

Radiation Safety Evaluation of some CT Units in Zliten city, Libya

Anwar Abdualsalam Bin Rabaa¹, Safyia Mohammed Albakoush², Salima Saleh
Abuazoum³, Mohammd Omar Almajdub⁴

¹Department of Physics Science, The Libyan Academy for Postgraduate Studies, Misrata

²Department of Physics, College of Science, Alasmarya Islamic University, Zliten

³Department of Physics, College of Science, Misrata University

⁴Department of radiology, College of Medical Technology, Misrata

Abstract

Key words

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This study aimed to evaluate scatter radiation levels outside computed tomography (CT) rooms in two public diagnostic centers in Zliten, Libya, and to assess compliance with international radiation protection standards. Measurements were performed between January and June 2024 using Geiger-Müller radiation detectors at multiple locations, including control- room windows, doors, corridors, and waiting areas.

The results revealed significant radiation leakage in both centers, particularly at doors and control room observation windows. In Souq Al-Thola'tha Polyclinic the highest leakage was recorded at the door- lock opening (48.28 $\mu\text{Sv/h}$) and beneath the CT- room door (27.3 $\mu\text{Sv/h}$). In Naima Hospital, the highest levels were observed at the upper right edge of the control room window (20.68 $\mu\text{Sv/h}$) and under the CT-room door (9.08 $\mu\text{Sv/h}$). Many measured values exceeded the recommended limit for uncontrolled areas (0.08 $\mu\text{Sv/h}$), indicating inadequate shielding.

These findings highlight that doors and observation windows are critical points for radiation leakage due to poor sealing and insufficient shielding. Gaps beneath doors and improper installation of shielding components contributed significantly to increased exposure. The survey also identified shortcomings in staff awareness and adherence to radiation-safety practices.

In conclusion, the study emphasizes the need to improve shielding design, ensure proper installation of protective materials, and implement regular monitoring and staff training. Compliance with international guidelines and with the ALARA (as Low as Reasonably Achievable) principle is essential to minimize radiation exposure and to enhance safety for healthcare workers and the public.

Introduction:

Computed Tomography (CT) is one of the most widely used medical imaging techniques in modern clinical practice due to its high diagnostic accuracy and ability to provide detailed anatomical information, which significantly enhances medical diagnosis [1,2]. However, this technique relies on the generation of relatively high-energy X-rays, resulting in both primary radiation and scattered radiation produced by the interaction of X-ray photons with the patient's body, system components, and the walls of the examination room [3,4].

Scatter radiation outside CT rooms represents a major concern in radiation protection, as it can reach adjacent areas such as corridors, waiting rooms, and administrative offices, leading to unintended exposure of staff and the general public [5,6]. International reports indicate that CT examinations contribute a substantial

proportion of the total medical radiation dose compared with other radiographic imaging modalities, highlighting the importance of investigating associated scatter radiation [7,8].

This scattered radiation arises mainly from physical interactions, particularly Compton scattering, in which X-ray photons deviate from their original path and lose part of their energy, allowing them to propagate in multiple directions and potentially penetrate insufficient shielding or leak through doors and observation windows if these are not designed according to international radiation protection standards [5,9].

Numerous studies have demonstrated that the level of scatter radiation outside CT rooms depends on several factors, including X-ray beam energy, scan protocol, gantry rotation angle, room design, shielding material thickness, and the measurement position relative to the radiation source and the patient [10–12]. Inadequate consideration of these parameters may result in radiation doses exceeding the permissible limits for occupationally exposed workers or the general public, as recommended by international radiation protection authorities [3,13].

The aim of this study is to measure scatter radiation levels outside CT rooms at different locations surrounding the examination area and to compare them with internationally recommended dose limits [3,14]. In addition, this study seeks to evaluate the effectiveness of radiation shielding and room design in reducing scatter radiation and to provide scientific recommendations to improve radiation safety practices in accordance with the principle of keeping doses As Low As Reasonably Achievable (ALARA) [13,15].

