

Occupational Radiation Dose Evaluation in University of Maiduguri Teaching Hospital, Maiduguri, Nigeria

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Abstract: Radiation is energy that travels through space or matter in the form of a particle (alpha and beta) or wave (X-rays and gamma rays). X-ray transfers a certain amount of energy, which is dangerous, when interacts with the biological system. Recently, great attention has been paid to monitor and estimate the dose limits of public exposure to X-ray in order to be able to provide an appropriate protection of patients/workers. This study aimed to assess the exposures of the workers to X-ray through measuring (using Radiation Alert Monitor “4”) and sampling (using questionnaires) the X-ray within and outside the Radiology Unit, University of Maiduguri Teaching Hospital (UMTH). The result showed that the average radiation dose around Radiology Unit as 0.0225 mSv/y. This is negligible when compared with an effective dose equivalent 50 mSv/y for whole-body exposure recommended by International Commission on Radiation Protection and National Council on Radiological Protection recommendations. This implies that the radiation workers at the Radiology Unit were not at any risk of radiation related ailments because of their work. Questionnaire based on the Code of Practice of X-ray Radiation Workers were also administered to senior staff in the Unit. The information obtained revealed that not all the necessary radiation safety regulations were in practice in the Unit. Hence, the need for radiation safety checks in place. The results obtained from this study could be helpful in prevent the risks of radiation exposures that may involve workers in radiology unit.

Keywords: Radiation, X-ray, Alert Monitor, Exposure, Dose, Radiology, Maiduguri.

1 Introduction

Human beings have been inevitably exposed to natural radioactivity which contributes significantly to the environmental radiation doses received from water, ground, plants raised on fertilized soil, foods, building materials, building interiors, inhalation of rock and fertilizer dust, recycled industrial waste products, elements in their own bodies etc [1-4]. The radiations in the biosphere are attributed to the releases of man-made or Naturally Occurring Radioactive Materials (NORM) occurs during the regular operation of a plant, industrial or research accident, nuclear weapons test, crime, mining etc. Several modern industries, particularly in the areas of power production and medicine, involve radiations [5]. Radiation is energy that travels through space or matter in the form of a particle (alpha and beta) or wave (X-rays and gamma rays). It can be produced by radioactive decay of radionuclides or by the interaction of a particle with matter (Bremsstrahlung) [6].

Radiology has earned a vital place in modern medicine where it has become one of the most powerful and indispensable diagnostic tools. The use of ionizing radiation in medical field contributes significantly to the source of exposure of the population [7]. Despite the ionizing nature of X-ray, it has proved to be very useful in the service of humanity. It has been estimated that about 30% - 50% of critical medical decisions are based on X-ray examinations and if suitable precautions were employed, its harmful effects could be avoided or minimized [8-9]. Radiation varied from place to place and from time to time, both in intensity and in quality. Exposure to environmental radiations can be from external or internal sources, though the effects of the radiation on the body are independent of the origin [10-14]. When X-ray penetrates, it transfers a certain amount of energy that is very dangerous to biological system [15].

University of Maiduguri Teaching Hospital (UMTH) has specialists in various medical fields with availabilities of specialized modern diagnostic equipment/machines that carry out measurement and accommodate the influx of people

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either hospitalized or referred to it. Radiology Unit is one of the Departments where radio-diagnostic examinations are carried out using specialized machine normally equipped with safety devices to protect personnel/patients against radiation hazard.

Therefore, great attention has been paid to monitor release of radiation into the environment and estimate the dose limits of public exposure to radiation sources in order to be able to provide an appropriate protection of humans and livestock [16].

This study aimed to assess the exposures and the Principles of Radiation Protection Adherence of the workers to radiation through sampling and testing for radiation within and outside the Radiology Unit, University of Maiduguri Teaching Hospital (UMTH). The knowledge of the radiation dose received by the workers during the radiological examination can be beneficial as it prevent the risks of exposures that may involve workers in radiology unit, UMTH, in particular and to the people of the northeast sub-region of Nigeria in general.

2 Material and Methods

Radiation monitoring was conducted in the Radiology unit of UMTH. The monitoring was carried out within and around the entire Unit. A Geiger Mueller Counter instrument named "Radiation Alert Monitor 4" was employed for the evaluation.

