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Occupational Radiation Dose and Ambient Dose Characterization in Selected Healthcare Facilities in Kitui County, Kenya

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Abstract

Radiation exposure during diagnostic radiology remains a critical occupational radiation safety concern as the global volume and complexity of medical imaging procedures continue to increase. This study assessed personal dose equivalents received by 14 radiographers in three high-workload hospitals in Kitui County, Kenya. Personal dose equivalents were monitored monthly for three consecutive months using TLD-100 (LiF:Mg,Ti) dosimeters, with readouts performed using the Harshaw 8800 reader system at Kenyatta National Hospital (KNH). Descriptive analysis showed modest inter-hospital variability in occupational doses, which may reflect differences in workload, examination practices, and occupational positioning. The mean monthly personal dose equivalents for Hp(0.07) ranged from 0.112 to 0.246 mSv, while those for Hp(10) ranged from 0.101 to 0.205 mSv. Across all monitored worker-month observations, the pooled mean personal dose equivalents were 0.156 mSv for Hp(0.07) and 0.141 mSv for Hp(10), corresponding to annualized projections of 1.87 and 1.69 mSv y^{-1}, respectively, assuming comparable exposure conditions throughout the year. Ambient dose-equivalent rates, H*(10), measured in 61 rooms across five selected hospitals, ranged from 0.09 to 0.34 $\mu Sv \cdot h^{-1}$, with a mean dose-equivalent rate of 0.198 ± 0.026 $\mu Sv \cdot h^{-1}$. Under an assumed indoor occupancy factor of 0.8, the corresponding annualized ambient dose equivalent ranged from 0.63 to 2.38 $mSv \cdot y^{-1}$, with a mean of 1.388 $mSv \cdot y^{-1}$. The findings indicate relatively low occupational personal dose equivalents and ambient dose-equivalent rates across the surveyed facilities, although continued occupational monitoring and optimization of radiation-protection practices remain warranted.

Keywords: Occupational radiation dose; ambient gamma radiation; ambient dose equivalent rate; TLD-100; diagnostic radiology; Kenya.

I. Introduction

The indispensable medical applications of ionizing radiation constitute one of the largest sources of artificial radiation exposure to both patients and healthcare workers [1–2]. Among these applications, diagnostic radiology (DR) is a major contributor to occupational radiation exposure, primarily due to scattered radiation generated during imaging procedures [3–5]. Although occupational doses in diagnostic radiology are generally low and remain within recommended dose limits, variations in imaging workload, equipment performance, shielding conditions, procedural complexity, and radiation-protection practices may contribute to differences in the magnitude and distribution of doses received by workers in radiology units [6–7].

Globally, approximately 4.2 billion radiological examinations are performed annually, reflecting the extensive use of ionizing radiation in medical practice and the potential for occupational exposure among healthcare personnel [8]. Consequently, routine occupational radiation monitoring remains an essential component of radiation protection programs, supporting dose assessment, identifying unusual exposure patterns, ensuring compliance with dose limits, and optimizing occupational radiation protection [5], [9].

The 2014 IAEA Basic Safety Standards define Hp(10) as the personal dose equivalent at a depth of 10 mm, Hp(0.07) as that at 0.07 mm for skin exposure, and Hp(3) as that at 3 mm for assessing exposure of the eye lens. In resource-constrained healthcare systems, limitations in radiation-protection infrastructure, quality-assurance programs, and personnel monitoring may pose additional challenges to effective occupational exposure control [10].

Previous studies in some healthcare facilities have reported inadequate protection measures, including inadequate structural shielding, limited availability of lead protective equipment, and inconsistent implementation of safety protocols [11–12]. Such inconsistencies may result in insufficient control of occupational exposure and increase the potential for unnecessary radiation exposure among radiology personnel, particularly in high-workload diagnostic environments. Accordingly, ICRP Publication 103 recommends occupational dose limits and advocates optimization of practical radiation protection measures to minimize occupational exposure while maintaining the benefits of medical imaging [5], [13–14].

In addition to occupational exposure associated with medical imaging procedures, ambient gamma radiation originating from naturally occurring radionuclides, including ^{238}U, ^{232}Th, and ^{40}K in building materials and the surrounding geological environment, constitutes a continuous source of external radiation exposure within indoor healthcare environments [7], [15]. Due to prolonged indoor occupancy, ambient gamma radiation may contribute to cumulative radiation exposure and should therefore be considered in comprehensive radiation protection assessments. Routine monitoring and optimization of radiation protection practices in accordance with the As Low As Reasonably Achievable (ALARA) principle are essential components of radiation safety.