The significance of this study lies in supporting radiation protection programs in healthcare facilities and contributing to the establishment of scientific guidelines for the design of CT rooms that ensure the protection of staff, patients, and the public from the potential health effects of long-term exposure to low levels of ionizing radiation [9,13].

Limited data exist on scatter radiation levels outside CT rooms in Libyan healthcare centers, motivating this study.

Materials and Methods:

This study was conducted from January to June 2024, to measure radiation leakage and scatter from CT-scan departments in two selected public diagnostic centers in Zliten: Souq al-Thola'tha Polyclinic-Zliten and Naima Hospital of Emergencies and Accidents-Zliten. The objective was to quantify radiation leakage and scatter from CT suites and to assess compliance with design and safety requirements.

Instrumentation: Scattered and leakage radiation were measured using two X-ray-sensitive survey instruments, including a GQ GMC-320S digital nuclear radiation detector (Geiger counter/radiation dosimeter). Both instruments employ a cylindrical Geiger–Müller end-window tube capable of detecting diagnostic-energy ionizing radiation. Instrument model numbers, serial numbers and calibration certificates were verified and recorded prior to field use.

Measurements were taken at positions representative of occupational and public exposure around each CT suite. Control-room measurements were obtained at five points around the viewing window (above, below, left, right and centre). Additional control-room positions included the console/table workspace and the nearest control-room wall. Door leakage was assessed at the bottom gap, the lock/opening, and the top of both the control-room door and the patient entrance door to the radiology room. Corridor and patient waiting-area measurements were collected immediately outside the CT room and at adjacent corridor locations. At each position three independent readings were recorded and the arithmetic mean was used for analysis. For each measurement the ambient background, instrument settings, date/time and typical CT exposure parameters observed during the survey (e.g., tube voltage and current) were documented.

Dose rates were expressed in microsieverts per hour ($\mu\text{Sv/h}$). Background radiation was measured at a reference location and accounted for in the analysis. Measured values were evaluated against relevant international guidance (IAEA) and local regulatory limits to classify exposures as acceptable or exceeding recommended limits for occupational and public exposure.

Instruments were checked for functionality each session. Calibration status was confirmed against available certificates. Three repeated measurements per site were obtained to reduce random error. All data and field notes were entered into a database and analysed using SPSS version 25. Descriptive statistics (mean, range) were computed for dose rates at each location; measurement counts (n) and uncertainty considerations are reported where relevant.

The amount of radiation leaking was measured in the patient waiting area and the corridors near the main door of the diagnostic radiology units. Three measurements were recorded for each site to minimize error.

Measurements were taken at positions representative of occupational and public exposure around each CT suite. Control-room measurements were obtained at five points around the viewing window (above, below, left, right and centre). Additional control-room positions included the console/table workspace and the nearest control-room wall. Door leakage was assessed at the bottom gap, the lock/opening, and the top of both the control-room door and the patient entrance door to the radiology room. Corridor and patient waiting-area measurements were collected immediately outside the CT room and at adjacent corridor locations. At each position three independent readings were recorded and the arithmetic mean was used for analysis. For each measurement the ambient background, instrument settings, date/time and typical CT exposure parameters observed during the survey (e.g., tube voltage and current) were documented.

The data were quantified by calculating radiation dose rates and determining whether each rate fell within safe limits or hazardous limits according to IAEA standards. Additionally, the extent of compliance with the specifications of the X-ray room was assessed, including the availability of the required conditions concerning the area and dimensions of the diagnostic room. Furthermore, the technicians' adherence to safety protocols was documented for each center.

Instruments were checked for functionality before each session. Calibration status was confirmed against available certificates. Three repeated measurements per site were obtained to reduce random error. All data and field notes were entered into a database and analysed using SPSS version 25. Descriptive statistics (mean, range) were computed for dose rates at each location; measurement counts (n) and uncertainty considerations are reported where relevant.

Prior notification and permission were obtained from facility management before conducting measurements. Surveys were performed with minimal disruption to clinical services and with attention to staff and patient safety. Any measurement indicating immediate risk to patients or the public was communicated promptly to facility management.

