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Excess lifetime cancer risk assessment of radiographers at some radiography facilities in Warri, Delta state

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Abstract
The Ionizing radiation emitted from X-ray machines has enough energy to bombard the atoms of living cells, damaging their genetic sequence, and resulting in cancer and other health risks. The focus of this study is radiologist. Therefore, measurements were performed at their point of impact. Instantaneous Dose Rate (IDR) was measured using a calibrated portable radiation detector GM-600 plus. The measured IDR in the studied facilities ranged from 0.09 – 16.47 µSv/hr. the calculated absorbed Dose Rate (ADR) ranged from 0.0009 – 0.1647 µSv/hr. The calculated Annual Effective Dose Equivalent (AEDE) also ranges from 0.0055 – 1.0099 mSv/yr. The arithmetic mean and standard deviation values of ADR are (0.0300±0.0407 µSv/hr.), AEDE (0.1838±0.2496 mSv/yr.). The estimated excess lifetime cancer risk (ELCR) for twenty-two X-ray facilities (X_1-X_{22}) ranged from 0.0153 $\times10^{-3}$ – 2.8151 $\times10^{-3}$, with an arithmetic mean and standard deviation of (0.5187±0.6917). Findings show that ADR and AEDE values are lower than the standards set by NCRP, as well as ELCR values in thirteen (13) as in 59.1% of twenty-two (22) radiology facilities, meaning that radiologist working at these facilities will have no risk of developing cancer during their lifetime. While nine (9) facilities (40.9%) had values greater than the recommended criterion of 0.29 $\times10^{-3}$, this indicates that radiologist at these facilities are susceptible to developing cancer in their lifetime.

Keywords: Absorbed dose, annual effective dose, cancer, life expectancy, radiographer, risk

Introduction
Despite many years of research on the biological effects of ionizing radiation, there is still great uncertainty over the role of radiation dose rate (Donna *et al*., 2022) [6]. Ionizing radiation has many beneficial applications in medicine, industry, agriculture and research, while low doses of ionizing radiation increase the risk of long-term effects such as cancer (WHO, 2023) [18]. Tadesse *et al*., (2023) [15] and UNSCEAR (2016) [17] also confirmed the WHO's findings that ionizing radiation has biological effects such as cancer and death. There is a strong correlation between radiation exposure in certain environments and health risks to the public and workers (Abba and Sani, 2023; Odoh *et al*., 2019; Inoue *et al*., 2020) [1, 11, 7]. Cancer is a major public health problem worldwide and is the second leading cause of death in the United States (Rebecca, *et al*., 2023) [14]. Rebecca, *et al*., (2023) [14] estimated that approximately 609,820 people will die of cancer in the United States in 2023, or 1670 deaths per day. In Nigeria, cancer causes 72,000 deaths each year and approximately 102,000 new cases each year according to the Nigeria National Cancer Control Plan (NCCP 2018-2022), cancer mortality in Nigeria is more worrisome compared to other Countries. In the United States 19% of breast cancer cases result in death while in Nigeria, the rate is 51% (NCCP 2018-2022). Cancer is a huge problem worldwide.

Despite the risk posed by ionizing radiation, the use of ionizing radiation for medical purposes accounts for 98% of public doses from all artificial radiation sources and 20% of public exposures. Worldwide, more than 4200 million diagnostic radiology examinations, 40 million nuclear medicine procedures and 8.5 million radiotherapy procedures are performed (WHO, 2023) [18], which is why the use of radiation exposure is so important and enduring. In hospitals and centres that provide X-ray services today, radiologists, nuclear medicine technologists and other physicians involved in X-ray and computed tomography (CT) examinations are at higher risk of radiation exposure than other hospital healthcare professionals (Covens *et al*., 2007) [4].

Furthermore; according to Cancio. D. report on UNSCEAR 2008, approximately 7.5 million workers are exposed to ionizing radiations for medical purposes, UNSCEAR, 2013 estimated that more than 2.5 million workers are monitored in the healthcare sector with a total exposure of 850 person-Sv. This is higher than the doses generated in industry and the military.