2.1 Research Design

University of Maiduguri Teaching Hospital (UMTH), the Centre of Excellency for this study among other things because;

- i. As a referral Centre, the rate at which X-ray examinations are taken should be quite higher than that of any other hospital in Maiduguri metropolis.
- ii. It has the required facilities such as modern laboratories where daily radiological examinations are carried out
- iii. These exposed the workers, patients and the public to various radiations

2.2 Data Collection

Information was obtained from two-method approaches: One is the physical measurement of radiation exposure using Radiation Alert Monitor 4 and the other is the use of questionnaires which serves to selected staff members of the Radiology Department, UMTH that have direct connection with X-ray/radiological examinations.

2.3 Instrument of Data Collection

A Solid State Geiger Mueller Counter instrument known as Radiation Alert Monitor 4" was used for the research. To operate, install a fresh 9-volt alkaline battery (NEDA # 1604A or equivalent). The battery life is up to 2,000 hours at normal background radiation levels. The monitor senses ionizing radiation by means a Geiger-Mueller (GM) tube

with a thin mica end window (alpha window and alpha screen). The tube is fully enclosed inside the instrument. When a ray or particle of ionizing radiation strikes the tube, is sensed electronically and displayed by a flashing count light. When the switch is in the Audio position, the instrument will also beep with each ionizing even. About 5 to 25 counts at random intervals (depending on one's location and altitude) can be expected every minute from naturally occurring background radiation. In the $\times 1$ (times one) position, the meter reads from 0-500 CPM (Counts Per Minute). In the $\times 10$ position, the reading is multiplied by 10, indicating levels up to 5000 CPM). In the $\times 100$ position, the reading is multiplied by 100, indicating up to 50,000 CPM (approximately 2,500 times background levels). To ensure the range switch is in the appropriate position when using the instrument, the range switch was kept in the $\times 1$ position.

2.4 Method of Data Analysis

Radiation can be either scattered or absorbed when interacts with matter. The mechanisms of the absorption of radiation are of interest because it is the principle upon which detection of radiation is based and may cause injury in the body tissues. However, the degree of absorption is the primary factor in determining proper shielding requirements. Absorbed dose is a measure of the energy deposited in a material by any type of radiation. The SI unit for absorbed dose is the gray (Gy), equal to 1 joule/kg. 1 Gy = 100 rads. In radiation protection, the roentgen (R) which is often interchangeable with rads, is used to measure exposure only to x-ray or gamma radiations since they are approximately equal in tissue [6]. Dose measurements are required to comply with some international guidelines and regulations [16]. The radiation data acquired in counts per minute (CPM) are then converted to milli-Roentgen per hour ($1 \text{ CPM} = 10^{-3} \text{ mRh}^{-1}$).

The exposure rate per day is expressed (in mRh^{-1}) as below:

$$\text{Exposure rate/day} = \sum_{i=1}^n R_i \quad (1)$$

where n stands for number of hour per day (i.e. $n = 24$).

The daily time exposure is defined as the total sum for the time for each exposure.

$$\text{Daily time} = \sum_{i=1}^n t_i \quad (2)$$

The daily dose within or outside is found by taking the product of the two equations above.

$$\text{Daily time dose (DD)} = \sum_{i=1}^n R_i t_i \quad (3)$$

The weekly dose within and outside (WD) is the sum of the daily dose for the week.

$$\text{WD} = \sum_{i=1}^n DD_i \quad (4)$$

Here n stands for number of workday per week (i.e. $n = 5$). Then in one year (52 weeks), the annual dose is

$$AD = 52 \sum_{i=1}^n DD_i \quad (5)$$

2.5 Research Questions/Hypothesis

- i. Are the workers at any radiation risk?
- ii. Are there safety standards/regulations in place?

Hypothesis (HO) involves ideas regarding solution to the problem, which are intelligent guesses, which are yet to be subjected to some verification. It is used to give likely answers to questions.

Hypothesis for this research are as follows:

QO₁: workers are at radiation risk

QO₂: there are no proper protection measures in place

The study sought to substantiate the above claims.

3 Results and Discussion

The daily, weekly and yearly dose within and outside the Radiology Unit are calculated using equation (3), (4) and (5) and the results are presented in Table 1-3.

Table 1 showed the measured radiation doses for radiology workers in different location inside Radiology Unit. Table 1 showed that the measured radiation doses ranged from 0.0189 mSv/y to 0.0258 mSv/y, with mean annual dose value of 0.0229 mSv/y.