The Basic Safety Standards designate Hp(10) and Hp(0.07) as the operational dose quantities for individual monitoring of external radiation exposure. Hp(10) represents the personal dose equivalent at a depth of 10 mm in soft tissue and is used to assess exposure to penetrating radiation, whereas Hp(0.07) represents the personal dose equivalent at a depth of 0.07 mm and is used to assess skin in workers. The International Commission on Radiological Protection (ICRP) recommends an occupational effective-dose limit of 20 mSv per year averaged over five years (100 mSv in five years), with no single year exceeding 50 mSv, and an equivalent-dose limit of 500 mSv per year for the skin and extremities of occupationally exposed persons [5]. In Kenya, ionizing radiation use is regulated by the Kenya Nuclear Regulatory Authority (KNRA) under the Radiation Protection Act (Cap 243), which provides for the monitoring and control of occupational exposure [16]. Despite the increasing deployment of diagnostic imaging services within decentralized healthcare systems in sub-Saharan Africa, surveillance data from county-level healthcare facilities remain limited.

Existing studies in Kenya have largely focused on major referral institutions such as Kenyatta National Hospital and Nairobi Hospital; comparatively limited information is available from Level IV and Level V county hospitals [17–19].

Additionally, studies integrating occupational personal dose monitoring with ambient gamma-radiation characterization within the same healthcare environment are limited. This study therefore addresses this gap by integrating assessment of occupational personal dose equivalents and ambient gamma radiation levels in selected county-level healthcare facilities in Kitui County, Kenya. Specifically, the study quantified occupational personal dose equivalents among radiographers, characterized ambient gamma radiation levels in selected hospitals, and established baseline radiological indices for the study area.

II. Materials and Methods

A. Study Area

Kitui County is in southeastern Kenya at approximately 1.365°S latitude and 38.017°E longitude, at an elevation of about 1120 m above sea level. The study included five of the largest healthcare facilities with radiological services: Kitui County Referral Hospital (KCRH), Kitui Jordan Level V Hospital (KJH), and three Level IV hospitals (Mwingi, Ikanga, and Zombe). Facility selection was based on the presence of active radiological services, relatively higher patient throughput, and relevance to occupational radiation exposure within the county. Personal dosimetry was conducted at three facilities: Mwingi Level IV Hospital, Kitui County Referral Hospital (KCRH), and Kitui Jordan Hospital (KJH), all of which had operational radiology equipment during the monitoring period, thereby facilitating TLD deployment and retrieval. In addition to radiology departments, routinely occupied non-radiology rooms and staff areas within the selected facilities were surveyed to characterize ambient gamma-radiation levels and provide comparative environmental measurements within the same healthcare facilities. The study was conducted between April and June 2025. Geographic coordinates of the sampled facilities were recorded using a GPS-enabled device and used to generate the study map presented in Fig. 1.

