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AN ASSESSMENT OF INTEGRITY OF RADIATION SHIELDING IN X-RAY RADIOGRAPHIC FACILITIES IN WARRI METROPOLIS

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ABSTRACT

The use of radiation-emitting equipment is highly controlled in order to limit the exposure level for both workers and visitors around such facilities. Shielding is an integral part of radiation protection. This study is aimed at assessing the shielding of x-ray radiographic facilities in Warri metropolis. A total of eleven facilities were assessed in which radiation protection safety checks were carried out across the facilities and the facilities were grouped as controlled and supervised areas following the NCRP 147 protocol. The instantaneous dose rate (IDR) was measured using a calibrated handheld GM-600 radiation detector. The IDR measured for various locations ranges from 0.20 – 89.60 µSv/hr. and their corresponding annual dose rate (ADR) was computed using the measured IDR and the occupancy factor to produce its value which ranges from 0.11 - 51.10 mSv/yr. The ADR results obtained were compared with the limits recommended by the National Commission for Radiation Protection (NCRP) (5 mSv/yr. and 1 mSv/yr. for controlled and supervised areas respectively) and it was observed that five facilities exceeded the NCRP limit for controlled areas while six facilities exceeded the NCRP limits for supervised areas. The study therefore showed that the obtained ADR from the studied facilities were partially within the NCRP recommended limits thus indicating a partial compliance with radiation protection principles. Hence, regular quality control of radiographic x-ray facility checks is recommended.

Keywords: Shielding, Radiation, Dose rate, X-ray, Annual dose

INTRODUCTION

The understanding of radiation brought novel revolutions in the field of medicine, due to its curing capacity, radiation is classified as ionizing and non-ionizing (Mokobia, et al., (2022) Agba et al., (2011) WHO, (2004). Unnecessary exposure to ionizing radiation can result in genetic disease, which can be transferred from parents to progeny and other health hazards ICRP (1996)). There is a strong correlation between radiation exposure and health hazards among the populace and workers in a given environment; Abba and Sani (2023), Odoh et al., (2019), Inoue et al., (2020), Avwiri, et al., (2007), Farai & Jibiri, (2000).

Furthermore, Oluwafisoye et al., (2010) reported that in Nigeria, X-ray is the most frequently used ionizing radiation in medicine, exposure to ionizing radiation can cause cancer and other health challenges including stunted growth and mental retardation in children of mothers exposed to radiation during pregnancy according to National Research Council (NRC, 2006) high radiation doses may also cause other health effects.

Cancer is a major public health problem worldwide and is the second leading cause of death in the United States, Rebecca, et al., (2023). In many hospitals that offer X-ray services today, radiologists, radiology and nuclear medicine technicians, and others involved in performing X-ray examinations and computed tomography (CT), have an increased risk of exposure to radiation than other hospital healthcare professionals (Covens et al., (2007)). Hence the need for this study to access the shielding of x-ray radiographic facilities in Warri Metropolis.

MATERIALS AND METHODS

In this study, Measurements were done in nine (9) different locations of safety interest in each facility using a calibrated GQ GMC-600 Plus digital radiation detector. The radiation survey instrument was well calibrated and tested by National Institute of Radiation Protection and Research (NIRPR) University of Ibadan, Nigeria, with certificate number NIRPR/JUTH/22/231. Background measurements were taken at all designated areas to determine if there were any environmental factor that could influence the measurements.

The detector was held 30cm away from the barrier to be assessed in all designated areas according to NCRP 147 procedure for taking readings during radiographic exposures. Also, the survey meter was positioned at the console to take measurement, which was practically the location where a radiographer stands to take exposures.

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

All barrier assessment measurements were taken at a set Focus to Detector Distance (FDD) of 100 cm (1 m), Set kVp of 100 and Set mAs of 60 according to NCRP 147 protocol (Omojola et al., 2020). With an x-ray field size of 35 cm x 35 cm was used for this study. The Instantaneous dose rate (IDR) readings were taken in µSv/hr directly from the display screen of the radiation detector.

The estimated ADR milli-Sievert per year (mSv/yr) were calculated, by multiplying the IDR by eight (8) working hours per day, five (5) working days per week and fifty (50) weeks per year according to international safe practice, as shown in equation one (1) below.

$$\text{IDR } (\mu\text{Sv/hr}) \times T \times F \times 10^{-3} = \text{ADR } (\text{mSv/yr}) \qquad (1)$$

where, the IDR is the instantaneous dose rate determined from the direct meter reading, F is occupancy factor, and T is the time to convert from hour to year (8(hr/day) x 5(days/week) x 50(weeks/year).

The Instantaneous dose rate (IDR) and the Annual dose rate (ADR) were recorded and compared to international standard. The ADR at any point within the controlled areas should be ≤ 5 mSv/yr which is the shielding design goals (P) recommended by NCRP Report number 147 (2004).

