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Safety of Ionizing Radiation in Selected Conventional X-ray Diagnostic Centres in Calabar and Uyo metropolises, Nigeria

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Abstract

Background: Humans are inevitably exposed to background radiation in work and public environments. The aim of this work is to assess the effectiveness of the secondary barriers in conventional x-ray diagnostic centers in Calabar and Uyo metropolises. This is by determining the weekly and annual effective dose in their respective uncontrolled areas and comparing them with the international recommendations. Materials and

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Methods: This cross-sectional study was conducted in three x-ray diagnostic centers in Calabar, represented as C1, C2, and C3 respectively, and in four x-ray diagnostic centers in Uyo, represented as U1, U2, U3, and U4 respectively. Background radiation was measured using Radex 1212 A-A battery-powered survey meter, at a distance of 2.5meters away from the x-ray units. Radiation measurement was taken at three different spots, and the recorded data were analyzed. Results: The mean calculated effective dose per week in mSv/week for each diagnostic center was given as 0.130 ± 0.0068mSv/week. Also, the mean calculated effective dose per year in mSv/year for each center was given as 0.66 ± 0.35mSv/year. These values are below the National Commission on Radiation Protection (NCRP) recommendations of 0.02mSv/week and 1mSv/year respectively. From the results, the mean calculated chance of developing cancer was 2.33 $\times 10^{-3}$% which was lower than the NCRP recommendation for continuous public exposure of 5.5$\times 10^{-3}$ %. Conclusion: It could be concluded that the integrity of the shielding designs and their dimensions assessed are safe.

Keywords: Safety, Radiation, Dose, Annual, Shielding

Introduction

Environmental safety is an essential area of health and safety practices, which include practices, policies, and procedures that ensure the safety and wellbeing ofanyone in the immediate area. This can include safety in terms of proper waste disposal, containment and storage of potentially toxic chemicals, proper design of radiation facility, and much more (Spokane Environmental Solution, 2017). Though environmental safety certainly makes a demand of business in terms of cost of compliance, the reality is that doing so is imperative. There are regulatory consequences of non-compliance and negligence, liabilities in civil suits as well as potential moral hazards in not obeying environmental safety practices. Some of the worst man-made disasters were caused by inadequate environmental safety measures and lawsuits are filed all the time by injured workers, residents near industrial operations, and by regulatory authorities when companies fail to observe proper environmental safety. Hence, businesses and organizations have an interest in doing so to avoid liabilities as well as other obligations (Spokane Environmental Solution, 2017).

Radiation has always been part of our natural environment, originating from space, the sun, and naturally radioactive substances in the ground and in our own bodies (Chiaghanamm *et al.*, 2019; Archibong and Chiaghanamm, 2020). We have developed ways of producing radiation and making use of radiation properties in research, healthcare, and industry. X-rays are electromagnetic radiation of the extremely short wavelength and

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high frequency with wavelengths ranging from about 10^{-8} to 10^{-12}meter and corresponding frequencies from about 10^{16} to 10^{20} Hz. X-rays are forms of ionizing radiation produced by accelerating or de-accelerating charged particles. Examples include a beam of electrons striking a metal plate in an x-ray tube and a circulating beam of electrons in a synchrotron particles accelerator or storage rig (Suraj, 2012).

Ionizing radiations are used in diverse modern applications. It is used in the diagnosis of disease, preserving food materials, purification of materials, and identification of components or compounds. These ionizing radiations enter the living tissues and can destroy living cells, chromosomal aberrations, and carcinogenic effects. Ionizing radiation can randomly cause damage to all cellular components and induces a variety of DNA defects. So x-rays are utilized in well-preventive and protective conditions (Ahmed, 2008).

The last two decades have witnessed a technological revolution in diagnostic and therapeutic medical imaging. However, minimizing the risk of radiation exposure is still a challenge. According to a 2010 US Food and Drug Administration (FDA) white paper 'per capita exposure to ionizing radiation (from all sources) increased from 3.6mSv (milli sievert) in 1980 to 6.25mSv in 2006". During this time, the contributions that were attributable to medical imaging increased from 15percent in 1980 to 45percent in 2006, and about two-thirds of all medical imaging in 2010 involved ionizing radiation (Mastracci, 2015).

Humans are inevitably exposed to background radiation both in work and public environments (Center for Disease Control and Prevention, 2014; Chiegwu *et al*., 2021). The level of exposure varies depending on latitude and longitude. According to Chad-Umorem *et al*(2007), chronic exposure to even low dose rates of nuclear radiation from an irradiated building has the potential to induce cytogenetic damage in human beings. In certain situations where the level exceeds the known average dose, the introduction of health protection measures needs to be considered.