Effective dose was introduced by ICRP with the sole important purpose of setting radiological protection limits (Paquet, *et al*., 2016) [13], since it is inferred rather than measured, the term “effective dose” reflects the correlation between measured physical quantity and biological effects, and if the dose and effect are correctly estimated, the absorbed dose is equivalent to biological effects (Darrel and Fredrick, 2017) [5], is worth noting; effective dose is calculated for a reference individual, and not for an individual (ICRP 2007) [8]. It is, therefore, necessary to measure the instantaneous dose rate, calculate the annual effective dose equivalent and determine the excess lifetime cancer risk affecting radiologists at some selected radiography facilities in Warri, Delta State.

Materials

The materials used for this research are

1. X-ray machines
2. Digital laser tape
3. Radiation detector (Geiger Muller Counter)

Method

In this study, Measurements were performed in twenty-two (22) x-ray facilities under study using a calibrated GQ GMC-600 Plus digital radiation detector. The radiation monitoring equipment has been well calibrated and tested by the National Institute of Radiation Protection and Research (NIRPR) University of Ibadan, with certificate number NIRPR/JUTH/22/231. The measuring device was positioned at the console or measurement screen viewpoint, which was the radiologist’s work area, imaging location and our point of interest.

The maximum readings during radiation exposure recorded by the survey meter were recorded.

All measurements for barrier assessment were performed according to NCRP 147 protocol (Omojola *et al*., 2020) [12] with a Focal Detector Distance (FDD) of 100cm (1m), kVp set =100 and mAs set = 60. An X-ray field measuring 35cm x 35 cm was used in this study. The Instantaneous dose rate (IDR) readings were measured in µSv/hr directly from the display screen of the radiation detector.

The Absorbed Dose Rate (ADR) was calculated from the measured Instantaneous Dose Rate (IDR) by using the conversion factor below,

$$1\mu\ R = 0.01\ \mu Sv/hr \text{ and } 1\mu Sv/hr = 870\ nGy/hr \quad (1)$$

ADR value is in micro-Sievert per hour (µSv/hr).

The annual effective dose equivalent (AEDE) is also derived, The ADR is one of the variables used to calculate its value, including UNSCEAR outdoor occupancy factor (F) and Time (T).

$$AEDE\ (\mu Sv/yr) = ADR \times T \times F \quad (2)$$

$$AEDE\ (\mu Sv/yr) = ADR \times 24 \times 365 \times 0.7 \times 10^{-3}$$

Excess Lifetime Cancer Risk (ELCR) is also calculated. This value is used to determine the likelihood that someone will develop cancer from exposure to ionizing radiation. It is calculated by multiplying the calculated annual effective dose equivalent, the average life expectancy (DL) and the risk factor (RF)(Sv^{-1}), the life expectancy and risk factor are International Standards.

$$ELCR = AEDE \times DL \times RF \quad (3)$$

Where AEDE is the annual effective dose equivalent, DL is the average duration of life which is 55.75 years by (WHO, 2023) [18], RF is the risk factor which is 0.05 for public exposure (Chinyere and Atisi, 2017) [3].

Results

Table 1: The points of measurements, the occupancy factor (F), the NCRP-147 shielding design goal (P) of the radiologist work area at various diagnostic facilities

Locations	Designation		P (mSv/yr)	F
	Control	Supervised		
X-ray Console Point	√		5	1
Viewing lead shield glass	√		5	1

Table 2: Facility Radiation Protection Checks

Parameters	Present		Absent	
	Frequency	%	Frequency	%
Main door to X-ray room	16	72.73	6	27.27
X-ray room Lead lined	20	90.91	2	9.09
Door interlock provided	16	72.73	6	27.27
Provision of Lead apron	22	100	0	0
Hazard warning light provided	4	18.18	18	81.82
Hazard warning sign displayed	16	72.73	6	27.27
Functional air conditioner provided	10	45.5	12	54.55
Personal Monitoring Device	4	18.18	18	81.82
Structure purpose built	4	18.18	18	81.82

Table 3: The values of IDR, ADR, AEDE and ELCR in comparison with standards, the mean and standard deviation of ADR, AEDE and ELCR