The measured radiation doses for radiology workers in different location outside Radiology Unit are presented in Table 2. The maximum value of radiation doses measured from Table 2 was 0.0206 mSv/y with the minimum radiation dose of 0.0271 mSv/y. The mean annual dose value of 0.0226 mSv/y was measured.

Table 3 showed that the maximum and minimum radiation doses measured from different location outside Radiology Unit are 0.0156 mSv/y and 0.0251 mSv/y respectively. The mean annual dose has the value 0.0218 mSv/y.

All the maximum values 0.0258 mSv/y, 0.0271 mSv/y and 0.0251 mSv/y recorded from Table 1, Table 2 and Table 3 respectively, are far below the dose limit recommended by International Commission on Radiation Protection [17] and National Council on Radiological Protection [18].

The information on the distribution of the annual effective dose (mSv/y) for radiation monitoring inside and outside

Table 1: The measured radiation doses for radiology workers in different location inside Radiology Unit

Location	No. of Counts	CPM	X-ray Dose			Dose (mRy ⁻¹)	Dose (mSv ⁻¹)
			μR_h^{-1}	μR_d^{-1}	μR_w^{-1}		
X-ray Lab	128	25.6	25.6	1.0667	5.3333	0.2773	0.0277
Lecture Lab	100	20.0	20.0	0.8333	4.1667	0.2167	0.0217
Ultrasonic Lab	119	23.8	23.8	0.9917	4.9585	0.2578	0.0258
Fluorescence Lab	104	20.8	20.8	0.8667	4.3333	0.2253	0.0225
Corridor	87	17.4	17.4	0.7250	3.6250	0.1885	0.0189
Reception	98	19.6	19.6	0.8167	4.0833	0.2123	0.0212
Mean Annual Dose						0.2297	0.0229

Table 2: The measured radiation doses for radiology workers in different location outside Radiology Unit

Location	No. of Counts	CPM	X-ray Dose			Dose (mRy ⁻¹)	Dose (mSv ⁻¹)
			μR_h^{-1}	μR_d^{-1}	μR_w^{-1}		
Window 1	95	19	19	0.7917	3.9583	0.2058	0.0206
Window 2	100	20	20	0.8333	4.1667	0.2167	0.0217
Window 3	95	19	19	0.7917	3.9583	0.2058	0.0206
Window 4	105	21	21	0.8750	4.3750	0.2275	0.0228
Window 5	105	21	21	0.8750	4.3750	0.2275	0.0228
Window 6	125	25	25	1.0417	5.2083	0.2708	0.0271
Mean Annual Dose						0.2257	0.0226

Table 3: The measured radiation doses for radiology workers in different location outside Radiology Unit

Location	No. of Counts	CPM	X-ray Dose			Dose (mRy ⁻¹)	Dose (mSv ⁻¹)
			μR_h^{-1}	μR_d^{-1}	μR_w^{-1}		
Window (HOD)	72	14.4	14.4	0.6000	3.0000	0.1560	0.0156
Window (Dr.)	103	20.6	20.6	0.8583	4.2917	0.2230	0.0223
Window (Dr.)	116	23.3	23.2	0.9667	4.8333	0.2513	0.0251
Lecture Lab	83	16.6	16.6	0.6917	4.4583	0.1798	0.0179
X-ray Lab	127	25.4	25.4	1.0583	5.2917	0.2750	0.0275
Within X-ray Lab	103	20.6	20.6	0.8583	4.2915	0.2230	0.0223
Mean Annual Dose						0.2180	0.0218

the radiology Unit presented in Tables 1-3 are further extended by plotting a charts shown in Figure 1-3.

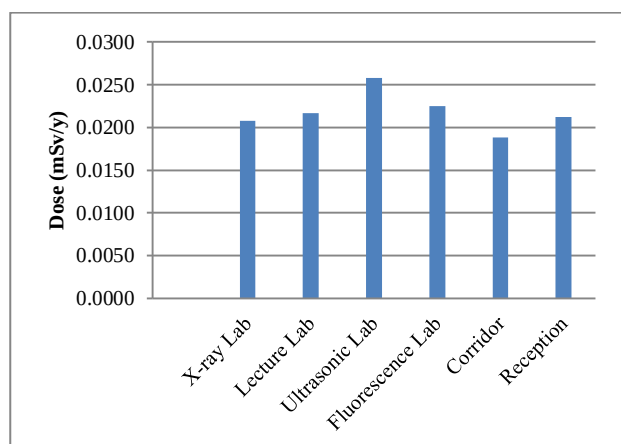


Fig. 1: Distribution of the annual effective dose (mSv/y) for radiation monitoring inside the radiology Unit

