

Assessment of Leakage and Scattered Radiation in Selected Computed Tomography Facilities over Jos, Plateau State, Nigeria

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ABSTRACT

This study assessed leakage and scattered radiation levels in three computed tomography (CT) facilities in Jos, Plateau State, Nigeria, as part of routine quality assurance and radiation safety evaluation. A calibrated GMC-600 digital Geiger Muller counter was employed to measure radiation levels, ensuring traceability to national calibration standards. The detector was positioned at 1 m from the gantry in four different directions (front, back, left, right) to determine leakage radiation, and at the console area to quantify scattered radiation during phantom exposures. The mean leakage radiation values recorded were 6.94, 5.93, and 8.97 mR/hr for facilities X1, X2, and X3, respectively. Mean scattered radiation levels at the console areas were 3.62, 2.14, and 2.94 mR/week. All results were well below the American Association of Physicists in Medicine (AAPM) recommended limits of 100 mR/hr for leakage and 10 mR/week for scatter, indicating full compliance with international safety standards. Statistical analysis revealed significant variation in leakage radiation between facilities ($p < 0.05$), with older equipment demonstrating higher leakage values. These findings suggest that equipment age and shielding design may influence radiation safety performance. Although compliance was achieved across all facilities, the study emphasizes the importance of periodic monitoring, preferably on an annual basis, to ensure sustained adherence to safety standards. Furthermore, integrating occupational dose monitoring and image quality assessments into routine quality control programs will strengthen radiation protection practices, optimize patient safety, and safeguard radiology personnel in resource-limited settings.

Keywords:

Computed Tomography (CT),
Leakage Radiation,
Scattered Radiation,
Radiation Safety,
Quality Assurance.

INTRODUCTION

X-ray examinations produce primary radiation directed at the patient; but secondary radiation, leakage and scatter also occur during computed tomography (CT). Leakage radiation refers to emissions from the tube other than the primary beam, while scattered radiation arises when X-rays interact with the patient or surrounding materials, deflecting in multiple directions (ICRU, 1992; IAEA, 2021). The patient therefore constitutes the principal source of scatter during CT imaging. CT is a powerful diagnostic modality that generates cross-sectional images with greater detail than conventional radiography (Egharevba et al., 2021). However, its use of ionizing radiation necessitates strict quality assurance (QA) and quality control (QC) programs to ensure patient and

occupational safety (AAPM, 1991). QA involves systematic checks to confirm equipment performance, image quality, and adherence to safety standards, while QC procedures verify mechanical stability and safety mechanisms such as interlocks and alarms. Radiation exposure carries stochastic risks that increase linearly with dose (Zira et al., 2020; Biere et al., 2022). Consequently, international guidelines emphasize the ALARA principle; keeping doses "as low as reasonably achievable" without compromising diagnostic quality (Akpolile et al., 2026). Regular assessment of leakage and scattered radiation is therefore essential to evaluate CT system performance, safeguard patients and staff, and identify areas requiring corrective action (Ike-Ogbonna et al., 2017).

This study addresses a critical gap by assessing leakage and scattered radiation levels in CT facilities in Jos, Plateau State, Nigeria, and comparing them with international standards. The findings provide baseline data for radiation safety monitoring and contribute to strengthening quality assurance practices in resource-limited settings.

MATERIALS AND METHODS

Radiation measurements were conducted in three CT facilities in Jos, Plateau State, Nigeria. A GMC-600 PLUS digital Geiger Muller counter (GQ Electronics), calibrated by the National Institute of Radiation Protection and Research (NIRPR; certificate number NIRPR/JUTH/25/162), was used for data collection. CT Machine Specifications are summarized in Table 1.

Table 1: Specifications of the CT Scanners Used in the Study

S/N	Equipment Name/ Model	Max. KVp	Max. mAs	Year of Manufacture
1	ANKE/ ANATOM 16	140	500	2019
2	SIEMENS/ SOMATOM	140	500	2020
3	SIEMENS/ SAMATOM SENSATION	150	600	2013

Table 2: Specifications of the GMC-600 PLUS Geiger Muller Counter

S/N	Parameter	Specification
1	Instrument	GMC-600 PLUS
2	Manufacturer	GQ Electronics
3	Detector type	Geiger Muller Tube
4	Calibration Certificate Number	NIRPR/JUTH/25/162
5	Calibration Authority	NIRPR

Leakage Radiation Measurement

The CT tube was operated at 120 kVp and 100 mA. The detector was positioned at 1 m from the gantry at four orientations (front, back, left, right) on the surface of an imaginary sphere centered at the focal spot. The tube window was blocked with ≥ 10 HVL equivalent of lead to isolate leakage radiation. Instantaneous dose rate (IDR, mR/hr) was recorded directly from the detector display.