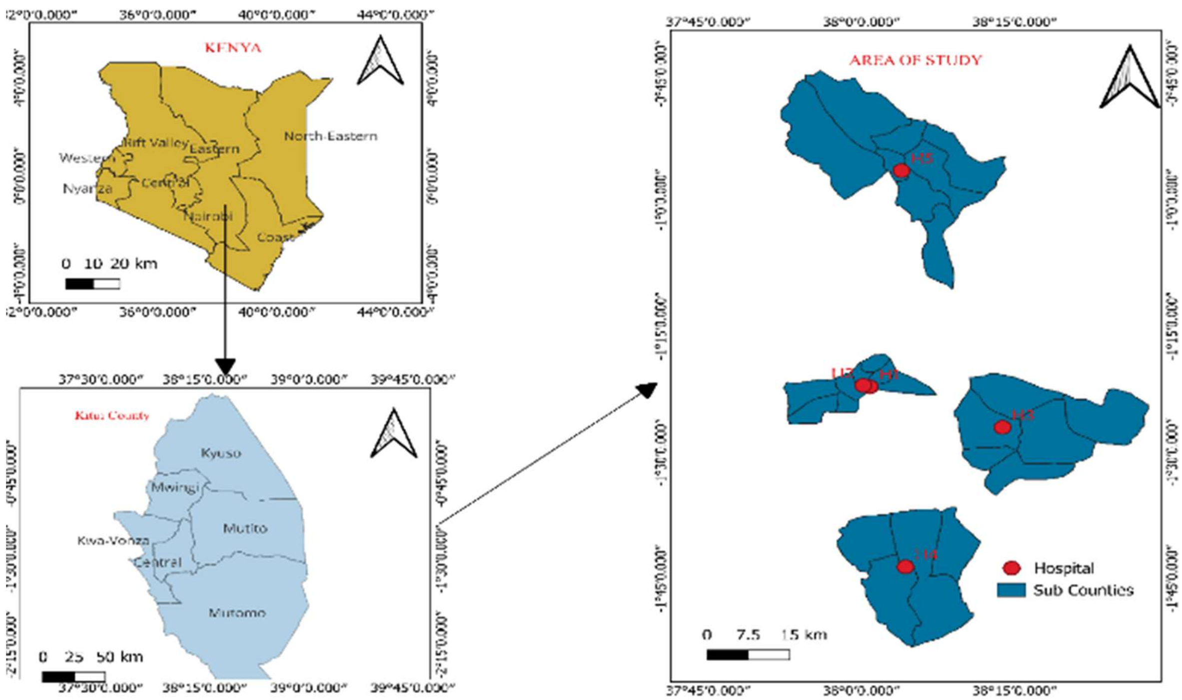

Fig. 1. Study map showing the geographical distribution and location of the five sampled hospitals in Kitui County, Kenya.

B. Personal Dose Measurement Using Thermoluminescent Dosimeters

This study used TLD-100 dosimeters (TLD) supplied by the Kenya Nuclear Regulatory Authority (KNRA). The TLD-100 dosimeters consist of LiF:Mg,Ti detector elements enclosed in barcoded holders fitted with appropriate filters for the evaluation of personal dose equivalents Hp(10) and Hp(0.07). This type of dosimeter was preferred because of its near-tissue equivalence, with an estimated effective atomic number (Z_eff) of 8.15 and density of 2.65 $g \cdot cm^{-3}$, as well as its stability and reproducibility for occupational dose monitoring within the diagnostic photon-energy range typical of medical imaging applications [20].

Before field deployment, the TLDs were annealed using two programmed heating stages. In the first stage, the dosimeters were preheated at 135 °C for 8 s, followed by heating at 300 °C for 20 s in the second stage to remove residual thermoluminescent signals while maintaining detector sensitivity [21]. The TLDs were housed in cassettes fitted with filters appropriate for Hp(10) and Hp(0.07) assessment. Each TLD was labeled with the date of deployment, wearer ID, and hospital name for traceability. TLDs were deployed to 14 radiographers from three high-workload hospitals during the study period: four from Mwingi Level IV Hospital, eight from Kitui County Referral Hospital (KCRH), and two from Kitui Jordan Hospital (KJH). Quality assurance procedures included automated calibration verification and uncertainty estimation, with measurement uncertainty maintained within ±5%. Fig. 2 illustrates a sample TLD-100 dosimeter used in this study.

The TLD badges were worn consistently on the upper-left chest, outside the lead apron, throughout the monitoring period. All monitored radiographers wore lead aprons during procedures requiring their use. The radiographers performed conventional diagnostic radiography, while those at Kitui Jordan Hospital also participated in fluoroscopic procedures. During conventional radiography, radiographers remained behind fixed lead-glass protective barriers, whereas during fluoroscopy, they remained in the procedure room as required for clinical duties. The badges were positioned outside the apron for standardized chest-level monitoring, and the resulting Hp(10) values were interpreted as personal dose equivalents at the badge location rather than as direct estimates of effective whole-body dose [22].

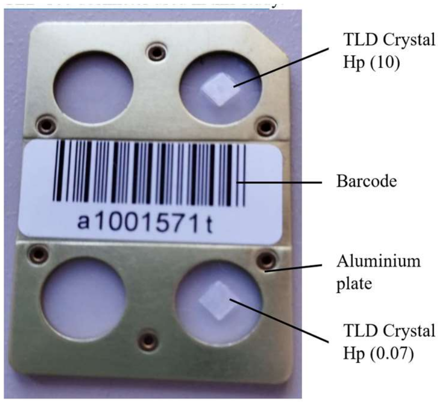

Fig. 2. TLD-100 thermoluminescent dosimeter (LiF:Mg,Ti) used in the study.

Six control TLDs, identical to those assigned to workers, were stored at a height of 1 m in designated low-exposure staff offices within non-radiology departments throughout the monitoring period for background correction. Each monitoring cycle lasted one month and was repeated for three consecutive months to minimize the effects of TLD signal fading. All deployed TLD badges were successfully retrieved, with no loss recorded during the monitoring period.