RESULT AND DISCUSSION

This study presents a radiation shielding assessment from secondary radiation of radio-diagnostic facilities in Warri Metropolis Nigeria. The shielding assessment was based on the NCRP-147 shielding protocols and the result obtained are shown in Table 1 - 4 and Figure 1 - 9 below.

Table 1: Facility Radiation Protection Checks

	PRESENT		ABSENT	
PARAMETERS	FREQ.	%	FREQ.	%
Main door to X-ray room	8	72.73	3	27.27
X-ray room Lead lined	10	90.91	1	9.09
Door interlock provided	8	72.73	3	27.27
Provision of Lead apron	11	100	0	0
Hazard warning light provided	2	18.18	9	81.82
Hazard warning sign displayed	8	72.73	3	27.27
Functional air conditioner provided	5	45.5	6	54.55
Personal Monitoring Device	2	18.18	9	81.82
Structure purpose built	2	18.18	9	81.82

Table 2: The points of measurements, the occupancy factor (T), the NCRP-147 shielding design goal (P) and the classifications of the areas at various diagnostic facilities.

LOCATION CODE	LOCATION	DESIGNATION		P (mSυ/yr)	T
		CONTROLLED AREA	SUPERVISED AREA		
L1	X-Ray console point	√		5	1
L2	Viewing lead shield glass	√		5	1
L3	Patient waiting area		√	1	¼
L4	Reception		√	1	1
L5	Entrance door		√	1	¼
L6	Primary barrier wall		√	1	1
L7	Secondary barrier wall-1(wall opposite primary barrier wall)		√	1	1
L8	Secondary barrier wall-2 (wall left of primary barrier wall)		√	1	1
L9	Secondary barrier wall-3(wall right of primary barrier wall		√	1	1

Table 3: Measured IDR for the different X-ray facilities

Location Code	IDR (μSv/hr)										
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
L1	1.19	0.24	4.60	5.11	0.99	3.11	0.88	0.59	0.91	10.20	16.47
L2	1.17	0.26	2.13	1.92	0.68	0.28	0.88	0.44	0.89	6.20	7.72
L3	0.28	0.24	0.25	0.49	0.27	0.25	0.30	0.24	0.24	0.22	4.22
L4	0.28	0.24	0.25	0.49	0.27	0.25	0.25	0.24	0.24	0.22	0.21
L5	11.61	0.32	0.21	3.42	0.29	3.11	89.60	0.59	1.31	102.20	56.32
L6	0.28	0.23	0.32	0.28	0.24	0.50	0.50	0.49	0.27	0.22	0.38
L7	0.28	0.24	0.26	0.24	0.26	0.23	0.30	0.23	0.25	0.21	0.21
L8	0.28	0.24	0.24	0.21	0.29	0.25	0.90	0.24	0.26	0.20	0.20
L9	0.28	0.24	0.27	0.24	0.26	0.23	0.30	0.24	0.26	0.22	0.22

Table 4: Annual Dose Rate (ADR) of studied facilities compared with standard limit

Location	ADR (mSv/yr)											NCRP
code	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	
L1	2.38	0.48	9.20	10.22	1.98	6.22	1.76	1.18	1.82	20.40	32.94	5
L2	2.34	0.52	4.26	3.84	1.36	0.56	1.76	0.88	1.78	12.40	15.44	
L3	0.14	0.12	0.13	0.25	0.14	0.13	0.15	0.12	0.12	0.11	2.11	
L4	0.56	0.48	0.50	0.98	0.54	0.50	0.50	0.54	0.48	0.44	0.42	
L5	5.81	0.16	0.61	1.71	0.15	1.56	44.80	0.30	0.66	51.10	28.16	
L6	0.56	0.46	0.64	0.56	0.48	1.00	1.00	0.98	0.54	0.44	0.76	1
L7	0.56	0.48	0.52	0.48	0.52	0.46	0.50	0.46	0.50	0.42	0.42	
L8	0.56	0.48	0.48	0.42	0.58	0.50	0.60	0.48	0.52	0.41	0.40	
L9	0.56	0.48	0.54	0.48	0.52	0.46	0.60	0.48	0.52	0.44	0.44	

Table 5: Comparison of IDR and ADR with other studies

References	Location	IDR	ADR
Present study	Warri	0.20 - 102.20	0.11 – 51.10
Omojola et al., 2022	Asaba	0.07 – 1.60	0.15 – 3.66
Peter et al., 2016	Keffi	0.10 – 1.83	0.05 – 3.66
NCRP, 2004	World limit	5.15 – 25.30	1, 5 (depending on the designated area)