Radiation can be beneficial, but it can also cause damage. To minimize its harmful effects on humans and the environment, all activities involving radiation must do more good than harm and doses must be limited as far as is reasonably possible (Annemay, 2018). From our observations, most diagnostic centers are cited in residential buildings that are not purposely built for radiation exposures in most cities in Nigeria and this is of great concern. Hence, this study was designed to evaluate the radiation protective measures put in place at radio-diagnostic centers for the protection of other medical staff, and non-radiation health workers within the selected centers in Calabar and Uyo metropolises in Nigeria and their comparison with the standard recommended values.

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Methods

This was a cross-sectional study carried out at three selected diagnostic centers in Calabar metropolis and four diagnostic centers in Uyo metropolis, Nigeria based on the inclusion criteria, which include centers with only conventional x-ray units. This study was conducted from June 2019 to September 2019 after obtaining ethical clearance and institutional permission for usage of the selected centers.

The equipment used includes (1) Radex 1212 A-A battery-powered survey meter, which can measure x-ray wall/door leakage, environmental radiation, and secondary radiation, and (2) conventional x-ray machines. Background reading was measured using Radex 1212 A-A battery-powered survey meter. This was measured at 2.5meters away from the x-ray unit in the surveyed diagnostic centers, and at three different locations. Data gotten was averaged and recorded.

During exposure to a lumbosacral region, data was obtained by measuring secondary radiation outside the secondary barriers (walls and doors respectively), at a distance of 0.3meters away from the secondary barriers. The readings were taken at three spots, averaged and data mean recorded. The exposure factors (75-120Kv and 16-100 mAs) used in the respective diagnostic centers and their machine types were also recorded, and the mean values of the exposures were documented and used for statistical analysis. The exposure factors and machine types, C1(Kv=120, mAs= 100,FFD= 100cm and GE medical system), C3(Kv= 90, mAs= 16, FFD=100cm and TMX4mobile) and U3(Kv=90, mAs = 40, FFD= 100cm and Toshiba) and U4 (Kv= 90, mAs= 16, FFD= 100cm and Toshiba)(Table 1).

The excess lifetime cancer risk, ELCR (x 10^{-3}) was computed using the equation below previously described by ICRP(1990) cited in Chiegwu *et al* (2021) study.

$$ELCR = AEDR \times DL \times RF \quad (1)$$

where AEDR = Total average annual effective dose (mSv y^{-1})
DL = Average duration of life (70years)
RF = Risk factor per Sv. (RF= 0.05 for the public, stochastic effects)

ELCR = a term used to estimate the difference between the proportion of persons who will develop or die of cancer (per sievert) in an exposed population compared to the people in a similar population that were not exposed to radiation.

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 21.0 (IBM Corp, Amornk, NY, 2012). Descriptive statistics

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such as mean, standard deviations, tables, and charts were used for statistical analysis.

Results

The mean and standard deviation values for the background radiation exposure rates obtained from the selected centers were C1 (0.09 ± 0.01 µSv/hour), C2(0.09±0.01 µSv/hour) C3 (0.08 ± 0.00 µSv/hour) and U1(0.08 ± 0.01 µSv/hour), U2(0.08±0.01 µSv/hour) and U3(0.09 ± 0.01 µSv/hour)(Table 2). The mean and standard deviation values of the exposure readings for outside secondary walls for C1 and U4 were 0.38 ± 0.07 µSv/h and 0.59 ± 0.07 µSv/h respectively while the mean and standard deviation values of the exposure reading for outside barrier doors for C1 and U4 were 0.41 ± 0.09 µSv/h and 0.65 ± 0.09 µSv/h(Table 3)

The effective dose per week (mSv/week) and effective dose per year (mSv/year) for the different centers in the metropolis were C1(0.015mSv/week, 0.76 mSv/year), C2(0.009mSv/week, 0.49mSv/year) and U1(0.009mSv/week, 0.27mSv/year) and U4(0.026mSv/week, 1.37mSv/year). The mean and standard deviation values for the effective dose per week and effective dose per year were 0.130±0.0068mSv/week and 0.66±0.35mSv/year respectively (Table 4)

From figure 1, the effective doses per week for each centre against the NCRP recommended values are C1(center value = 0.014mS/week; NCRP value= 0.02mSv/week), C2(center value= 0.009mSv/week, NCRP value = 0.02mSv/week) while in U2(center value= 0.011mSv/week, NCRP value = 0.02mSv/week) and U4(0.026mSv/week, NCRP value = 0.02mSv/week). The effective doses per year for each centre against the NCRP recommended values are C1(center value = 0.076mS/year; NCRP value= 1Sv/week), C2(center value= 0.49mSv/week, NCRP value = 1mSv/week) while in U2(centre value= 0.59mSv/week, NCRP value = 1mSv/week) and U4(1.37mSv/week, NCRP value = 1mSv/week)(Figure 2). The percentage chance for developing cancer for C1, C2, U1 and U2 are 2.66 x 10^{-3}% , 1.72 x 10^{-3}%, 0.95 x 10^{-3}% and 2.07 x 10^{-3}% respectively (Table 5).