TLD readout was performed at the Kenyatta National Hospital (KNH) Radiological Physics Laboratory using a Harshaw 8800 TLD reader (Thermo Fisher Scientific, USA) operated with the integrated Windows Radiation Evaluation and Management System (WinREMS) software. The doses measured by the TLDs, expressed as personal dose equivalents Hp(10) and Hp(0.07), were determined using (1).

$$\mathrm{D}_{TLD} = \frac{Q \times ECC}{RCF} \quad (1)$$

where Q represents the thermoluminescent signal (nC), (ECC) is the element correction coefficient, and (RCF) is the reader calibration factor. Background doses obtained from the control TLDs were subtracted from the corresponding worker measurements to account for environmental and storage-related background exposure. The net personal dose (D_{net}) was calculated using (2).

$$\mathrm{D}_{net} = \mathrm{D}_{TLD} - \mathrm{D}_{bg} \quad (2)$$

where D_{TLD} is the measured dose, and D_{bg} is the background dose (mSv).

C. Assessment of Ambient Dose Using a Survey Meter

Ambient dose rate H*(10) was measured directly in μSv·h⁻¹ using a factory-calibrated NT6102 gamma survey meter (Shanghai Minghe, China). The instrument is a Geiger–Muller (GM) tube-based gamma detector with a digital display and a portable housing. The instrument is factory calibrated with a stated measurement accuracy of ±5% over a temperature range of −20 °C to 50 °C and maximum relative humidity of less than 95%. The survey meter has a dose rate measurement range of 0.01–5000 μSv·h⁻¹ and a photon energy response range of 40 keV to 3 MeV.

The instrument directly reports ambient dose equivalent rate, H*(10), in μSv·h⁻¹; therefore, no absorbed-dose-to-effective-dose conversion coefficient was applied to the measured values. A total of 61 routinely occupied rooms from the five selected healthcare facilities were surveyed to establish ambient gamma radiation levels. In each room, measurements were obtained at five predefined points, including the centre of the room, with the measurements taken at a height of 1 m above the floor. At each measurement point, six one-minute readings were recorded and averaged, and the arithmetic mean from the five measurement points was used as the representative ambient dose equivalent rate for each room. The measurement height of 1 m was adopted as the recommended level for approximating the exposure zone for seated and standing staff [5]. Descriptive statistical parameters, including the range, mean, standard deviation, and coefficient of variation, were used to summarise the measured ambient dose-equivalent rates and assess spatial variability among the sampled hospital rooms.

D. Annualized Ambient Dose Equivalent (mSv·y⁻¹)

The annualized ambient dose equivalent, H*annual(10), associated with ambient gamma radiation in the studied healthcare facilities was estimated using (3) [4].

$$H^*_{annual} = H^*(10) \times T \times OF \quad (3)$$

where H*(10) is the measured ambient dose equivalent rate (μSv·h⁻¹), T is the total number of hours in a year (8760 h·y⁻¹), and OF is the assumed indoor occupancy factor of 0.8. Thus, the calculation corresponds to an assumed annual indoor occupancy time of 7008 h·y⁻¹. The resulting value was converted from μSv·y⁻¹ to mSv·y⁻¹.

The annualized values represent indoor environmental exposure estimates under the assumed occupancy conditions and were not interpreted as individual occupational doses. Spatial variability was assessed using the coefficient of variation as shown in (4).

$$CV = \frac{\sigma}{\mu} \times 100\% \quad (4)$$

where σ is the standard deviation, and μ is the mean ambient dose rate.

E. Excess Lifetime Cancer Risk

Excess lifetime cancer risk (ELCR) associated with the ambient gamma-radiation field was estimated from the annualized ambient dose equivalent using the linear no-threshold (LNT) model, as shown in (5).

$$ELCR = H^*_{annual} \times DL \times RF \quad (5)$$

where H*annual is the annualized ambient dose equivalent expressed in Sv·y⁻¹, DL is the assumed lifetime exposure duration of 70 years, and RF is the nominal lifetime cancer risk coefficient of 0.05 Sv⁻¹ [5].

F. Statistical Analyses

Descriptive statistics, including mean, standard deviation, range, minimum, maximum, and coefficient of variation (CV), were used to summarize occupational personal dose equivalents [Hp(10) and Hp(0.07)] and ambient dose-rate measurements. Hospital-specific and monthly summaries were computed to assess variations in occupational exposure, while ambient dose-rate data were used to estimate the annualized ambient dose equivalent and excess lifetime cancer risk (ELCR). Statistical analyses and graphical visualizations were performed using Python version 3.12.

III. Results and Discussion

A. Individual Dose

The net monthly personal dose equivalents, Hp(10) and Hp(0.07), are presented in Table I.