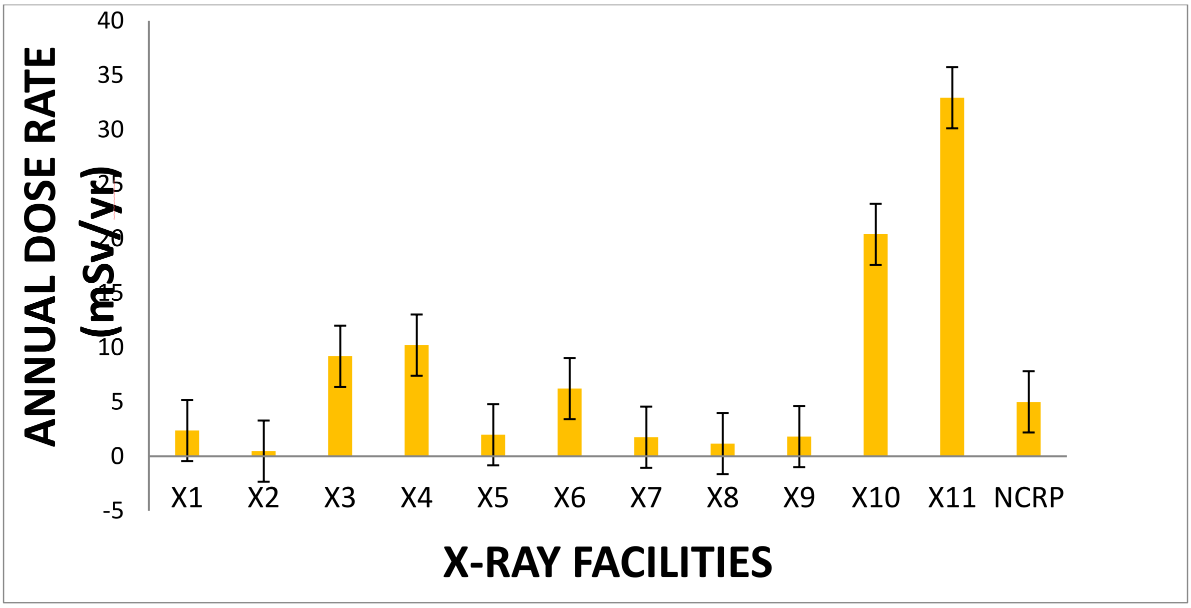

Figure 1: Annual dose rate (ADR) measured at the console point of the various diagnostic facilities.

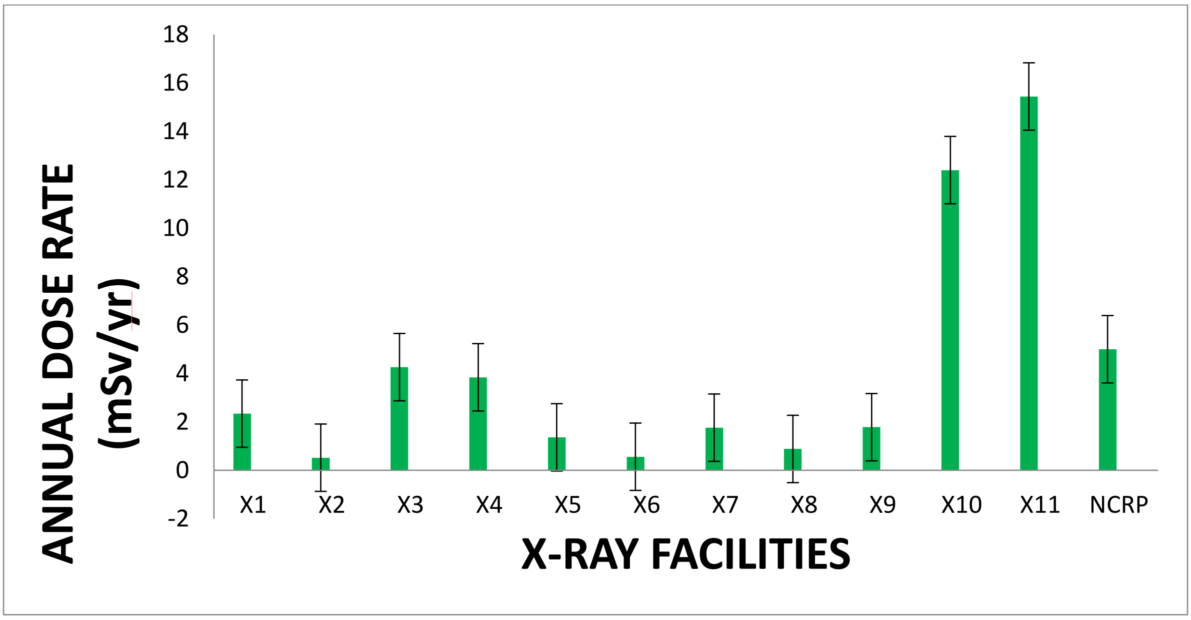

Figure 2: Annual dose rate (ADR) measured behind the shielded lead glass (viewing screen) of the various diagnostic facilities.

