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Recent Advancement in TLD (Thermoluminescent Dosimeters) in Radiology: A Systematic Review

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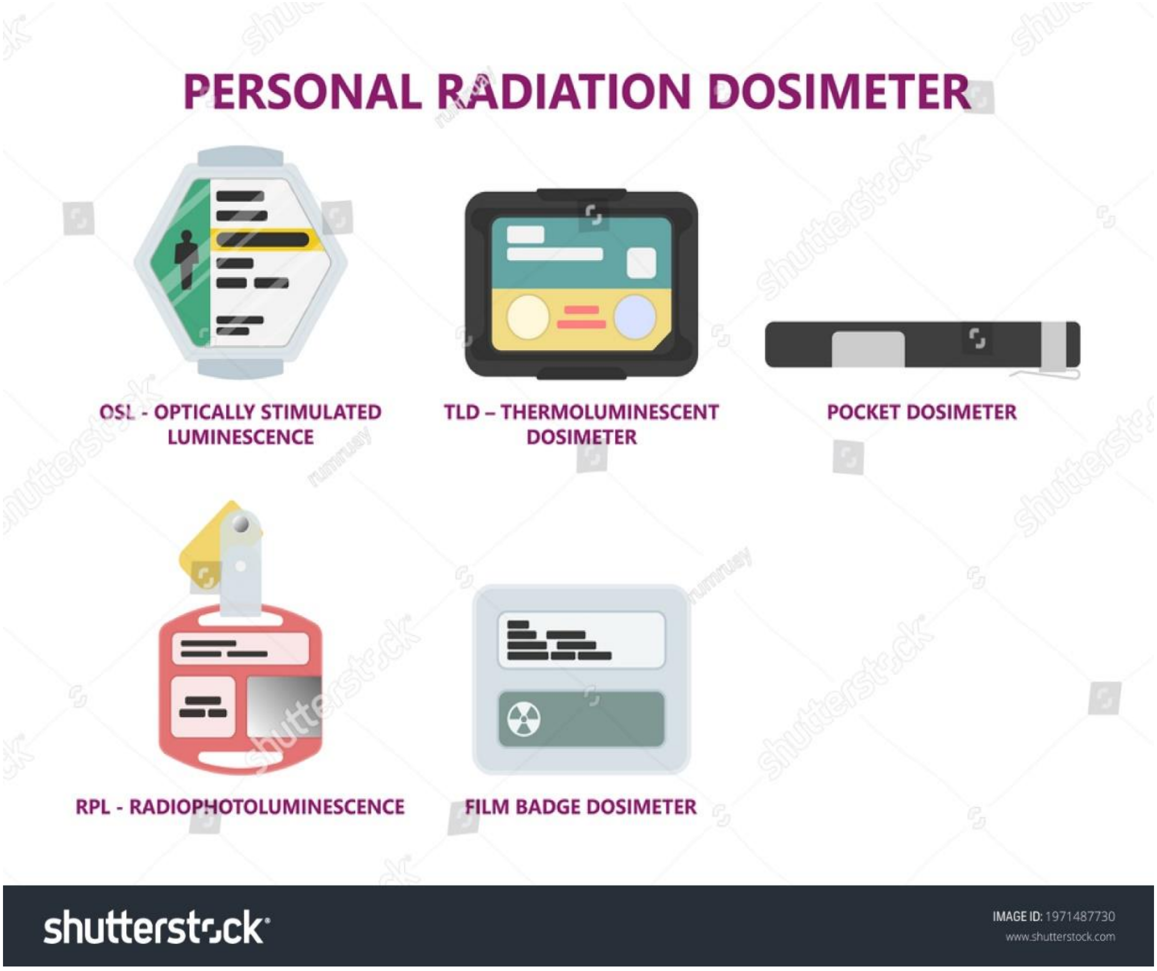
ABSTRACT