Table I. Monthly descriptive statistics of personal dose equivalents Hp(0.07) and Hp(10) for staff (mSv).

Hospital	Month	Hp(0.07) Mean ± SD (mSv)	Range	CV (%)	Hp(10) Mean ± SD (mSv)	Range	CV (%)
Kitui Jordan Level V	Month 1	0.159 ± 0.049	0.101–0.223	30.8	0.143 ± 0.038	0.111–0.224	26.6
	Month 2	0.156 ± 0.051	0.097–0.235	32.7	0.141 ± 0.036	0.094–0.249	25.5
	Month 3	0.166 ± 0.041	0.132–0.190	24.7	0.144 ± 0.028	0.127–0.190	19.4
Kitui County Level V	Month 1	0.118 ± 0.032	0.094–0.161	27.1	0.102 ± 0.021	0.091–0.164	20.6
	Month 2	0.126 ± 0.039	0.099–0.236	31.0	0.111 ± 0.028	0.097–0.195	25.2
	Month 3	0.176 ± 0.058	0.131–0.246	33.0	0.155 ± 0.034	0.140–0.228	21.9
Mwingi Level IV	Month 1	0.112 ± 0.011	0.089–0.131	9.8	0.101 ± 0.009	0.098–0.105	8.9
	Month 2	0.118 ± 0.020	0.089–0.139	16.9	0.107 ± 0.025	0.090–0.152	23.4
	Month 3	0.246 ± 0.066	0.133–0.288	26.8	0.205 ± 0.051	0.084–0.295	24.9

Across all hospitals and monitoring periods, individual personal dose equivalents ranged from 0.089–0.288 mSv for Hp(0.07) and 0.084–0.295 mSv for Hp(10).

Across all individual worker-month observations, the pooled mean personal dose equivalents were 0.156 mSv for Hp(0.07) and 0.141 mSv for Hp(10), respectively. The corresponding annualized personal dose equivalents were approximately 1.87 $mSv\cdot y^{-1}$ and 1.69 $mSv\cdot y^{-1}$, respectively, assuming similar exposure conditions throughout the year.

The projected annualized Hp(10) dose was substantially below the ICRP-recommended occupational effective-dose limit of 20 $mSv\cdot y^{-1}$. The Hp(0.07) values likewise remained far below the applicable occupational equivalent-dose limit for the skin.

The monthly mean Hp(0.07) values were generally higher than the corresponding Hp(10) values, suggesting a greater shallow-dose response than a deep-dose response under the monitoring conditions. This difference may reflect the energy and angular distribution of the scattered radiation field and the response of the dosimeter to radiation at different tissue depths [23]. However, the small difference between the two quantities suggests that both superficial and deep-dose exposures remained low throughout the monitoring period.

Monthly mean dose equivalents ranged from 0.112 to 0.246 mSv for Hp(0.07) and 0.101 to 0.205 mSv for Hp(10), with the highest values recorded at Mwingi Level IV Hospital during Month 3. Despite this variability, all monthly mean doses remained below 0.3 mSv, suggesting relatively low occupational exposure across the surveyed facilities. Similar low occupational dose levels have been reported among diagnostic radiology workers in facilities operating under routine radiation protection programs [7], [10]. Overall, the measured doses were below the applicable occupational dose limit, although dose levels alone cannot establish optimization in accordance with ALARA.

B. Variability of Occupational Exposure

Occupational personal dose equivalents exhibited low-to-moderate variability among workers and between hospitals throughout the monitoring period, with coefficients of variation ranging from 8.9% to 33.0%. The coefficients of variation for Hp(0.07) ranged from 9.8% to 33.0%, while those for Hp(10) ranged from 8.9% to 26.6% (Table I). The highest variability was observed at Kitui County Referral Hospital during Month 3 and at Kitui Jordan Hospital during Month 2, whereas Mwingi Hospital showed comparatively lower variability during the first month of monitoring.

Across the three monitoring months, Kitui Jordan Hospital had the highest mean monthly dose equivalents, with mean monthly Hp(0.07) and Hp(10) values of 0.160 ± 0.005 mSv and 0.143 ± 0.002 mSv, respectively. These values were approximately 13–35% higher than those observed in the other facilities, suggesting modest but consistent differences in occupational exposure levels.