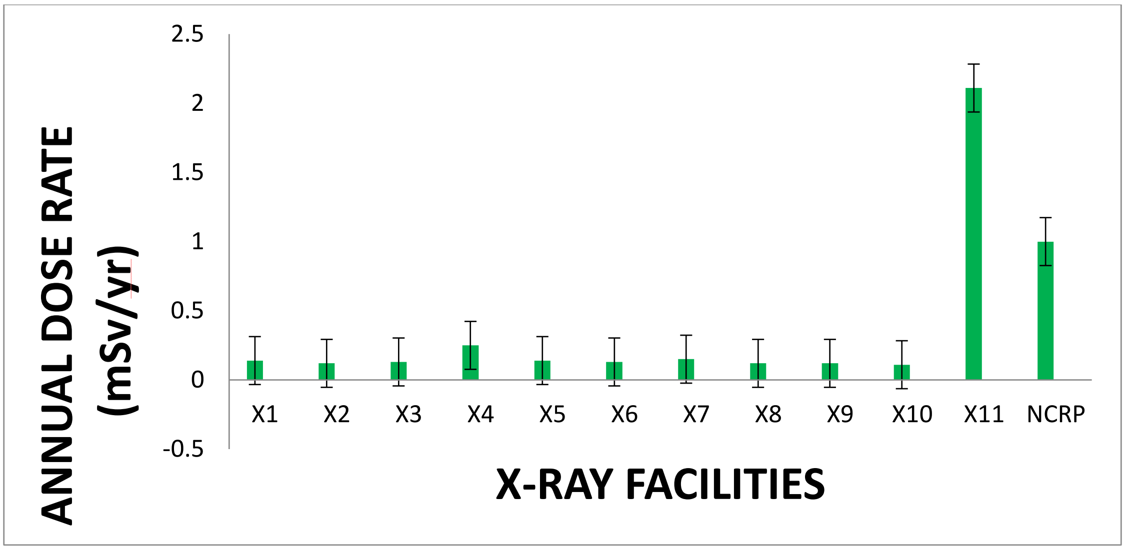

Figure 3: Annual dose rate (ADR) measured at the patient waiting area of the various diagnostic facilities.

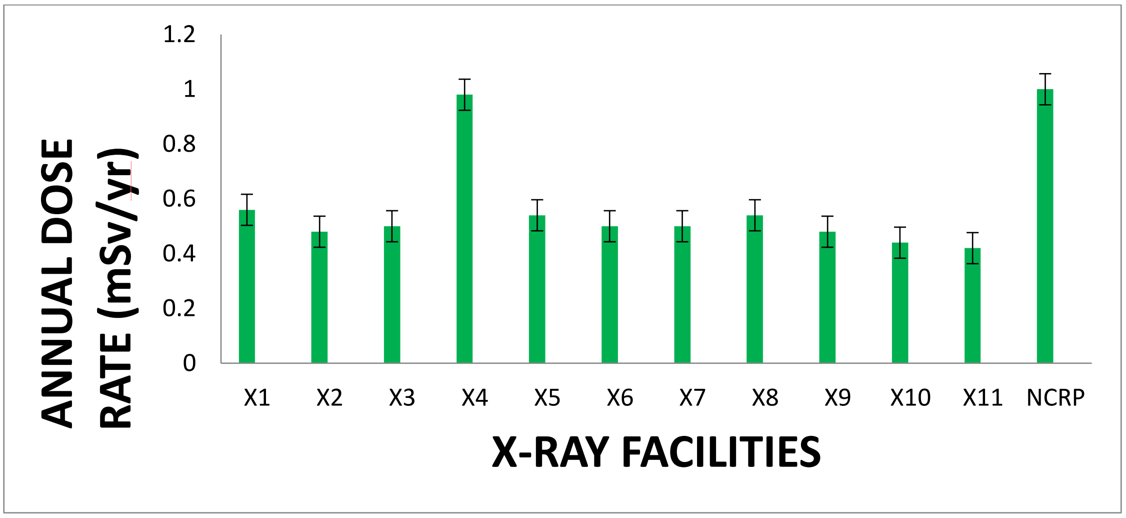

Figure 4: Annual dose rate (ADR) measured at the reception area of the various diagnostic facilities to standard.