The objective of this study was to evaluate the X-ray energy dependence of the measured response of detectors (TLD-100) and determine the accurate dose provided to patients during normal X-ray examinations. Since the 1970s, the way protection standards are expressed has changed from a dose-based approach to a risk-based one, with dose limits set to generate risks to medical radiation workers .The secondary standard dosimetry lab (SSLD) in Cairo, Egypt, of the National Institute of Standards' Ionizing Radiation Met. Lab was used to measure the response of Thermoluminescent dosimeters (TLD) as a function of low energy range. Patient Dose Reduction in Diagnostic Radiology, published by the UK National Radiological Protection Board (NRPB), sparked interest in patient dose measuring around the world. At nominal x-ray energies of 25, 50, and 100 kVp, the X-ray dose was measured. The linearity, repeatability, and relative sensitivity of the TLD-100 were examined. To find the calibration coefficient of the TLD system and the correction factors used for the dosage calculation (readings (nC)/radiation dose (mGy), many sets of TLD-100 were exposed to varying x-ray beam energies (0.69 (mGy) to 350 (mGy). In diagnostic radiology, the radiation dosage to the patient was estimated for the currently in use working protocols (head, pelvis, abdomen, and lumbar spine). As a result, new diametric measuring tools, methodologies, and vocabularies have emerged, posing issues for people working in clinical settings and those supporting them in calibration facilities. The present study examines the current state and future trends in diagnostic radiology dosimetry employing thermoluminescence phenomena.

INTRODUCTION:

In radiology, TLD stands for Thermoluminescent Dosimeter. It is a device used to measure the dose of ionizing radiation received by individuals, such as radiologists, technicians, or patients undergoing medical imaging procedures like X-rays or CT scans. TLDs work based on the principle of thermoluminescence, where certain materials emit light when heated after being exposed to radiation. This emitted light is proportional to the amount of radiation absorbed by the TLD. Radiation exposure is a significant concern in radiology due to its potential health risks, such as the development of cancer or genetic mutations. By using TLDs, healthcare providers can monitor the radiation doses received by personnel in the radiology department to ensure they are within safe limits. This helps in optimizing radiation safety protocols, implementing necessary precautions, and minimizing the risk of overexposure. The hazards of X-rays of radiations lie on radiobiology and epidemiology studies are based on the assessment of radiation dose, particularly dosimetry. The most basic dosimetry in X-ray equipment is probably the dose determination of the X-ray tube output. Additional exposure factors (kilovolt, milliampere, exposure time) should be assessed. TLDs are small and portable, making them convenient for personal dosimetry. They can be worn as badges or placed in various locations to measure radiation levels in different areas of the body or the environment. After a certain period of time, the TLDs are collected, and the accumulated radiation dose is analysed in a specialized reader to determine the exposure levels accurately. Thermoluminescence (TL) dosimeters are widely used in various fields of dosimetry, including diagnostic radiology (Faghihi et al., 2012; Sina et al., 2014; Berni et al., 2002), radiation therapy (Hsi et al., 2013; Lambert et al., 2007; Sina et al., 2011; Mosleh Shirazi et al., 2012), and personal monitoring (Biran et al., 2004). Exact dosimetry requires a thorough understanding of optimal dosimetry processes. Energy, dose rate, and angular dependency pre- and post-irradiation fading, annealing, optimal time-temperature profile for TLD readout, and radiation field homogeneity are all critical issues in optimizing TLD responses (Karsch et al., 2012; Nunn et al., 2008; Stadtmann et al., 2006; Shachar and Horowitz, 1992; Lee et al., 2015; Doremus et al., 1994; Knoll, 1999).



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Types of Material:

Thermoluminescent dosimetry (TLD) is a technique used for measuring ionizing radiation doses. There are different types of materials used in TLD dosimeters, each with its specific characteristics and applications. Here are some common types of TLD materials used in dosimetry:

1. Lithium Fluoride (LiF): LiF is one of the most commonly used materials in TLD dosimeters due to its high sensitivity and wide dose range. It is suitable for measuring both high and low doses of ionizing radiation, making it versatile for various applications such as medical radiation therapy and environmental monitoring.

2. Calcium Sulphate (CaSO4): CaSO4 is another popular TLD material known for its tissue-equivalent properties, meaning it closely resembles human tissue in its response to ionizing radiation. This makes $CaSO_4$ dosimeters ideal for measuring radiation doses in medical imaging and radiation therapy.

3. Lithium Borate ($Li_2B_4O_7$): $Li_2B_4O_7$ is a TLD material with high sensitivity and stability, making it suitable for measuring low to moderate doses of radiation. It is often used in occupational radiation monitoring and environmental dosimetry.