The availability of radiation protection tools was assessed across all centers involved in the study. Additionally, all observations regarding the technicians' adherence to safety protocols were documented for each center.

Results:

This center receives an average of 25 cases per day during 6 working hours, i.e., leading to an average of 4 cases per hour.

The data shown in Figure 1 present the measured dose rates for diagnostic tomography. These results indicate significant radiation leakage from the main door of the CT room: dose rates measured at the bottom of the door ranged from 8.50 to 51.23 $\mu\text{Sv/h}$. The door's clearance from the floor is approximately 2 cm, so lead strips should be added to the door.

Measurements at the door-lock opening ranged from 24.8 to 74.25 $\mu\text{Sv/h}$ at exposure parameters of 150 kV and tube currents of 200 and 250 mA, indicating that the door is not adequately shielded. Door misalignment also contributes to elevated leakage in the corridor, with values exceeding normal limits (1.53–2.97 $\mu\text{Sv/h}$). These dose rates could pose a risk to the public because they would contribute toward the recommended annual effective dose limit for the general public (1 mSv/year).

Patient waiting seats were originally located in the corridor opposite the CT-room door. Officials were notified and the waiting area was relocated; subsequent measurements at the new location were 0.03–0.07 $\mu\text{Sv/h}$, which are within normal background levels and considered safe.

The control room lacks an observation window and is equipped with cameras and an audio system for patient communication. Measurements from the control-room walls were satisfactory and within acceptable limits, with average readings of 0.14 $\mu\text{Sv/h}$. For the reported patient throughput (4 cases per hour) this corresponds to a cumulative rate of $0.14 \times 4 = 0.56 \mu\text{Sv/h}$ in the measured positions, indicating that the room's walls provide adequate shielding except at the main door.

No protective equipment was observed inside the CT unit. During the survey, significant gaps in some technicians' understanding of ionizing-radiation hazards were noted. In some cases, technicians performed multiple CT scans of the same patient during a single session without apparent justification or consideration of the radiation dose.