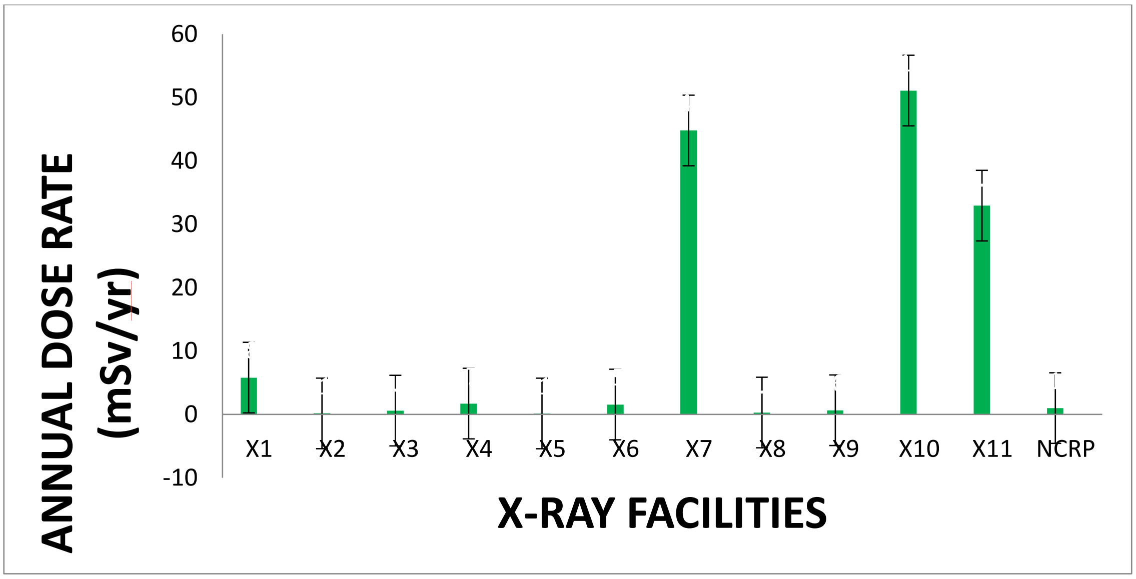

Figure 5: Annual dose rate (ADR) measured at the x-ray room entrance door area of the various diagnostic centres.

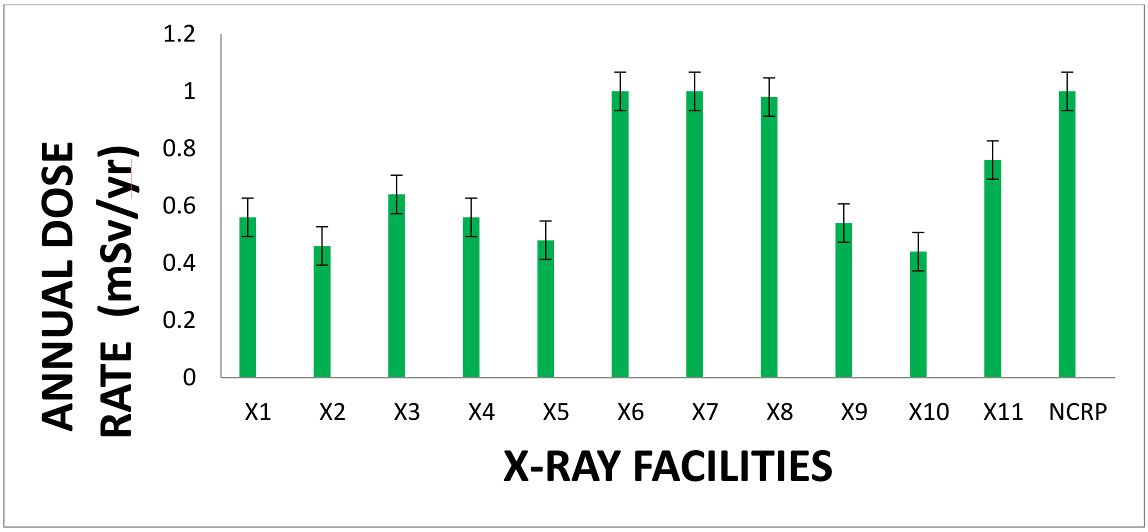

Figure 6: Annual dose rate (ADR) measured behind the primary barrier wall of the various diagnostic facilities.