Table 1- Exposure factors used and their machine types

Centers	Kv	mAs	FFD (cm)	X-ray machine types
C_1	120	100	100	GE medical system
C_2	115	40	90	GE medical system mobile
C_3	90	16	100	TMX 4 mobile
U_1	75	25	100	Phillips 800
U_2	90	32	100	Eureka
U_3	90	40	100	Toshiba
U_4	90	16	100	Toshiba

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Table 2- Background readings in micro Sieverts per hour (µSv/hour)

Centers Surveyed	2.5m Away From X-ray Room			
	1st	2nd	3rd	Mean ±SD
Center C_1	0.08	0.10	0.08	0.09 ± 0.01
Center C_2	0.09	0.09	0.09	0.09 ± 0.00
Center C_3	0.09	0.08	0.08	0.083 ± 0.00
Center U_1	0.08	0.07	0.09	0.08 ± 0.01
Center U_2	0.09	0.07	0.10	0.08 ± 0.01
Center U_3	0.09	0.08	0.10	0.09 ± 0.01
Center U_4	0.07	0.07	0.08	0.07 ± 0.00

Table 3 - Exposure reading in micro Sieverts per hour (µSv/h)

Centers	Outside Secondary Wall				Outside Barrier Door			
Surveyed	1st	2nd	3rd	Mean ± SD	1st	2nd	3rd	Mean ± SD
C_1	0.45	0.41	0.30	0.38 ± 0.07	0.42	0.32	0.50	0.41 ± 0.09
C_2	0.18	0.26	0.24	0.22 ± 0.04	0.35	0.40	0.36	0.37 ± 0.02
C_3	0.27	0.29	0.32	0.29 ± 0.02	0.45	0.31	0.48	0.48 ± 0.09
U_1	0.20	0.13	0.12	0.15 ± 0.04	0.27	0.23	0.22	0.24 ± 0.02
U_2	0.24	0.22	0.30	0.25 ± 0.04	0.21	0.41	0.46	0.36 ± 0.13
U_3	0.27	0.28	0.22	0.25 ± 0.03	0.22	0.41	0.29	0.30 ± 0.09
U_4	0.61	0.65	0.51	0.59 ± 0.07	0.76	0.61	0.58	0.65 ± 0.09
				0.30 ± 0.03				0.40 ± 0.07

Table 4- Effective dose per week in millisievert per week (mSv/week), and effective dose per year (mSv/year).

Centers	Effective Dose Per Week (mSv/week)	Effective dose per year (mSv/year)
C_1	0.015	0.76
C_2	0.009	0.49
C_3	0.014	0.74
U_1	0.009	0.27
U_2	0.012	0.59
U_3	0.008	0.44
U_4	0.026	1.37
Mean ± SD	0.130±0.0068	0.66±0.35

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Figure 1: Bar chart showing effective dose per week of surveyed centers in comparison to the NCRP recommendations

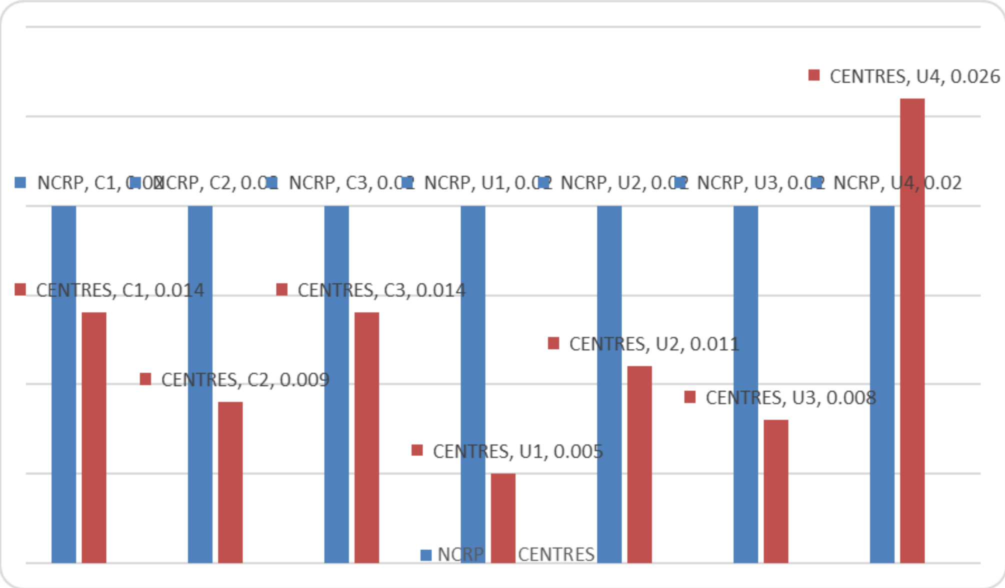

Figure 2: Bar chart showing effective dose per year of each center in comparison to the NCRP recommendations