4. Magnesium Tetraborate (MgB_4O_7): MgB_4O_7 is a TLD material that offers good sensitivity and energy response, making it useful for measuring radiation doses in a wide range of applications. It is commonly used in radiation protection dosimetry and personal monitoring.

5. Aluminium Oxide (Al_2O_3): Al_2O_3 is a TLD material that exhibits excellent dosimetric properties, including high sensitivity and minimal fading. It is commonly used in radiation therapy dosimetry and environmental monitoring due to its stability and reliability.

Recent trends of TL dosimetry in diagnostic radiology:

One of the recent advancements in Thermoluminescent dosimetry (TLD) technology is the development of more sensitive and precise TLD materials and readout systems. Here are some of the key advancements in TLD dosimetry:

1. Nanotechnology Applications: Nanotechnology has been integrated into TLD dosimetry to enhance the sensitivity and precision of TLD materials. By incorporating nanoparticles into TLD crystals, researchers have achieved higher sensitivity and improved energy response, leading to more accurate radiation dose measurements.

2. Micro-structured TLD Materials: Micro-structured TLD materials have been designed with specific patterns or structures at the microscale to enhance their dosimetric properties. These materials offer improved spatial resolution and dose measurement accuracy, making them suitable for applications that require precise dose localization, such as radiography and radiation therapy.

3. High-Temperature TLD Materials: Advances in high temperature TLD materials have enabled the measurement of radiation doses in extreme environments, such as nuclear reactors and aerospace applications. These materials can withstand high temperatures without losing their dosimetric properties, allowing for accurate dose measurements in challenging conditions.

4. Real-Time TLD Readout Systems: Real-time TLD readout systems have been developed to provide instant dose measurements during radiation exposure. This technology allows for continuous monitoring of radiation doses in real-time, enhancing radiation safety in medical settings, industrial facilities, and emergency response scenarios.

5. Multi-Element TLD Arrays: Multi-element TLD arrays consist of arrays of TLD detectors that enable simultaneous measurement of radiation doses at multiple points. These arrays provide spatial information on dose distribution, making them valuable for quality assurance in radiotherapy treatment planning and verification.

6. Wireless TLD Systems: Wireless TLD systems have been designed to enable remote monitoring of radiation doses without the need for physical retrieval of dosimeters. These systems use wireless communication technology to transmit dose data in real-time, allowing for efficient dose tracking and management in various applications.

7. Automated TLD Analysis Software: Automated TLD analysis software has been developed to streamline the processing and interpretation of TLD dose measurements. These software tools automate the readout and analysis of TLD data, reducing human error and increasing efficiency in dose assessment and reporting.

Overall, these advancements in TLD dosimetry technology aim to improve the accuracy, sensitivity, and efficiency of radiation dose measurements across various applications. By integrating new materials, readout systems, and data analysis tools, researchers and practitioners can enhance radiation safety, quality assurance, and dose optimization in medical, industrial, and environmental settings.

Parts of TLD (Thermoluminescent Dosimeter):

TLD stands for Thermoluminescent Dosimeter, which is a type of radiation measurement device used to monitor the amount of radiation exposure received by individuals who work with radiation in medical imaging facilities. The main components of a TLD in radiology include the following:

1. *Detector*: The detector in a TLD is typically made of a crystalline material such as lithium fluoride. When exposed to ionizing radiation, the detector absorbs the radiation energy. The absorbed energy is stored in the form of trapped electrons within the crystal lattice of the detector material.

2. *Readout System*: The readout system is used to measure the amount of radiation dose absorbed by the TLD. This is usually done by heating the TLD material in a controlled manner, which causes the trapped electrons to be released and recombine with the lattice defects in the crystal. As this recombination happens, the stored energy is released in the form of visible light, which can be detected and measured by the readout system.

3. *Calibration Device*: A calibration device is used to calibrate the TLD system to ensure accurate measurement of radiation dose. This device exposes the TLD to a known amount of radiation, allowing the system to establish a reference point for correlating the amount of light emitted by the TLD with the actual radiation dose received.

4. *Holder/Case*: The TLD is usually housed in a protective holder or case to prevent damage and contamination. This holder also helps in positioning the TLD correctly during radiation exposure and storage.

5. *Labeling*: Each TLD is labeled with a unique identifier to track and identify the individual to whom the dosimeter belongs. This is important for maintaining accurate records of radiation exposure for each individual over time.