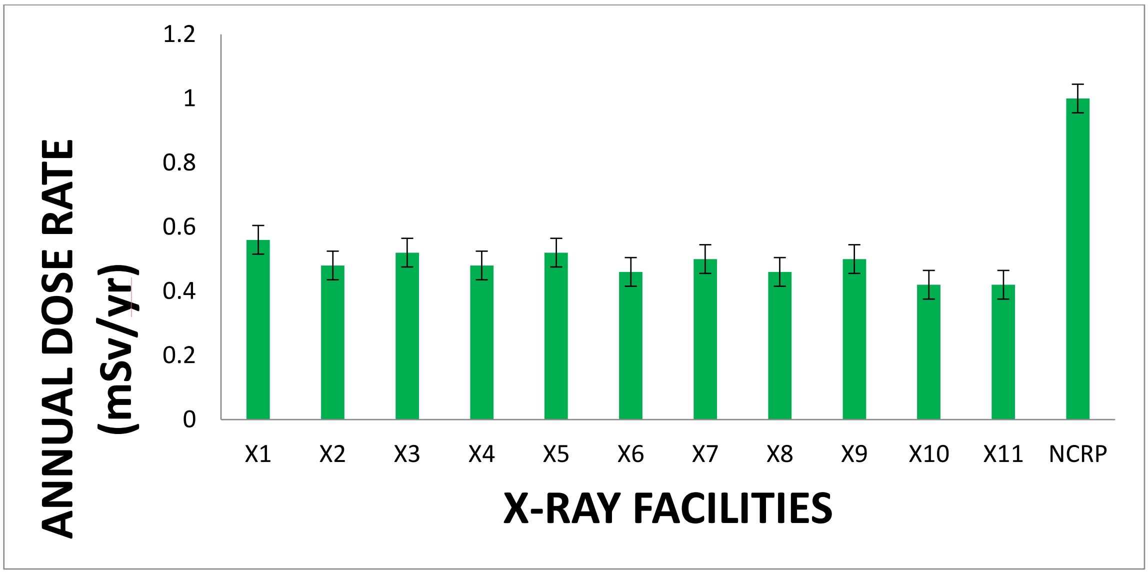

Figure 7: Annual dose rate (ADR) measured behind the secondary barrier wall-1 of the various diagnostic facilities.

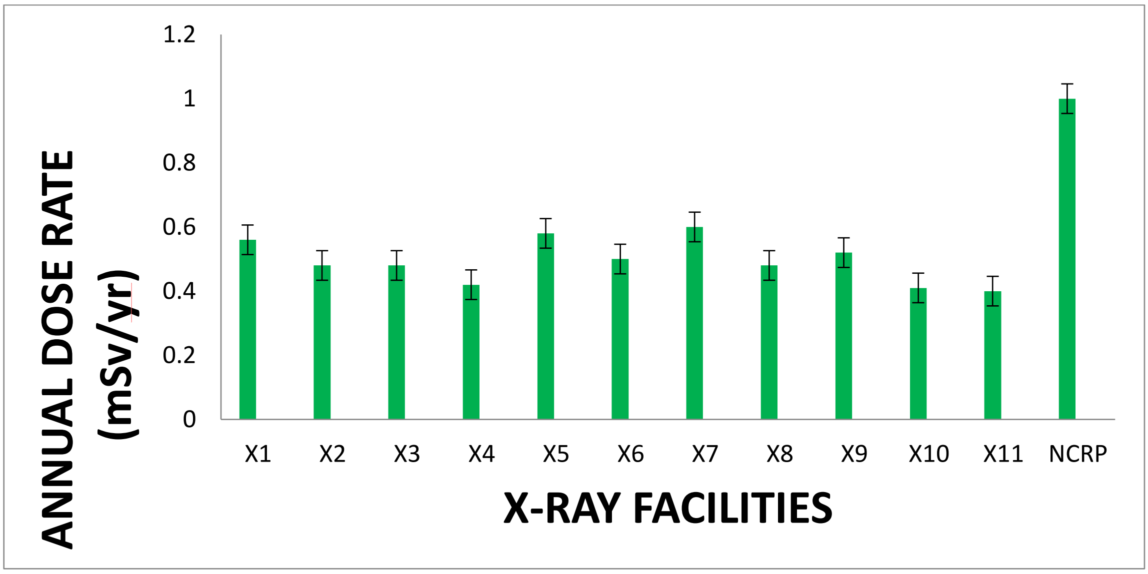

Figure 8: Annual dose rate (ADR) measured behind the secondary barrier wall-2 of the various diagnostic facilities.