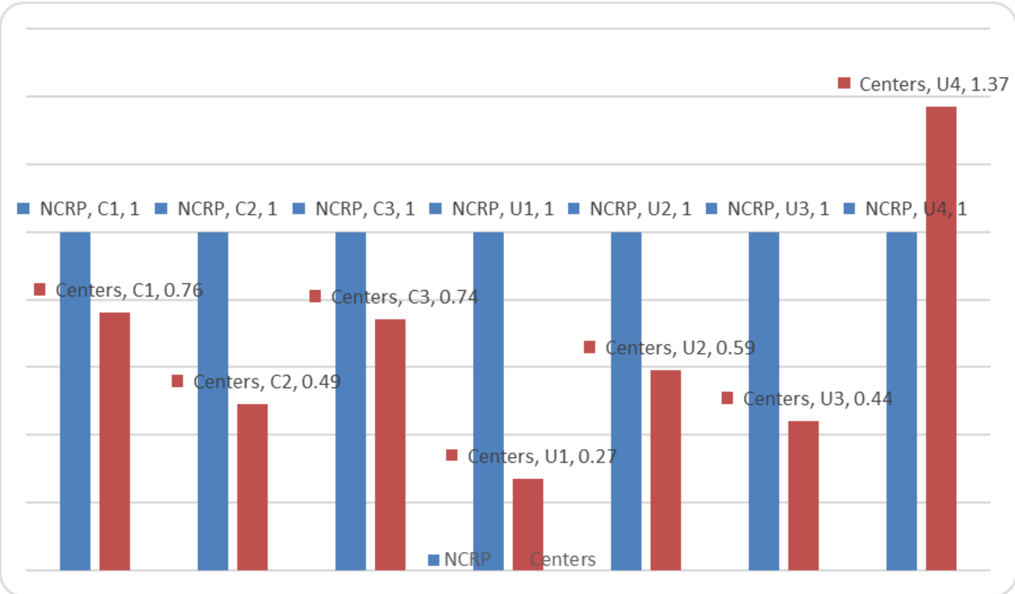

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Table 5: Percentage chance of developing cancer in a year

Centers	Effective dose per year	percentage(%) chance
C_1	0.76	2.66 x 10^{-3}
C_2	0.49	1.72 x 10^{-3}
C_3	0.74	2.59 x 10^{-3}
U_1	0.27	0.95 x 10^{-3}
U_2	0.59	2.07 x 10^{-3}
U_3	0.44	1.54 x 10^{-3}
U_4	1.37	4.80 x 10^{-3}
Average		**2.33 x 10^{-3} %**

Discussion

From NCRP (1993), it was assumed that for uniform whole-body exposure to x-ray (Photon), the radiation weighting factor is 1 and the tissue weighting factor of all the organs adds up to 1, therefore, an absorbed dose of 1 milligray (mGy) equals an effective dose of 1milliSievert (mSv).

A review of the National Council on Radiation Protection and Measurements (International Commission on Radiation Protection, 2007) guideline for medical radiation facilities showed that a suitable source for shielding individuals in uncontrolled areas in or near medical radiation facilities will give an effective dose of 1mSv in any year. This recommendation can be achieved for medical radiation facilities with a weekly shielding design goal of 0.02mGy. The results from this study gave an effective dose of 0.13±0.0068mSv/week and 0.66 ±0.35mSv/year respectively and are within safe limits from the values of the same parameters by NCRP per week, and a year respectively.

Also, one can infer that recommended percentage (%) chance of developing cancer in a year, from the effective dose of 1mSv per year is 5.5x10^{-3}%, (NCRP, 1993), which states that 1mSv has a percentage chance of 55% (percent). The calculated value of the same parameter from this study is 2.33 x 10^{-3} % and is below the recommended percentage.

Conclusion

This study shows that persons within the uncontrolled areas around the diagnostic centers are safe as the results indicate that radiation exposure to such persons in the said areas is within safe limits.

Conflict of interest: None declared among the author's.

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