Scattered Radiation Measurement

Scatter was assessed using the manufacturer's CT water phantom, aligned with CT positioning lights. Exposures were performed with routine abdominal CT parameters. The detector was placed at the console area (operator's position) to record IDR (mR/hr). Values were converted to weekly exposure (mR/week) by multiplying by 40, assuming an 8-hour workday and 5-day workweek.

Data Analysis

Measurements were averaged across orientations and facilities. Descriptive statistics (mean, range, standard deviation) were calculated. Facility comparisons were performed using ANOVA to assess differences in leakage and scatter levels.

RESULTS AND DISCUSSION

Table 3 summarizes background radiation and leakage radiation at 1 m from the CT scanners. Background radiation ranged from 0.024–0.027 mR/hr (48–54 mR/yr), well below the ICRP annual limit of 1 mSv, confirming no external influence. Mean leakage radiation values were 6.94 mR/hr (X1), 5.93 mR/hr (X2), and 8.97 mR/hr (X3).

Table 3: Background radiation (BG) and leakage radiation of CT room at 1 meter from the studied CT scanners

Machine	BG(mR/hr)	Leakage Radiation (mR/hr)				
		Front	Back	Left	Right	Mean
X1	0.026	6.30	5.95	7.55	7.97	6.94
X2	0.024	5.54	5.10	6.68	6.40	5.93
X3	0.027	8.99	9.27	9.00	8.62	8.97
MINIMUM	0.024	5.54	5.10	6.68	6.40	5.93
MAXIMUM	0.027	8.99	9.27	9.00	8.62	8.97
MEAN	0.030	6.94	6.77	7.74	7.66	7.28

Table 4 presents console room background radiation and scattered radiation. Background levels were 0.024–0.025 mR/hr, while mean scattered radiation was 3.62 mR/week (X1), 2.14 mR/week (X2), and 2.94 mR/week (X3).

Table 4: Background radiation (BG) and scattered radiation of the console room at the console areas

Machine	BG (mR/hr)	Scattered Radiation (mR/hr)		
		1 ST Reading (mR/hr)	2 ND Reading (mR/hr)	Mean (mR/week)
X1	0.025	0.089	0.092	3.620
X2	0.024	0.053	0.054	2.140
X3	0.025	0.076	0.071	2.940
MINIMUM	0.024	0.053	0.054	2.140
MAXIMUM	0.025	0.089	0.092	3.620
MEAN	0.025	0.073	0.072	2.900

Figure 1 compares leakage radiation measured at different positions around the CT scanners with the AAPM recommended limit.

