1 is considered based on the calibration data for dose rate measurements calculation.

Figure-3a (Raysafe X2 Survey dose meter) Figure-3b (RGD 27091 Survey dose meter)

Suitability Assessment: The suitability of each dosimetry method for routine leakage radiation assessment in digital x-ray machines is evaluated based on the experimental results and practical considerations.
Overall, the methods and materials employed in this study aim to provide a comprehensive comparison of ion chamber dosimetry and Semiconductor diode dosimeters for assessing leakage radiation dose in digital x-ray machines, with a focus on accuracy, precision, practicality, and regulatory compliance.

III. RESULTS AND DISCUSSION

The results of the comparative analysis between ion chamber dosimetry and Semiconductor diode dosimeters provide valuable insights into the accuracy, precision, and practicality of each method for assessing leakage radiation dose in Digital x-ray machines. Ion chamber dosimetry demonstrates high accuracy and reliability, consistent with its established reputation as a standard dosimetry technique. However, its larger size, complexity, and requirements for careful handling may limit its practicality in certain environments.

In contrast, Semiconductor diode dosimeters offer a more practical and user-friendly alternative, with advantages such as compactness, ease of use, and the potential for real-time data acquisition. While slight variations in measurements compared to ion chamber dosimetry may be observed, Semiconductor diode dosimeters prove effective in compliance with regulatory standards and providing timely feedback on radiation levels.

Operating Parameters:

Digital Radiography mode SRO 33100 ROT 380	FDD (cm): 100cm	kVp (Max) = 150	mA = 50	Time(s) ≈ 1 sec

Location (At 1.0m from the focus)	**Measurements Table1: Test Method-1 (RGD Survey based on ion chamber)**					
	Pos-1	Pos-2	Pos-3	Pos-4	Pos-5	Pos-6
For Tube (mR/hr)	110.8	119	113	126.5	128.5	115
For Tube (mR in one hour)	**6.65**	**7.14**	**6.78**	**7.59**	**7.71**	**6.9**
For Collimator (mR/hr)	95.8	104.6	98	121.4	118.0	101.0
For Collimator (mR in one hour)	**5.75**	**6.28**	**5.88**	**7.28**	**7.08**	**6.06**

Location (At 1.0m from the focus)	**Measurements Table2: Test Method-2: (X2 Survey based on Semiconductor diode)**					
	Pos-1	Pos-2	Pos-3	Pos-4	Pos-5	Pos-6
For Tube (mR/hr)	98.5	107	105.5	116.4	119.1	103.5
For Tube (mR in one hour)	**5.91**	**6.42**	**6.33**	**6.99**	**7.15**	**6.21**
For Collimator (mR/hr)	81.6	98.4	88.6	113.2	114	92.2
For Collimator (mR in one hour)	**4.90**	**5.90**	**5.32**	**6.79**	**6.84**	**5.54**

Acceptance Criteria: The maximum leakage radiation at one- meter from the focal point should be ≤ 1 mGy or 114 mR in one hour.

The maximum leakage calculated in measurement table-1 and measurement table-2 based on the equiation-1

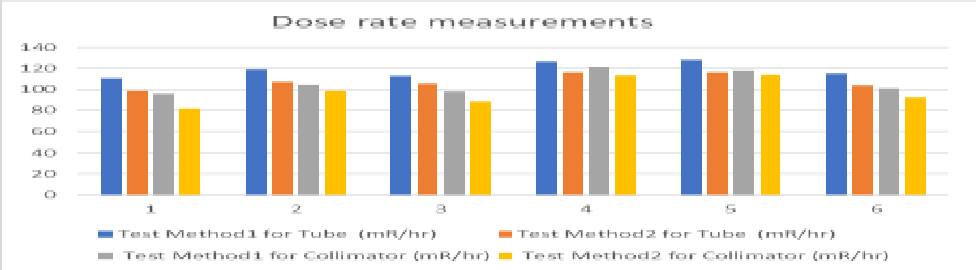
Test Method 1 -Measurements Table1 (RGD Survey based on ion chamber)
The maximum leakage radiation from tube housing in digital x-ray machine = **7.71** mR in one hour
The maximum leakage radiation from collimator in digital x-ray machine = **7.28** mR in one hour

Test Method 2- Measurements Table2 (X2 Survey based on Semiconductor diode)
The maximum leakage radiation from tube housing in digital x-ray machine = **7.15** mR in one hour

The maximum leakage radiation from collimator in digital x-ray machine = **6.84** mR in one hour

Results Measurement Table-3			
Location (At 1.0m from the focus)	Max value for Test Method 1 from table1	Max value for Test Method 2 from table2	Deviation
For Tube (values mR in one hour)	**7.71**	**7.15**	**0.0727**
For Collimator (values mR in one hour)	**7.28**	**6.84**	**0.0604**

The measurements values from test method-1 and test method-2 are within the specified limits (114 mR in one hour) of AERB requirement. And deviation in both the test methods is available in measurement table 3.