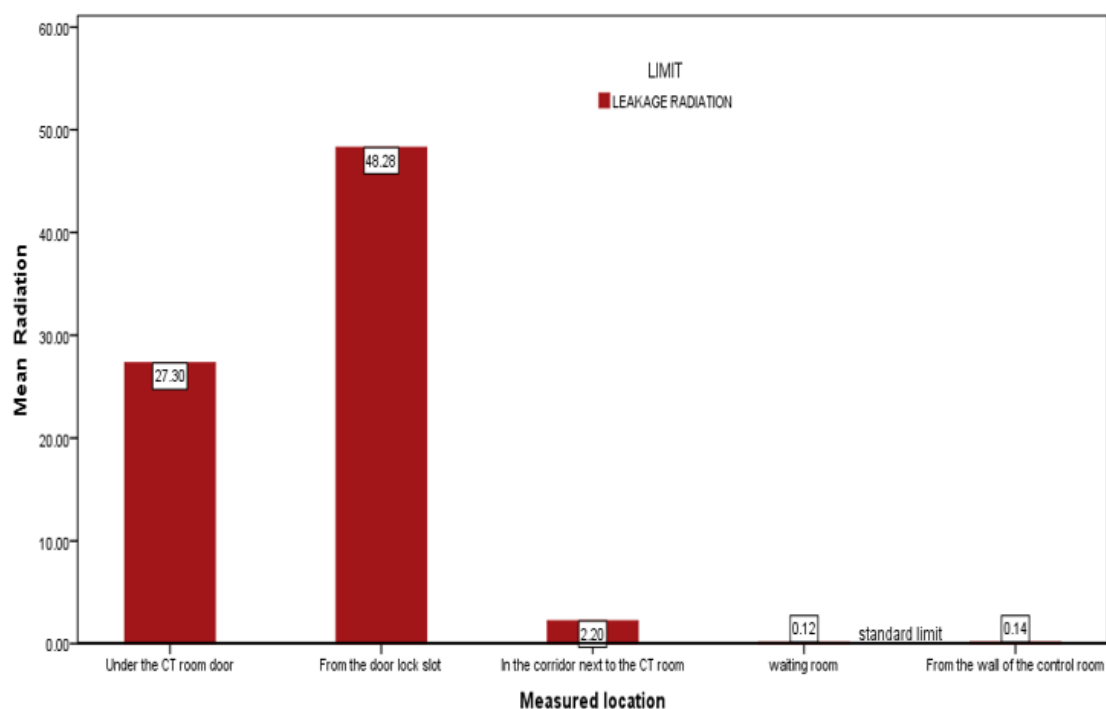


Figure (1): Average amounts of radiation in Souq-althola'tha Polyclinic (CT-scan)-Zliten

Statistical Analysis of Diagnostic CT for Souq-althola'tha Polyclinic - Zliten :

The results are shown in a table (1). the results showed the presence of radiation leakage in all areas of the Souq-althola'tha Clinics Complex (CT-scan) in Zliten, exceeding 0.08 µSv/h. It was found that the average value of the radiation leakage ranged between 0.12 µSv/h and 48.28 µSv/h. Measurements showed that the area (From the door lock slot) recorded the largest average value at 48.28 µSv/h, which does not comply with the advisory level as it exceeded very significantly 0.08 µSv/h, while the (waiting room) area recorded the lowest average value amounting to 0.12 µSv. /h, which does not correspond to the heuristic level. Also, it was noted that the average value of the radioactive leakage did not reach the indicative level and exceeded 0.08 µSv/h in all areas, (From the door lock slot-Under the CT room door-In the corridor next to the CT room-From -waiting room, recorded 48.28, 27.3, 2.2, and 0.12 µSv/h, respectively:

Table (1): Statistical description of the study locations in Souq-althola'tha Polyclinic (CT-scan) -Zliten

Measured location	Mean (µSv/h)	Standard Deviation (µSv/h)	Standard Error of Mean (µSv/h)	Minimum (µSv/h)	Percentile 25 (µSv/h)	Median (µSv/h)	Percentile 75 (µSv/h)	Maximum (µSv/h)
Under the CT room door	27.30	21.82	12.60	8.50	8.50	22.16	51.23	51.23
From the door lock slot	48.28	24.82	14.33	24.80	24.80	45.78	74.25	74.25
In the corridor next to the CT room	2.20	0.72	0.42	1.53	1.53	2.11	2.97	2.97
waiting room	0.12	0.12	0.07	0.03	0.03	0.07	0.25	0.25
From the wall of the control room	0.14	0.03	0.02	0.11	0.11	0.15	0.16	0.16

results of the comparisons : Chi-Square -test=12.433 , p-value=0.014*

** significant at 0.01 level-* significant at 0.05 level

Quantitative physical analysis of survey results Diagnostic CT Naima Hospital of Emergencies and Accidents-Zliten.

Measured dose rates from the survey results for Naima Emergency and Accident Hospital are shown in figure 2. All measurements from the control room's window, particularly from the upper right side, as well as from the door separating the control room and the radiology room, were higher than expected and above normal levels.

The measurement under the entrance door for patients in the CT room revealed dose rates ranging from (6.38 $\mu\text{Sv/h}$ to 11.78 $\mu\text{Sv/h}$) at exposure factors of 120 kV and currents of 30 - 250 mA, respectively, as a result of the height of the lower door opening from the ground about 2 cm. This situation necessitates the addition of lead strips to prevent radiation leakage from beneath the door, which is not properly closed and requires maintenance.

Similarly, the lower part of the door separating the control room and the radiology room recorded a dose of 6.06 $\mu\text{Sv/h}$, signaling a need for lead strips to mitigate leakage. Dose rates from the control room's window were alarmingly high, ranging from (2.01-20.68 $\mu\text{Sv/h}$), which is unacceptable for optimal radiation protection. Given the average of patients per day (25 patients), personal exposure doses for technicians may exceed permissible values, necessitating the replacement of the current window with one composed of thicker.