6. *Analysis Software*: After the TLD has been read using the readout system, the data is typically analyzed using specialized software. This software helps in interpreting the results and calculating the actual radiation dose received by the individual during a specific period of time.

7. *Dosimetry Report*: The final component of a TLD system is the dosimetry report, which provides a detailed summary of the individual's radiation exposure over a specific period. This report is essential for monitoring radiation dose levels, ensuring compliance with safety regulations, and taking appropriate measures to minimize radiation exposure if necessary.

Uses Of TLD (Thermoluminescent Dosimeter):

Thermoluminescent dosimeters (TLDs) are widely used in various fields for radiation dose measurement and monitoring. Some key uses of TLD dosimetry include:

1. *Occupational Radiation Monitoring*: TLDs are commonly used to monitor radiation exposure levels for individuals working in occupations where they are exposed to ionizing radiation, such as radiographers, nuclear medicine technicians, radiation therapists, and nuclear power plant workers. TLDs provide an accurate assessment of the radiation dose received by personnel over a specific period, helping to ensure compliance with safety regulations and guidelines.

2. *Patient Dosimetry in Radiology*: TLDs are also used to measure radiation doses received by patients during radiological procedures such as X-rays, CT scans, and fluoroscopy. By placing TLDs on patients or using phantoms with TLDs, healthcare providers can assess the actual radiation dose delivered to specific areas of the body, helping to optimize imaging protocols and minimize unnecessary radiation exposure to patients.

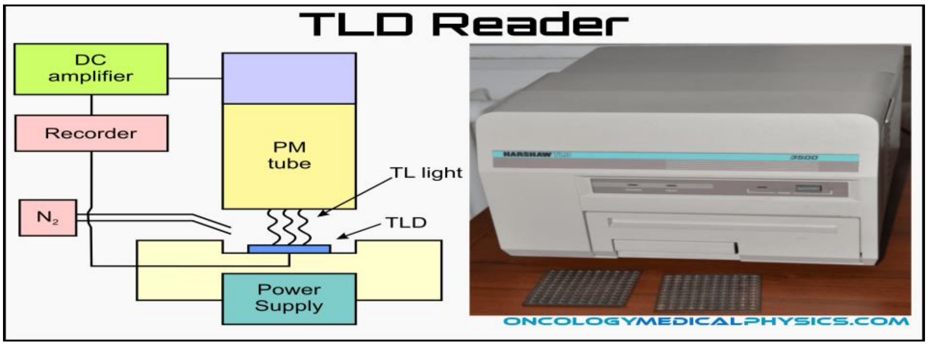
3. *Environmental Monitoring*: TLDs are used for environmental radiation monitoring in areas near nuclear facilities, radioactive waste storage sites, and other radiation sources. By deploying TLDs in the environment, authorities can monitor background radiation levels, assess potential radiation hazards, and ensure the safety of the surrounding population.

4. *Radiation Therapy Quality Assurance*: In radiation therapy, TLDs are used for quality assurance purposes to verify the accuracy and consistency of radiation dose delivery to the target area during cancer treatment. TLDs placed in tissue-equivalent phantoms mimic patient tissues and provide valuable information on the actual dose distribution within the target volume, helping to ensure effective tumor control while minimizing damage to surrounding healthy tissues.

5. *Dosimetry in Research and Development*: TLDs play a crucial role in research and development activities related to radiation protection, dosimetry calibration, and radiobiology studies. Researchers use TLDs to measure radiation doses in experimental setups, test new radiation shielding materials, and investigate the effects of radiation on biological systems.

6. *Space Radiation Monitoring*: TLDs are employed in space missions to monitor radiation exposure levels experienced by astronauts in space. By wearing TLD badges or deploying TLDs in spacecraft, scientists can assess the risks of cosmic radiation exposure during long-duration spaceflights and develop strategies to minimize the health effects of space radiation on human space explorers.

7. *Emergency Response and Disaster Management*: In the event of radiological accidents, nuclear incidents, or terrorist attacks involving radioactive materials, TLDs can be used for rapid assessment of radiation exposure levels in affected areas and populations. TLD dosimetry plays a critical role in emergency response efforts to protect first responders, evacuate at-risk individuals, and mitigate the consequences of radiological emergencies.