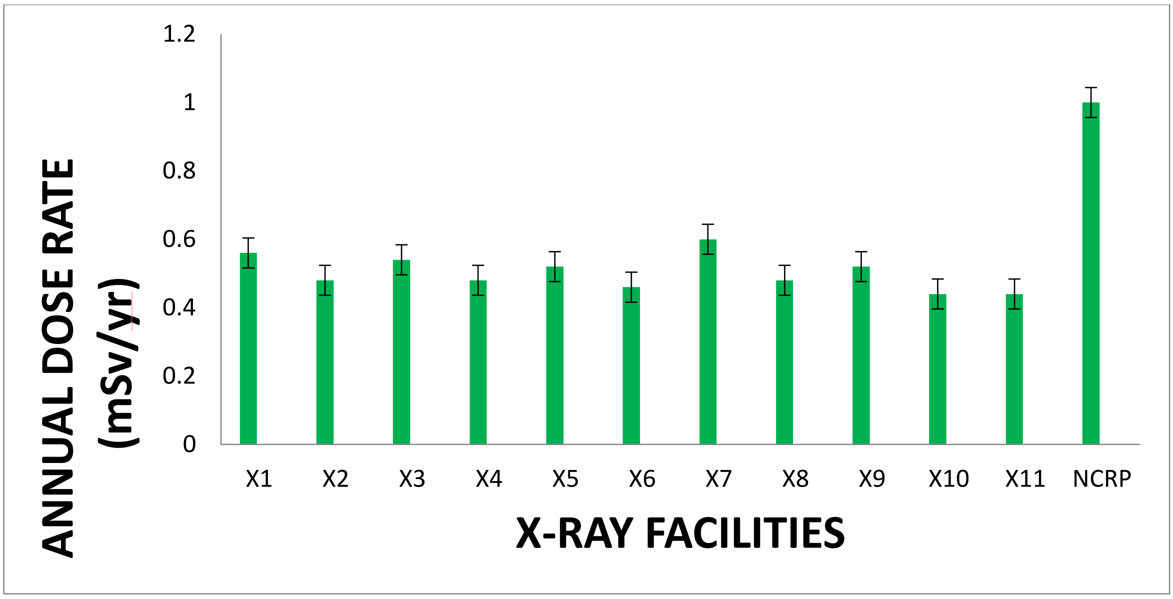

Figure 9: Annual dose rate (ADR) measured behind the secondary barrier wall-3 of the various diagnostic facilities.

DISCUSSION.

Table 1 shows Radiation Protection Measures that were considered in the studied facilities, these measures include; a check if main door to x-ray room lead lined, if the x-ray room lead lined, if door interlock is provided, provision of lead apron, if hazard warning light provided, if hazard warning sign is displayed, if functional air-conditional is provided, if personal monitoring device provided, if the structure was purpose built or not. From the table 1, it was observed that only 72.73% have the main door to x-ray room lead lined, 90.91% lead lined the x-ray room, 72.73% installed door interlock, 100% made provision for lead apron, 18.18% mounted radiation warning light, 72.73% had radiation warning sign displayed, 45.45% had functional air-conditional, 18.18% use personal monitoring device and 18.18% of all the studied facilities were purpose built to house x-ray facility. (81.82%) of the facilities under study were built for residential purposes which was modified for radiological use, this pose a serious challenge in terms of radiation safety. Also observed, was the very high rate of non-monitoring of classified radiation workers within the studied facilities. 81.82% had no monitoring device provided for personal monitoring, non-monitoring of staff is an unsafe radiological practice and should be discouraged. Another pressing observation is the low rate of radiation warning light installation, the warning light is a safety check to prevent the entry into the x-ray room during exposure, when the light is on, it indicates that exposure is ongoing and prohibit entry to the x-ray room, therefore prevent unnecessary radiation exposure to staff with assess to the exposure room.

The instantaneous dose rate (IDR) measured beyond the barriers and the calculated annual dose rate (ADR) from the studied diagnostic facilities were also shown in Tables 3 and 4 respectively. From the Tables, the IDR from the respective console area were; 1.19, 0.24, 4.60, 5.11, 0.99, 3.11, 0.88, 0.59, 0.91, 10.20 and 16.47 µSv/hr with respective ADR of 2.38, 0.48, 9.20, 10.22, 1.98, 6.22, 1.76, 1.18, 1.82, 20.40 and 32.94 mSv/yr corresponding to X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} and X_{11}. The highest IDR and ADR were observed at facility, X_{11}, while the least IDR and ADR were observed at facility X_2. The shielding design goal for the console area according to NCRP area classifications was 5 mSv/yr, hence the ADR of the console area was compared to the NCRP specifications as shown in Figure 1, from Figure 1, facilities X_3, X_4, X_6, X_{10}, and X_{11} had values above the NCRP shielding goal which implies that they were not adequately shielded. From this finding, only 54.55% of the shielding at the console of the studied facilities met this requirement while 45.45% did not. The readings collected just behind the viewing screen to ascertain the shielding capabilities were shown in the Tables 3-4. The results revealed that the IDR of the eleven facilities ranges from 0.26 - 7.72 µSv/hr and the ADR was 0.52 and 15.44 mSv/yr corresponding to the facilities X_2 and X_{11} respectively. The highest IDR and ADR was observed at the console and viewing screen of X_{11} while the lowest was at X_2 thus suggesting that the thickness of the lead screen was inadequate. When the ADR was compared with the NCRP standard of 5m Sv/yr for controlled area, as shown in Figure 3-4, it was revealed that only facilities X_{10} and X_{11} were above the NCRP-147 shielding design goal. From Figure 2, 81.82% had adequate viewing lead glass screen while 18.18% had inadequate lead screen glass. The waiting area is a crucial area, patients wait for a while at the waiting area even before going in for their radiological examinations and this area has an occupancy factor of one quarter (1/4).