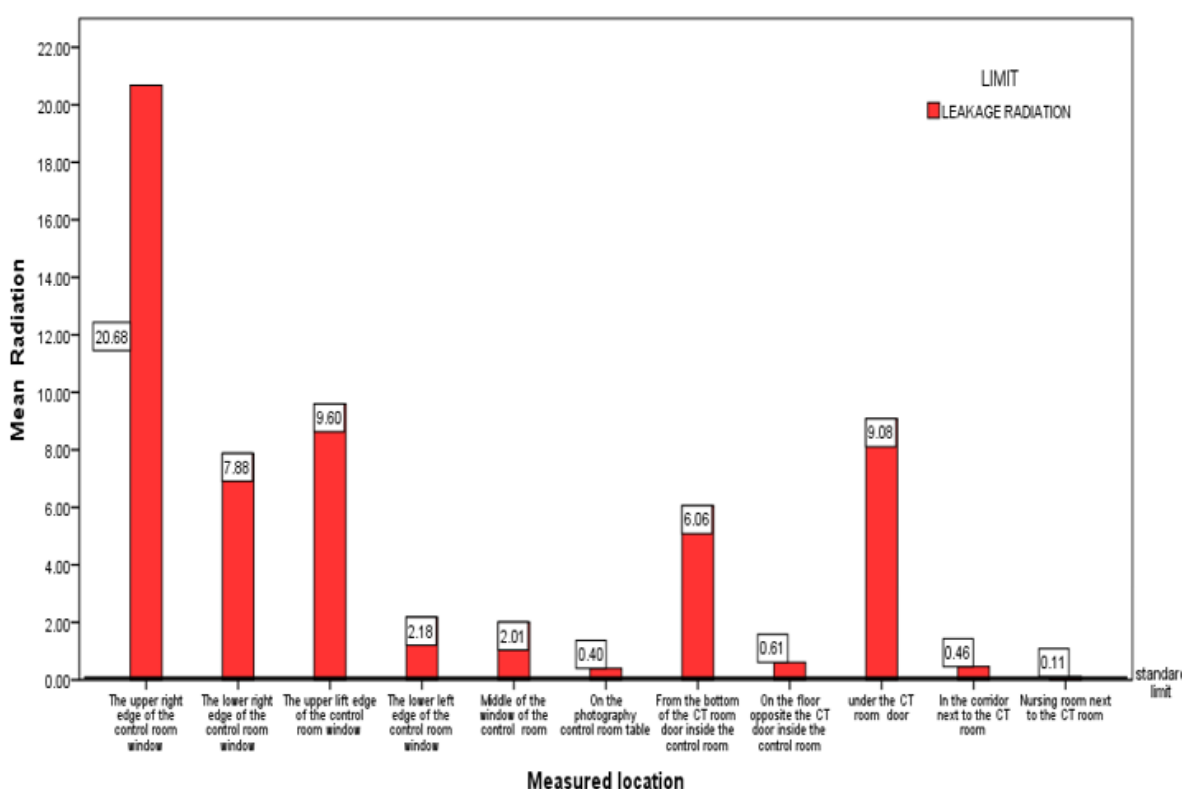


Figure (2): Average amounts of radiation in Naima Hospital of Emergencies and accidents-Zliten.

Statistical Analysis of Diagnostic CT Naima Hospital of Emergencies and Accidents-Zliten:

Table (2) showing the results showed a radiation leakage in all areas of Naima Accident Hospital in Zliten that exceeded 0.08 $\mu\text{Sv/h}$. It was found that the value of the average radiation leakage ranged between 0.11 $\mu\text{Sv/h}$ and 20.68 $\mu\text{Sv/h}$., as measurements showed that:

- The average value of the radioactive leakage resulting from the area (The upper right edge of the control room window) reached 20.68 $\mu\text{Sv/h}$.
- The average value of the radioactive leakage resulting from the area (The upper left edge of the control room window) recorded 9.6 $\mu\text{Sv/h}$.
- The average value of the radiation leakage resulting from the area (under the CT room door) recorded 9.08 $\mu\text{Sv/h}$.