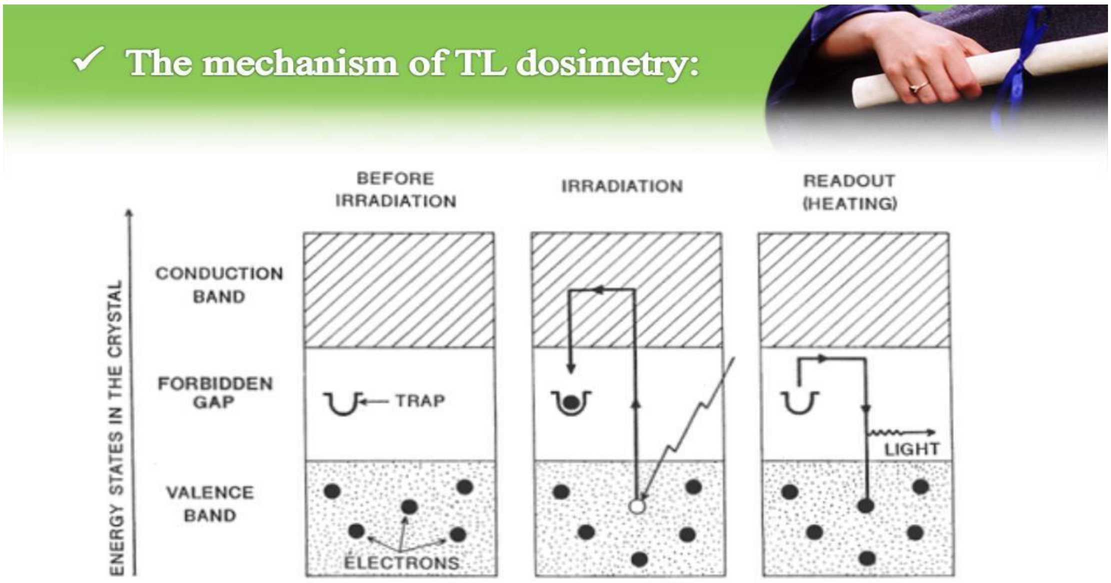


Figure 6 : The mechanism of TL dosimetry

Declaration of competing interest

The authors state that they have no known competing financial interests or personal ties that could have seemed to affect the work described in this study.

REFERENCES:

1. A.R. El-Sersy *et al.*(Characterization study on NIS X-ray beam qualities and its applications)Measurement(2012)
2. C.C. Guimaraes *et al.* Blind performance testing of personal and environmental dosimeters based on TLD-100 and natural CaF2: NaCl Radiat. Meas.(2003)
3. D. Berni *et al.* Use of TLD in evaluating diagnostic reference levels for some radiological examinations Radiation Prot Dosimetry(2002)
4. T. Biran *et al.* Measurements of occupational exposure for a technologist performing 18F FDG PET scans Health Phys.(2004)
5. C.P. Christensen *et al* . Required accuracy threshold in individual monitoring Radiat. Protect. Dosim.(1994)
6. S. Doremus *et al.*Pre-irradiation fade and post-irradiation fade for LiF: Mg, Ti, TLD-600, and TLD-700, as a function of time Radia tProt Dosimetry (1994)
7. European Council directive 97/43 Euratom on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure Official Journal of the European Communities(9 July 1997)
8. M.A. Fadel *et al.*An In-Vivo Study on the Energy Dependence of X-Ray Biological Effectiveness Volume 17, No 1 International Journal of Radiation Research(January 2019)
9. R. Faghihi *et al* . Radiation dose to neonates undergoing X-ray imaging in special care baby units in IranRadiatProtDosimetry(2012)
10. D. Hart *et al.*Doses to Patients from Medical X-Ray Examinations in the UK- 2000 Review. National Radiological Protection Board, NRPBW14 (2002)
11. J. Azorin Preparation methods of thermoluminescent materials for dosimetric applications: an overviewAppl. Radiat. Isot.(2014)

12. S. Del Sol Fernández *et al.*Thermoluminescent dosimeters for low-dose X-ray measurementsAppl. Radiat. Isot.(2016)

13. A.S. Frayre *et al.*Radiation dose reduction in a neonatal intensive care unit in computed tomographyAppl. Radiat. Isot.(2012)

14. E. Gaona *et al.*Exploratory survey of image quality on CR digital mammography imaging systems in MexicoAppl. Radiat. Isot.(2014)