Facilities	IDR µSv/hr	ADR µSv/hr	AEDE mSv/yr	ELCR × 10^{-3}
X1	1.19	0.0119	0.0730	0.2035
X2	0.24	0.0024	0.0147	0.0410
X3	4.60	0.0460	0.2821	0.7864
X4	5.11	0.0511	0.3133	0.8733
X5	0.09	0.0009	0.0055	0.0153

X6	3.11	0.0311	0.1907	0.5316
X7	0.88	0.0088	0.0540	0.1505
X8	0.59	0.0059	0.0362	0.1009
X9	0.90	0.0090	0.0552	0.1539
X10	10.20	0.1020	0.6255	1.7436
X11	16.47	0.1647	1.0099	2.8151
X12	1.17	0.0117	0.0717	0.1999
X13	0.26	0.0026	0.0159	0.0443
X14	2.13	0.0213	0.1306	0.3640
X15	1.92	0.0192	0.1177	0.3281
X16	0.68	0.0068	0.0417	0.1162
X17	0.28	0.0028	0.0172	0.0479
X18	0.88	0.0088	0.0540	0.1505
X19	0.44	0.0044	0.0270	0.0753
X20	0.89	0.0089	0.0546	0.1522
X21	6.20	0.0620	0.3802	1.0598
X22	7.72	0.0772	0.4734	1.3196
Mean± SD		0.0300±0.0407	0.1838±0.2496	0.5187±0.6917
Standard limit		0.5	5.5	0.29

IDR: Instantaneous Dose Rate, ADR: Absorbed Dose Rate, AEDE: Annual Effective Dose Equivalent and ELCR: Excess Lifetime Cancer Risk.