The elevated dose equivalents at Kitui Jordan Hospital may reflect differences in workload, procedural complexity, and staff positioning [10]. In contrast, the lowest mean dose equivalents were observed at Mwingi Hospital during the first two monitoring months. Despite the observed inter-hospital differences, the projected annualized Hp(10) dose remained substantially below the ICRP-recommended occupational effective dose limit of 20 $mSv\cdot y^{-1}$ [5]. Furthermore, most coefficients of variation were below 30%, although values exceeding 30% were observed during selected monitoring months, particularly at Kitui Jordan Hospital and Kitui County Referral Hospital. The overall mean monthly Hp(0.07) and Hp(10) dose equivalents across the three hospitals are presented in Fig. 3.

The occupational personal dose equivalents obtained in this study were compared with selected values reported in local, regional, and international studies, as presented in Table II.

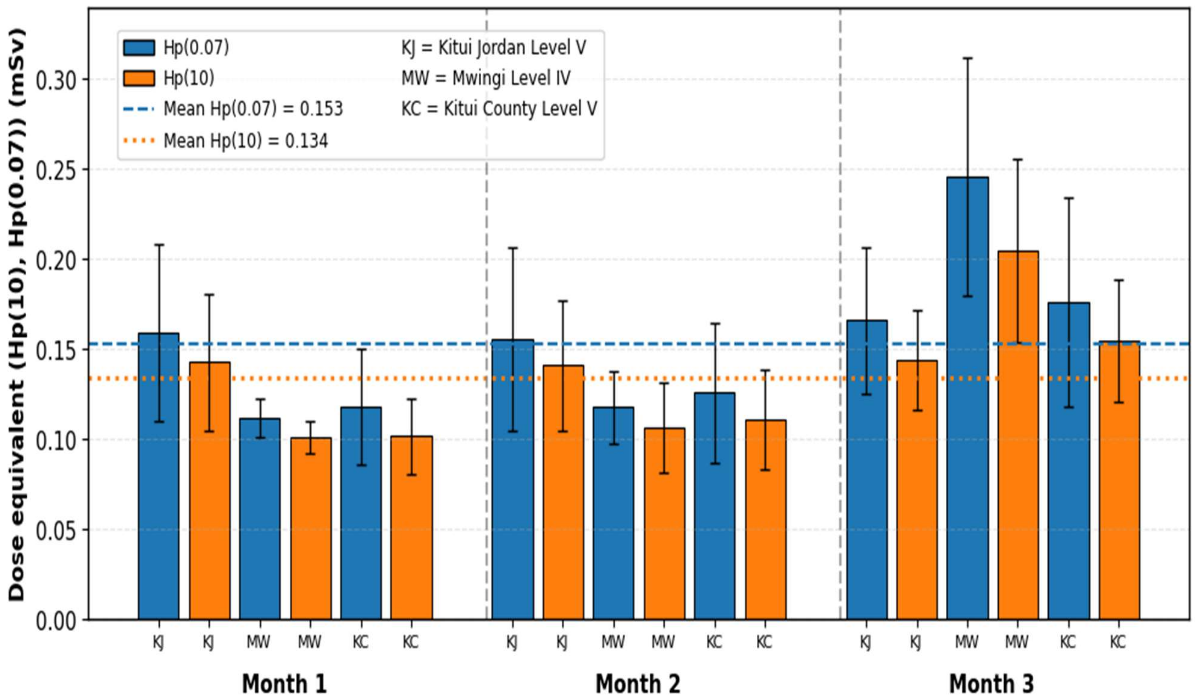

Fig. 3. Overall mean Hp(0.07) and Hp(10) dose equivalents across the studied hospitals.

Table II. Comparison of occupational dose equivalents reported in this study and selected published studies.

Country	Region	Staff Group	Monthly Dose (mSv)	Reference
Kenya	Kitui County	Radiographers	0.156 (Hp(0.07)); 0.141 (Hp(10))	This work
Kenya	Nairobi County	Mixed	0.12 (Hp(10))	[19]
Tanzania	Lake Zone Centres	Diagnostic radiographers	(0.09–1.12) Hp(10)	[24]
Ghana	Various hospitals	Radiographers	(0.024–0.034) Hp(10)	[25]
Saudi Arabia	Aseer region	Radiology personnel	(0.12–0.33) Hp(10)	[26]
Gabon	Multiple centres	DR, NM, and RT workers	0.028 Hp(10)	[27]
Colombia	Bogotá	Radiographers	2.1 ± 0.6 Hp(10)	[28]
Colombia	Bogotá	Physicians	1.5 ± 0.3 Hp(10)	[28]
Italy	Interventional Radiology Units	Radiologists	(0.13–0.37) Hp(10)	[29]
United States	National cohort	Radiologic technologists	0.05 Hp(10)	[30]

Relative to the Kenyan value reported in [19] (0.12 mSv month^{-1}), the average Hp(10) observed in the present study (0.141 mSv month^{-1}) was approximately 17.5% higher. However, the present values remained considerably lower than those reported in interventional and fluoroscopy-intensive settings such as Colombia and some European interventional radiology units, where prolonged staff presence near radiation sources contributes substantially to occupational dose accumulation.