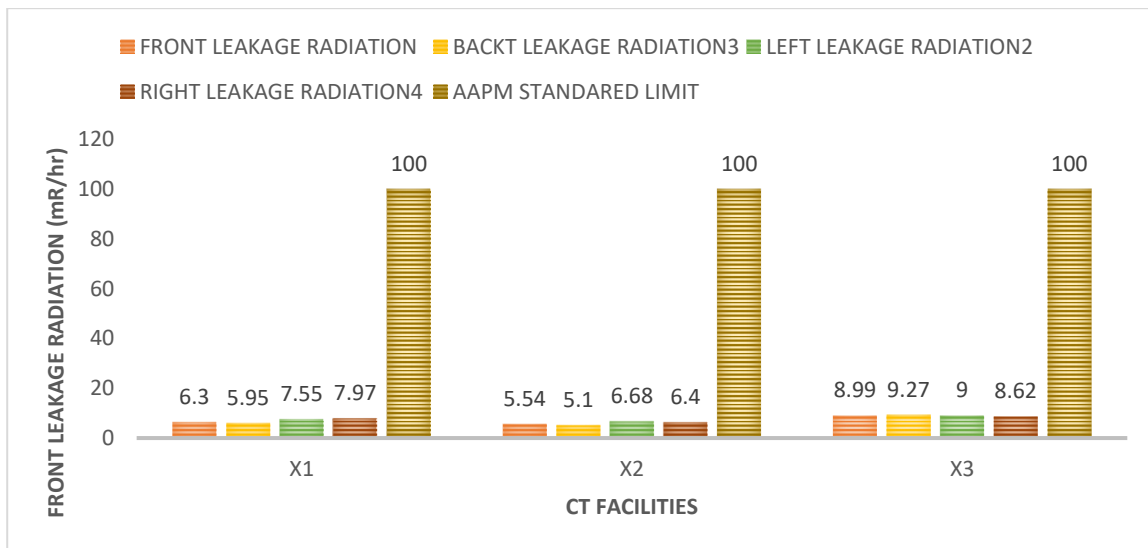


Figure 1: Comparison of the leakage radiation at the CT to standard limit

Figure 2 presents the mean leakage radiation values for the three CT facilities.

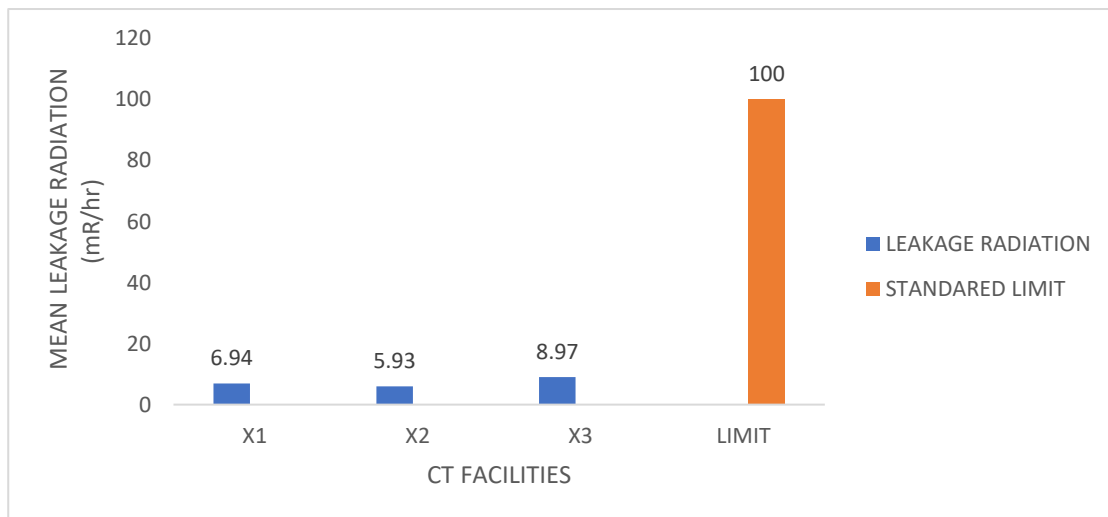


Figure 2: Comparison of the mean leakage radiation of the CT scanner to standard limit

Figure 3 illustrates the variation in scattered radiation levels relative to the recommended safety limit.

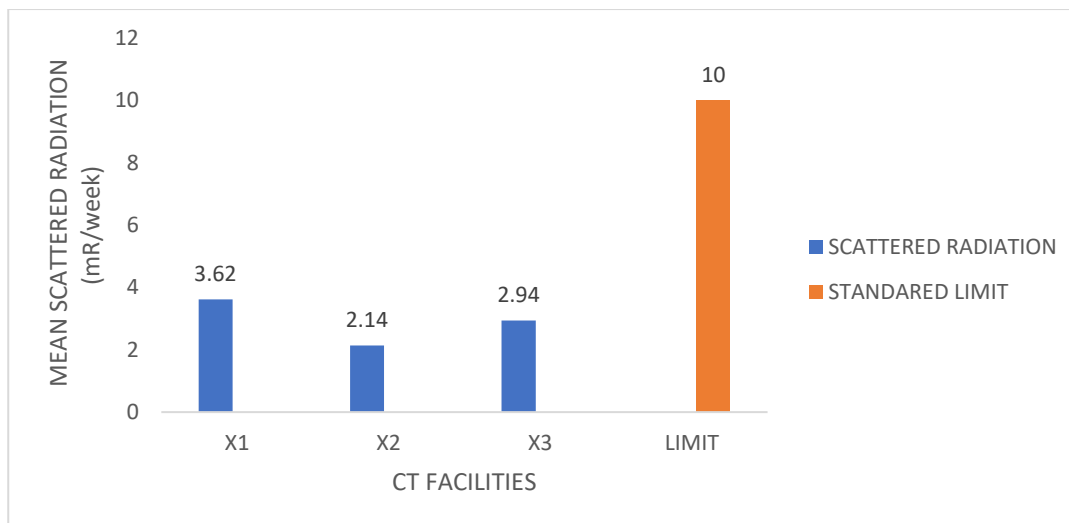


Figure 3: Variations of the scattered radiation from the studied facilities to standard limit