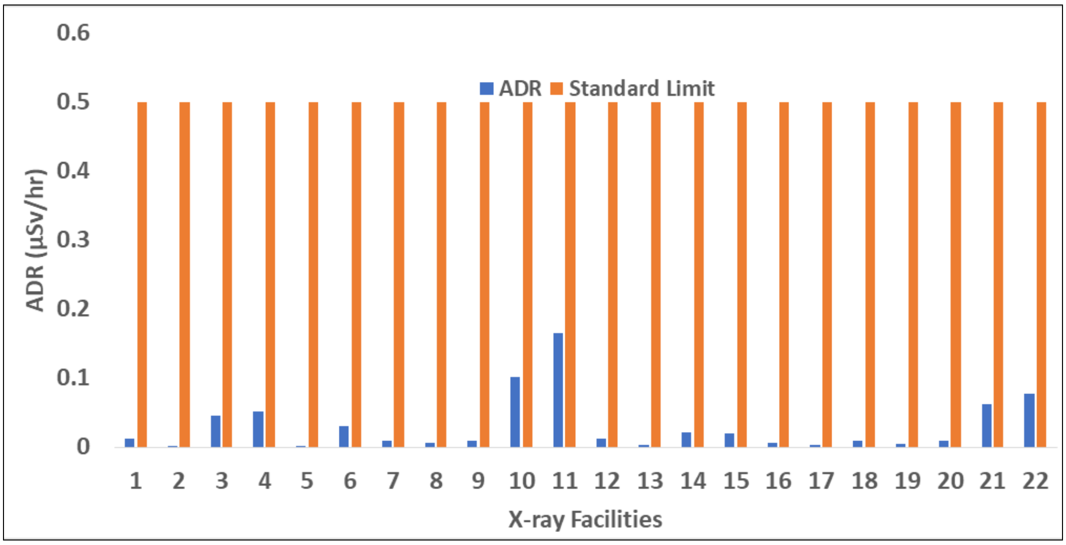

Fig 1: Absorbed Dose Rate (µSv/hr) at various X-ray Radiographic Facilities

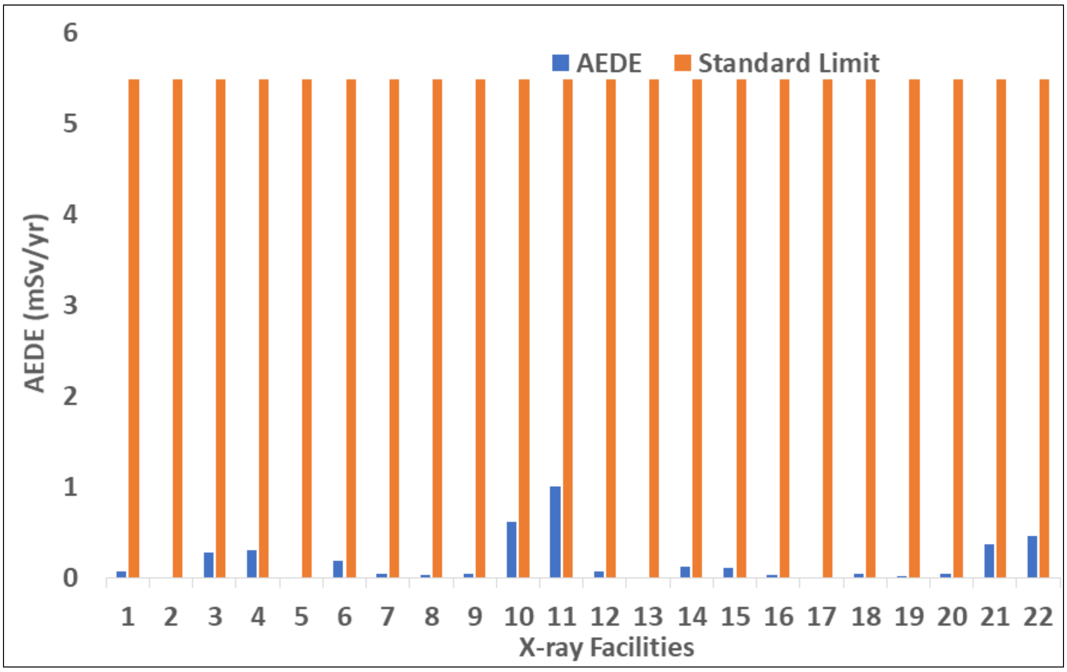

Fig 2: Annual Effective Dose Equivalent (mSv/yr) at various X-ray Radiographic Centres

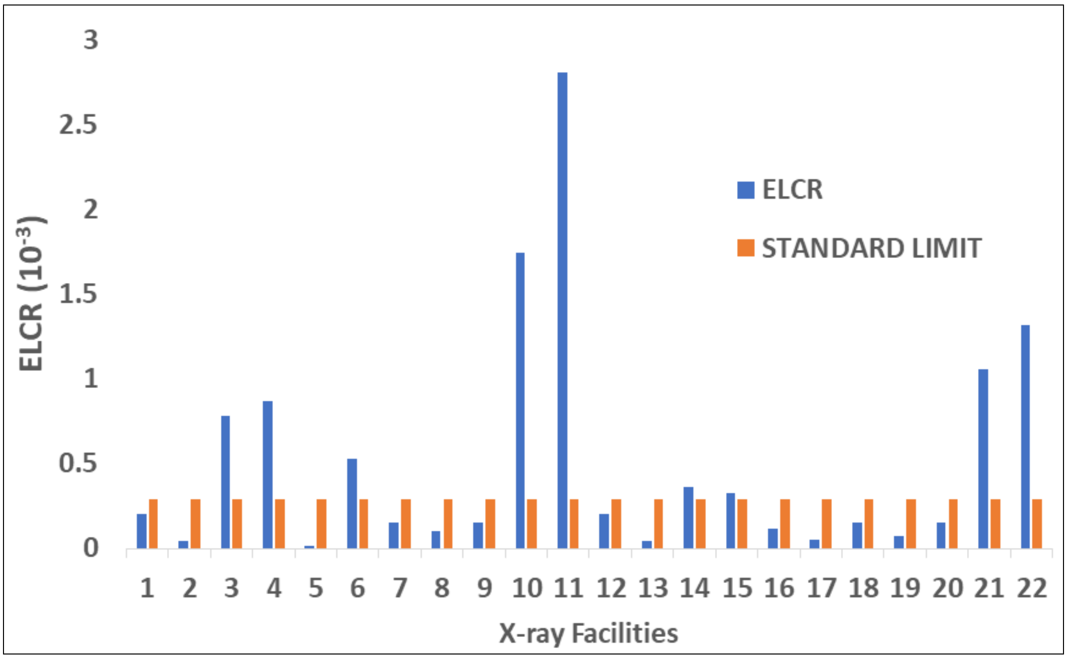

Fig 3: Excess Lifetime Cancer Risk of X-ray Radiographic Workers in Facilities under study