From Figure 3 the ADR from the various facilities were compared with the NCRP standard (1mSv/yr) for uncontrolled/supervised area which reflected that only one facility (X_{11}) failed in this respect. Hence, a 90.9% pass rate and 9.1% fail rate were recorded. The reception being an area with full occupancy, T =1, shows a significantly low value for both IDR and ADR across the studied facilities. The IDR ranges from 0.21 - 0.49µSυ/hr while the ADR ranges from 0.42 - 0.98 mSv/yr. The peak ADR was less than 1mSv/yr which is the shielding design goal. Based on the NCRP shielding design goal for reception, 100% passed rate was observed as shown in Figure 4.

The IDR and ADR observed in this study for the entrance door to the x-ray facilities were shown in Tables 3-4. The entrance door has an occupancy factor of ¼ with a shielding design goal of 1 mSv/yr. X_{11} was observed to have the highest IDR and ADR value of 102.22 µSv/hr and 51.10 mSv/yr respectively. Facilities X_1, X_4, X_6, X_7, X_{10} and X_{11} have ADR of 5.81, 1.71, 1.56, 44.80, 51.10, 28.16 mSv/yr respectively, these value were seen to be higher that the NCRP limit while facilities, X_2, X_3, X_5, X_8 and X_9 with ADR value of 0.16, 0.61, 0.15, 0.30, 0.66 mSv/yr respectively had values below the limit, figure 5. From observation showed that 54.55% of the x-ray room entrance door of the studied facilities were not adequately shielded or not properly interlock hence experiences some form of radiation leakage. 45.45% of the studied facilities were adequately shielded with well interlocking doors. The IDR and ADR measured behind the primary barrier walls of the x-ray facilities were all moderately ok, having ADR less than or equal to 1 mSv/yr as shown in Table 3 - 4. 100% compliance was observed as shown in Figure 6. Similarly, the IDR and ADR measured behind the secondary barrier walls (wall-1, wall-2, and wall-3) of the x-ray facilities were all moderately ok, having an ADR less than 1 mSv/yr as shown in Table 3-4. The secondary barrier wall-1, wall-2, and wall-3 showed a 100% compliance when compared to NCRP limit as shown in Figures 7-9 respectively. The range of the IDR across the studied facilities was 0.21 - 102.2 µSv/hr while the ADR across the facilities ranges from 0.20 - 51.10 mSv/yr.

One of the requirements of the NNRA is to make sure that shielding design goals are met, this is a key effort to the reduction of radiation exposure to classified worker within a radiological facility. The National Council on Radiation Protection and measurements report number 147 (NCRP 147) provides the widely accepted traditional methodology for radiation shielding designing. Because of high patient workload and less preventive maintenance, breakdowns are common. In addition to that most rooms used to host x-ray facilities were not originally intended for the purposes and are often smaller than the recommended standard format of 6m x 4m for general-purpose x-ray machines. This study has shown that most radiation workers were not provided with personnel monitoring device such as a thermo-luminescence dosimeter (TLD) or optically stimulated dosimeter (OSL) to keep check on the radiation doses to the workers. An estimate of the dose radiation dose absorbed by radiation workers within the studied area was carried out. Table 3-4 shows the classified radiation workers (radiographers/technicians) instantaneous dose rate (IDR) and the annual dose rate (ADR) measured from the various diagnostic facilities. From the Table, it was observed that X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10} and X_{11} had an IDR of 1.19, 0.24, 4.60, 5.11, 0.99, 3.11, 0.88, 0.59, 0.91, 10.20 and 16.47 µSv/hr while the ADR were 2.38, 0.48, 9.20, 10.22, 1.98, 6.22, 1.76, 1.18, 1.82, 20.4 and 32.94 mSv/yr respectively.

This study's IDR and ADR values varied from 0.20 - 102.20 µSv/hr and 0.11 - 51.10 mSv/yr, respectively, which is higher than Omojola et al., (2022), which ranged from 0.07 - 1.60 µSv/hr and 0.15 - 3.66 mSv/yr and Peter et al., (2016), which ranged from 0.10 - 1.83 µSv/hr and 0.05 - 3.66 mSv/yr. Omojola et al., (2022) and Peter et al., (2016) study has IDR and ADR values that are lower than the required limit. While some X-ray radiographic facilities in this study generated IDR and ADR over the Standard Limit (Table 5).

CONCLUSION.

The shielding assessment of the studied radiographic facilities were successfully carried out and it was observed that only 36% of the studied facilities were purpose built to house an x-ray machine while 64% were modified to house x-ray machine. however, a review of radiation shielding conditions should be carried out periodically and when the x-ray machine is replaced or when there is a change in the facility design. Quality control checks should be done periodically to ensure compliance to radiation health guidelines. Radiation workers in the studied location should be provided with radiation monitoring devices. Shielding assessment should be extended to computed tomography (CT) diagnostic technique.

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