These observations may be consistent with the implementation of standard radiation-protection practices across the studied facilities. Nevertheless, descriptive differences in mean dose values indicate that operational factors such as fluoroscopic workload, room occupancy, examination complexity, and staff positioning remain important determinants of individual worker exposure.

Direct comparisons should be interpreted cautiously because the cited studies involved different worker categories, imaging modalities, monitoring periods, and healthcare settings, all of which can substantially influence occupational dose levels. Although variations in mean dose levels were present, occupational exposures across the studied facilities remained broadly comparable. The observed differences may reflect operational factors such as workload, fluoroscopic procedures, room occupancy, and staff positioning rather than hospital-level designation.

The values obtained in this study fall within the lower to mid-range of reported occupational exposures, indicating relatively low radiation levels in the studied facilities. Despite these variations, the observed monthly doses remain well below the annual occupational dose limit of 20 mSv recommended by the ICRP [5], [7]. Higher values reported in some studies are typically associated with interventional procedures and high-workload environments.

C. Ambient Dose and Corresponding Radiological Parameters

The maximum measured ambient dose rate (0.34 μSv·h⁻¹) was approximately 3.8 times higher than the minimum value (0.09 μSv·h⁻¹), although the overall coefficient of variation remained relatively low (13.1%), indicating limited spatial heterogeneity across the surveyed facilities. Fig. 4 presents a histogram with an overlaid normal distribution curve used to visually assess the distribution and variability of the measured ambient dose rates, while Table III summarises the ambient dose rates and associated radiological parameters derived from the measured dose rates.

Across the 61 surveyed rooms, ambient dose rates ranged from 0.09 to 0.34 μSv·h⁻¹, with a mean ± standard deviation of 0.198 ± 0.026 μSv·h⁻¹ and a coefficient of variation of 13.1%. Terrestrial gamma radiation is influenced by the distribution of NORMs in soil, rocks, and building materials.

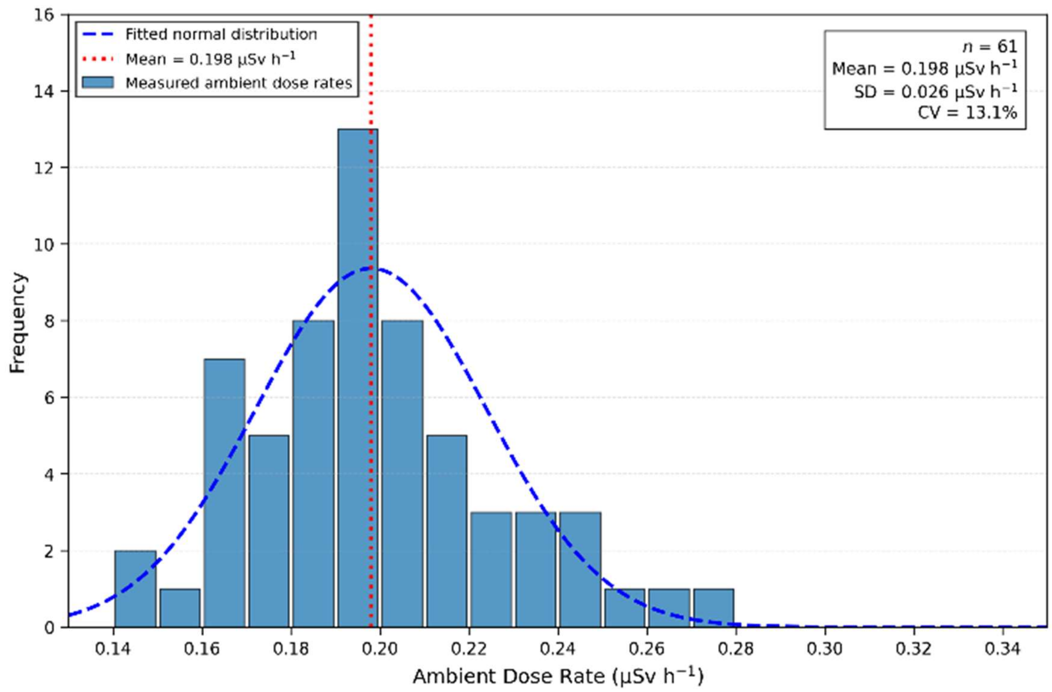

Fig. 4. Histogram of ambient dose-equivalent rates, H*(10), measured in the 61 surveyed rooms, with the corresponding fitted normal distribution curve.