Discussion

Radiation protection is very important in all x-ray radiographic facilities due to the risk involved, to ensure that the x-ray facility is well shielded or protected, the size of the x-ray room and other safety measures established by regulatory agency must be considered when building a facility to house an x-ray machine. Table 2, shows the Radiation Protection Measures we considered, according to the measures we examined, only 72.73% of cases have the main door to x-ray room lead lined, 90.91% of cases lead lined the x-ray room, 72.73% of cases installed door interlock, 100% of cases made provision for lead apron, 18.18% of cases mounted radiation warning light, 72.73% of cases had radiation warning sign displayed, 45.45% of cases have operable air conditioners, 18.18% of cases use personal monitoring device and 18.18% of cases were purpose built to house x-ray facility while 81.82% of cases under study were built for residential purposes but were converted for radiological use, representing a risk. From the radiation safety perspective, we also noted that 81.82% of radiation workers at the studied facility were not monitored because they did not have personal monitoring equipment, which is unsafe and should not be commended. We also observed a low radiation level warning light, which help prevent personnel from entry during exposure.

The World Health Organization (2023) [18] states that absorbing low doses of ionizing radiation increases the risk of long-term effects, including cancer, in other words, the effect is not immediate, but is said to be as a result of the absorption of continuous dose, the age of 55 is the life expectancy factor (WHO, 2023) [18]

As a result of this study, the Absorbed Dose Rate (ADR) calculated based on the measured Instantaneous Dose Rate (IDR) was in the range of 0.1647 – 0.009 µSv/hr., and the arithmetic mean and standard deviation (SD) were 0.0300±0.0407 µSv/hr., (Table 3 and Figure 1). The Annual Effective Dose Equivalent (AEDE) ranged from 1.0099 – 0.0055 with a mean and standard deviation of 0.1838±0.2496 (Table 3 and Figure 2). In this study, the ADR and AEDE values and the corresponding mean and standard deviation are relatively low compared to Standard Limit (Table 3).

The Excess Lifetime Cancer Risk (ELCR) values ranged from 2.8151-0.0410 with an arithmetic mean and standard deviation of 0.5187±0.6917, indicating the presence of some radiographers with mean ECLR and deviations above the standard limits (Table 3, Figure 3). Thereby, indicating that radiographers in x-ray facility 3, 4, 6, 10, 11, 14, 15, 21 and 22 are susceptible to cancer in their life time, while radiographers in facility 1.2, 5, 7, 8, 9, 12, 13, 16, 17, 18, 19 and 20 are not susceptible to cancer in their life time, since the ELCR value in these facilities is lower than standard limits.

Conclusion and Recommendations

Findings shows that ADR and AEDE values are below the standard set by NCRP, also observed is the ELCR values of thirteen (13) facilities, 1.2, 5, 7, 8, 9, 12, 13, 16, 17, 18, 19 and 20 (59.1%) of the twenty-two (X_1-X_{22}) facility under study, had ELCR values below standard limits, signifying that radiographers in these facilities are not prone to cancer in their lifetime. While radiographers in nine (9) facilities, 3, 4, 6, 10, 11, 14, 15, 21 and 22 (40.9%) had ELCR values higher than the recommended standard of 0.29 $\times 10^{-3}$, indicating that radiographers in these facilities are susceptible to cancer in their lifetime, if urgent actions are not taken to safeguard their lives by reviewing the shielding protocols and guidelines, provision of personal monitoring device and x-ray rooms should be purpose built so as to prevent radiation leakage., hence reducing IDR to minimum level. From the studied facilities, facility whose IDR ranged from 0.09 -1.19 µSv/hr., generated low ELCR values (Table 3, Figure 3), the value of ELCR is dependent on IDR, high IDR value generates high ELCR value.

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