Graphical representation of dose rate measurements for test method 1 and test method 2.

Accuracy and Precision: Ion chamber dosimetry and Semiconductor diode dosimeters both provided accurate measurements of leakage radiation dose, with slight variations observed between the two methods. Deviation is less tham 10%.
Practicality and Ease of Use: Ion chamber dosimetry is reliable but complex and requires careful handling. Semiconductor diode dosimeters are more practical and user-friendly due to their smaller size and simplified operation.
Real-time Data Acquisition: Semiconductor diode dosimeters offer real-time data acquisition, allowing for immediate feedback on radiation levels and facilitating prompt corrective actions.
Compliance with Regulatory Standards: Both methods complied with regulatory standards, including ICRP and, AERB guidelines for leakage radiation dose limits.
Overall, the comparative study suggests that both ion chamber dosimetry and Semiconductor diode dosimeters are effective methods for assessing leakage radiation dose in digital x-ray machines. Ion chamber dosimetry excels in accuracy and reliability but may be less practical in terms of size and complexity. Semiconductor diode dosimeters offer advantages in terms of practicality, ease of use, and real-time data acquisition, making them a viable alternative for routine radiation monitoring in digital x-ray facilities. Ultimately, the selection of dosimetry method should consider factors such as accuracy, practicality, cost, and regulatory compliance to ensure optimal radiation safety in medical imaging environments.

IV. CONCLUSION

In conclusion, both ion chamber dosimetry and Semiconductor diode dosimeters are effective methods for assessing leakage radiation dose in Digital x-ray machines. While ion chamber dosimetry offers high accuracy and reliability, Semiconductor diode dosimeters provide practical advantages in terms of ease of use and real-time data acquisition. The choice between the two methods should consider factors such as accuracy requirements, practicality, and regulatory compliance.
Overall, this study contributes valuable insights to the optimization of radiation safety protocols and quality assurance in Digital x-ray imaging.

V. REFERENCES

1. Atomic Energy Regulatory Board (AERB). "Safety Code for Diagnostic X-ray Equipment and Installations." Available at: https://www.aerb.gov.in.
2. International Atomic Energy Agency (IAEA). "Radiation Safety in Diagnostic Radiology and Interventional Procedures Using X Rays." Safety Report Series No. 39. https://www-pub.iaea.org.
3. National Council on Radiation Protection and Measurements (NCRP). "Radiation Protection in Diagnostic X-Ray Facilities." Report No. 147, 2004.
4. Bushberg, J.T., et al. "The Essential Physics of Medical Imaging." 3rd ed., Lippincott Williams & Wilkins, 2011.

5. Ardran, G., and Kemp, F. "Leakage Radiation from Diagnostic Tubes." Br Med J, vol. 2, no. 4983, 1956, p. 41.
6. Radiology Key. "The X-ray Tube." Chapter 5. https://radiologykey.com.
7. Bari, D.S., Amin, P.M., and Abdulkareem, N.A. "Measurement of Effective Dose Radiation," 2015.
8. Chaloner, P. "Diagnostic X-ray Equipment Compliance and Facility Survey." Environmental Health Directorate, Health Protection Branch, Ottawa, 1994.
9. International Atomic Energy Agency (IAEA). "Radiation, People and Environment." 1st ed., Vienna: ICRP, 2004.
10. Malone, J.F. "Design of Diagnostic Medical Facilities Using Ionising Radiation." 1st ed., Dublin: Radiological Protection Institute of Ireland, 2009.
11. American Association of Physicists in Medicine (AAPM). "Standardized Methods for Measuring Diagnostic X-ray Exposures." AAPM Report No. 31, 1990.
12. Martin, A., Harbison, S., Beach, K., and Cole, P. "An Introduction to Radiation Protection." CRC Press, 2018.
13. Kim, J.H. "Three Principles for Radiation Safety: Time, Distance, and Shielding." Korean J Pain, vol. 31, 2018, p. 145.
14. International Commission on Radiological Protection (ICRP). "The 2007 Recommendations of the ICRP." ICRP Publication 103, Ann ICRP, vol. 37, 2007, p. 2.