Table III. Ambient dose rates and derived radiological parameters for the studied hospitals

Health Facility	Dose rate (μSv·h⁻¹)	Ambient dose equivalent (mSv·y⁻¹)	ELCR ×10⁻⁴
Kitui County Level V	0.10–0.34	0.70–2.38	24.5–83.4
Kitui Jordan Level V	0.11–0.29	0.77–2.03	26.9–71.1
Zombe Level IV	0.12–0.30	0.84–2.10	29.4–73.6
Ikanga Level IV	0.09–0.28	0.63–1.96	22.1–68.7
Mwingi Level IV	0.16–0.29	1.12–2.03	39.2–71.1
MEAN	0.198 ± 0.026	1.388 ± 0.182	48.58 ± 6.38

The spatial variation, as indicated by the CV of 13.1%, may therefore partly reflect differences in local environmental and construction characteristics. Given the geological variability associated with granitic and gneissic lithologies within the broader Mozambique Belt, local geology may be a potential consideration when establishing radiation-protection baselines in healthcare facilities in southeastern Kenya. However, geological composition and radionuclide concentrations were not directly measured in the present study; consequently, the observed variation cannot be attributed specifically to lithology.

The corresponding annualized ambient dose equivalent ranged from 0.63 to 2.38 $mSv \cdot y^{-1}$, with a mean of 1.388 $mSv \cdot y^{-1}$. These values represent environmental exposure indices derived from the measured ambient dose rates using an assumed indoor occupancy factor of 0.8 and should not be interpreted as directly measured individual occupational doses.

The mean annual dose estimated in this study is comparable with reported values of 0.36, 0.65, 0.33, 0.58, 0.25, 0.63, 0.48, and 0.45 mSv for Chile, Iran, the UK, Malaysia, the USA, Spain, Norway, and Finland, respectively [31–33]. Differences between the present estimate and values reported in other countries may reflect variations in local geology, building materials, room construction, occupancy patterns, measurement protocols, and detector characteristics. Such methodological and environmental differences should be considered when comparing ambient radiation estimates across geographical settings.

The corresponding ELCR values ranged from 22.1×10^{-4} to 83.4×10^{-4} across the facility-specific ranges presented in Table III, with a mean of 48.58×10^{-4}. Although the ELCR estimates varied by a factor of approximately 3.8 across the overall measured ambient dose-rate range, this variation primarily reflected differences in the measured ambient dose-equivalent rates. These ELCR values represent hypothetical lifetime environmental exposure indicators based on the assumed indoor occupancy conditions and should not be interpreted as estimates of individual occupational cancer risk. The calculated values were within the ranges reported in previous studies of indoor environmental gamma radiation [34]. The observed variation among facilities reflects differences in measured ambient dose rates and the occupancy assumptions applied in the risk model. The calculated values were derived using the nominal lifetime cancer risk coefficient specified in the methodology and therefore represent model-based comparative radiological indicators rather than direct predictions of individual cancer incidence [9], [35].

IV. Conclusion

Occupational monitoring of radiographers in selected healthcare facilities in Kitui County yielded mean monthly personal dose equivalents of 0.141 mSv for Hp(10) and 0.156 mSv for Hp(0.07), corresponding to annualized projections of 1.69 and 1.87 $mSv \cdot y^{-1}$, respectively. These projections were substantially below the ICRP-recommended occupational effective-dose limit. Ambient gamma dose-equivalent rates ranged from 0.09 to 0.34 $\mu Sv \cdot h^{-1}$, with a mean of 0.198 ± 0.026 $\mu Sv \cdot h^{-1}$ and an annualized mean ambient dose equivalent of 1.388 $mSv \cdot y^{-1}$ under the assumed occupancy conditions. Using the same occupancy assumption, the measured ambient dose-rate range corresponds to 0.63–2.38 $mSv \cdot y^{-1}$.

Overall, the measured occupational personal dose equivalents and ambient dose-equivalent rates were relatively low, with modest spatial variation. The findings establish a baseline for radiation exposure in county-level healthcare facilities in Kitui County, and support continued occupational dose surveillance and efforts to optimize radiation-protection practices.

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Conflict of Interest

The authors declare no conflict of interest.

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