The results of this study demonstrate that leakage and scattered radiation levels in the three CT facilities investigated in Jos Plateau State remain well below internationally accepted limits. Table 2 shows that leakage radiation ranged between 5.93 mR/hr and 8.97 mR/hr, while Table 3 indicates scattered radiation at the console areas varied between 2.14 mR/week and 3.62 mR/week. These values are significantly lower than the AAPM recommended thresholds of 100 mR/hr for leakage and 10 mR/week for scatter, confirming that all facilities operate within safe limits.

Although compliance was universal, the data revealed important variations. Facility X3, equipped with the oldest CT scanner (manufactured in 2013), consistently recorded the highest leakage radiation, while X2, with the newest scanner (2020), had the lowest. This observation suggests that equipment age may influence radiation output characteristics and shielding performances. Similar findings were reported by Akpochafor et al (2017), who observed performance variations among diagnostic X-ray systems attributable to equipment condition and technical factors. Figure 1 visually reinforces this observation, showing that while all facilities remain below the AAPM limit, X3 consistently exhibits higher leakage values compared to X1 and X2.

Figure 2 presents the mean leakage radiation values for each CT scanner relative to the standard limit. Again, all facilities remain well below the permissible threshold, but the figure highlights the variation between facilities. The differences, confirmed by statistical analysis ($p < 0.05$), suggest that preventive maintenance and age-related monitoring are essential to sustain compliance over time.

Scattered radiation levels also varied across facilities despite identical phantom exposures and technique factors. This variation is likely attributable to differences in room shielding, console positioning, and structural

design, echoing findings by Martins et al. (2020), who observed similar discrepancies in Nigerian radiology departments. Eyisi-Enuka et al. (2021) demonstrated that scattered radiation can contribute to unintended exposure of radiosensitive organs, highlighting the need for adequate shielding an adherence to radiation protection principles during diagnostic imaging procedures. Figure 3 illustrates these variations, showing that Facility X2 recorded the lowest scatter while Facility X1 had the highest. Importantly, the scattered radiation levels observed here correspond to effective occupational doses of <0.1 mSv/year, far below the ICRP occupational limit of 20 mSv/year, confirming safe working conditions for radiographers. Although shielding effectiveness may influence scatter radiation levels, this study did not assess specific shielding materials. Therefore, no recommendation regarding the best shielding material can be made based on the present findings.

In general, the findings from both Tables and Figures provide strong evidence that CT facilities in Jos operate safely within international standards. However, they also highlight the influence of equipment age and facility design on radiation performance. These findings underscore the importance of annual leakage and scatter assessments, preventive maintenance, and occupational dosimetry programs to ensure sustained compliance and optimize radiation protection for both patients and staff. Globally, concerns about cumulative CT exposure remain significant, with recent projections estimating substantial contributions to population cancer risk (Smith-Bindman, 2025). Thus, adherence to the ALARA principle remains critical in both local and international contexts.

CONCLUSION

This study assessed leakage and scattered radiation levels in three CT facilities in Jos, Plateau State, against

international safety standards. All measured values were well below the AAPM recommended limits of 100 mR/hr for leakage and 10 mR/week for scatter, demonstrating a 100% compliance rate and confirming that the facilities operate within safe radiation protection standards. Despite this compliance, variations were observed across facilities, with older equipment showing higher leakage and differences in scattered radiation likely influenced by shielding design and room layout. These findings emphasize that while current practices are safe, radiation performance is not static and can change with equipment age, workload, and facility design. Therefore, routine monitoring of leakage and scattered radiation should be conducted at least annually, in line with AAPM and IAEA recommendations, to ensure sustained compliance and early detection of performance issues. Preventive maintenance, optimization of exposure parameters, and integration of occupational dosimetry programs are also essential to minimize unnecessary radiation exposure to patients, staff, and the public. By providing baseline data for CT facilities in Jos, this study contributes to strengthening radiation safety practices in Nigeria and supports the broader global effort to uphold the ALARA principle in diagnostic imaging.

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