- The average value of the radiation leakage resulting from the area (The lower right edge of the control room window) recorded 7.88 $\mu\text{Sv/h}$.
- The average value of the radiation leakage resulting from the area (From the bottom of the CT room door inside the control room) recorded 6.06 $\mu\text{Sv/h}$.
- The average value of the radiation leakage resulting from the area (The lower left edge of the control room window) recorded 2.18 $\mu\text{Sv/h}$.
- The average value of the radiation leakage resulting from the area (Middle of the window of the control room) recorded 2.01 $\mu\text{Sv/h}$.
- The average value of the radiation leakage resulting from the area (On the floor opposite the CT door inside the control room) recorded 0.61 $\mu\text{Sv/h}$.
- The average value of the radiation leakage resulting from the area (In the corridor next to the CT room) recorded 0.46 $\mu\text{Sv/h}$.
- The average value of the radioactive leakage resulting from the area (on the photography control room table) recorded 0.4 $\mu\text{Sv/h}$.
- The average value of the radiation leakage resulting from the area (Nursing room next to the CT room) recorded 0.11 $\mu\text{Sv/h}$.

Table (2): Statistical description of the study locations in Naima Hospital of Emergencies and accidents-Zliten

Measured location	Mean ($\mu\text{Sv/h}$)	Standard Deviation ($\mu\text{Sv/h}$)	Standard Error of Mean ($\mu\text{Sv/h}$)	Minimum ($\mu\text{Sv/h}$)	Percentile 25 ($\mu\text{Sv/h}$)	Median ($\mu\text{Sv/h}$)	Percentile 75 ($\mu\text{Sv/h}$)	Maximum ($\mu\text{Sv/h}$)
The upper right edge of the control room window	20.68	-	-	20.68	20.68	20.68	20.68	20.68
The lower right edge of the control room window	7.88	-	-	7.88	7.88	7.88	7.88	7.88
The upper left edge of the control room window	9.60	-	-	9.60	9.60	9.60	9.60	9.60
The lower left edge of the control room window	2.18	-	-	2.18	2.18	2.18	2.18	2.18
Middle of the window of the control room	2.01	-	-	2.01	2.01	2.01	2.01	2.01
On the photography control room table	0.40	-	-	0.40	0.40	0.40	0.40	0.40
From the bottom of the CT room door inside the control room	6.06	-	-	6.06	6.06	6.06	6.06	6.06
On the floor opposite the CT door inside the control room	0.61	-	-	0.61	0.61	0.61	0.61	0.61
under the CT room door	9.08	3.82	2.70	6.38	6.38	9.08	11.78	11.78
In the corridor next to the CT room	0.46	-	-	0.46	0.46	0.46	0.46	0.46
Nursing room next to the CT room	0.11	-	-	0.11	0.11	0.11	0.11	0.11
results of the comparisons : Chi-Square -test=10.000 , p-value=0.440								

** significant at 0.01 level- * significant at 0.05 level

Conclusion:

The results of this study demonstrated a clear variation in X-ray leakage levels between the two investigated CT imaging centers, reflecting differences in shielding efficiency and room design. In the first center, elevated leakage levels were detected at the control room window, the door between the control room and the scanning room, and the patient entrance door, indicating insufficient radiation shielding at these critical points. In the

second center, the highest leakage levels were observed at the CT room door, while other locations showed relatively lower values.

These findings indicate that doors and leaded windows represent the most vulnerable points for X-ray leakage, and that proper shielding and effective sealing play a crucial role in minimizing radiation exposure outside CT rooms. Overall, the study highlights the importance of evaluating shielding performance and room design to ensure compliance with radiation protection standards and to reduce unnecessary exposure to staff and the public.

Recommendations:

- This study recommends the enhancement of radiation shielding in areas exhibiting elevated levels of X-ray leakage, particularly at doors, leaded windows, and corners, to ensure that radiation levels are reduced to values within internationally accepted limits.
- It is essential to verify that the thickness of the shielding materials (lead or equivalent) used in the walls and doors of CT scan rooms complies with specifications established by international authorities.
- Periodic and systematic measurements of radiation leakage around the CT scan room are recommended, especially at locations where higher levels were observed, to monitor potential changes and ensure continued radiological safety.
- The study emphasizes the importance of training medical and technical staff in radiology departments on radiation protection principles and safe operation of CT scanners, including strict adherence to the (As Low as Reasonably Achievable) principle.
- Staff compliance with appropriate personal protective equipment, such as lead aprons and thyroid shields, is recommended, particularly when in proximity to the CT room during imaging procedures.
- Implementing a personal dosimetry program for radiology personnel is recommended, with regular monitoring of dose readings to evaluate individual exposure and ensure it remains within permissible limits.
- The study recommends conducting future comparative studies between modern and older CT scanners regarding radiation leakage levels, as well as examining the effect of daily scan volume on leakage rates outside the imaging room.
- It is further suggested to expand future research to include multiple hospitals and diverse geographic regions to obtain more comprehensive and generalizable results for informing national radiation protection policies.
- The study recommends establishing a national registry of radiation leakage measurements in diagnostic radiology departments to serve as a reference database supporting decision-making and improving radiation protection programs at the national health level.

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تقييم السلامة الإشعاعية لبعض وحدات الأشعة المقطعية بمدينة زليتن، ليبيا

أنور عبد السلام بن رابعة 1، صفية محمد البكوش 2، سليمة صالح أبو عزوم 3، محمد عمر المجدوب 4
1 قسم علوم الفيزياء، الأكاديمية الليبية – مصراتة، 2 قسم الفيزياء، كلية العلوم، الجامعة الأسمرية الإسلامية، زليتن، 3 قسم
الفيزياء، كلية العلوم، جامعة مصراتة، 4 كلية التقنية الطبية، مصراتة

الملخص

هدفت هذه الدراسة إلى تقييم مستويات الإشعاع المنتشرة خارج وحدات التصوير المقطعي المحوسب (CT) في مركزين تشخيصيين عامين بمدينة زليتن، ليبيا، وتقييم مدى الامتثال لمعايير الحماية الإشعاعية الدولية. أُجريت القياسات بين يناير ويونيو 2024 باستخدام كاشفات جايجر-مولر في مواقع متعددة، شملت نوافذ غرفة التحكم، الأبواب، الممرات، ومناطق الانتظار. كشفت النتائج عن تسرب إشعاعي ملحوظ في كلا المركزين، لا سيما عند الأبواب ونوافذ مراقبة غرفة التحكم. في مجمع سوق الثلاثاء، سُجل أعلى تسرب عند فتحة قفل الباب (48.28 ميكروسيفرت/ساعة) وأسفل باب غرفة التصوير (27.3 ميكروسيفرت/ساعة). في مستشفى نعيمة، لوحظت أعلى المستويات عند الحافة العلوية اليمنى لنافذة غرفة التحكم (20.68 ميكروسيفرت/ساعة) وأسفل باب غرفة التصوير (9.08 ميكروسيفرت/ساعة). تجاوزت العديد من القياسات الحد الموصى به للمناطق غير المسيطر عليها (0.08 ميكروسيفرت/ساعة)، مما يدل على تدرج غير كافٍ. تُبرز هذه النتائج أن الأبواب ونوافذ المراقبة هي نقاط حاسمة لتسرب الإشعاع بسبب سوء الإحكام وعدم كفاية التدرج. أسهمت الفجوات أسفل الأبواب التصميم والتركيبة غير السليم لمكونات التدرج بشكل كبير في زيادة التعرض. كما سلط المسح الضوء على قصور في وعي العاملين والالتزام بممارسات السلامة الإشعاعية. ختاماً، تؤكد الدراسة على ضرورة تحسين تصميم التدرج، وضمان التركيب الصحيح للمواد الحامية، وتنفيذ برامج رصد دورية وتدريب للكوادر. إن الامتثال للإرشادات الدولية ومبدأ ALARA (خفض التعرض إلى أدنى ما يمكن تحقيقه) أمران أساسيان لتقليل التعرض الإشعاعي وتعزيز السلامة للعاملين في الرعاية الصحية والجمهور.

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