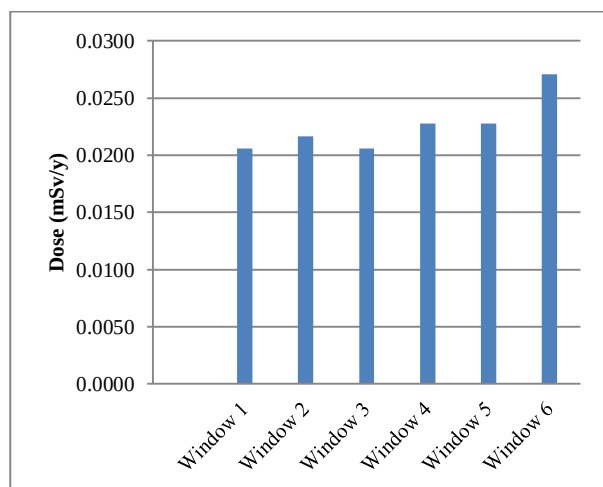


Fig. 2: Distribution of the annual effective dose (mSv/y) for radiation monitoring outside the radiology Unit

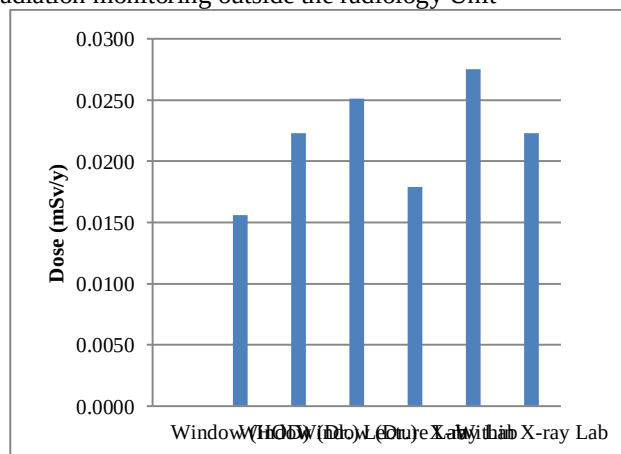


Fig. 3: Distribution of the annual effective dose (mSv/y) for radiation monitoring outside the radiology Unit

The Figure 1-3 pictorially compared the measured radiation doses for radiology workers in different location inside Radiology Unit.

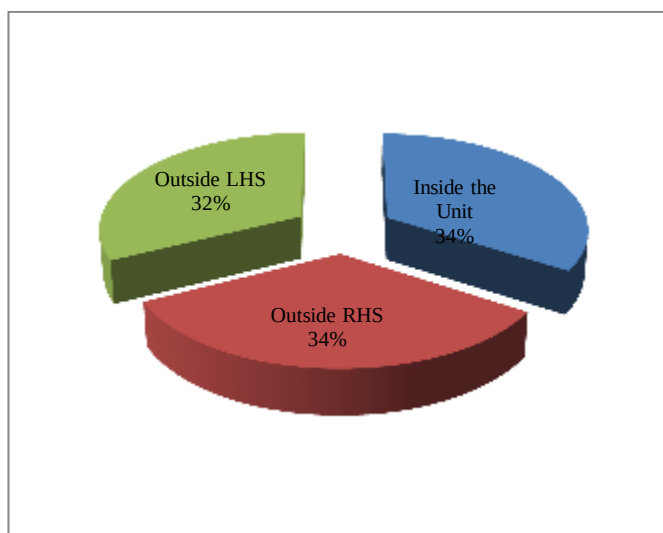


Fig. 4: Contribution of each location to total radiation inside and outside the Radiology Unit

Figure 4 showed the graphical representation of the mean annual dose of 0.0229 mSv/y, 0.0226 mSv/y and 0.0218 mSv/y, recorded from Tale 1, Table 2 and Table 3, respectively. The average radiation dose around Radiology Unit is therefore 0.0225 mSv/y.

The study has revealed that radiation monitoring within and around the surrounding area of the Radiology Unit were far less than 50 mSv/y, the limit impose dose for an X-ray worker and an effective dose equivalent of approximately 3.60 mSv (whole-body exposure) per year from all sources [19]. This means that radiation workers at UMTH are not at any radiation risks from exposures within and outside the surrounding area of the Radiology Unit. The radiation exposure does not contribute to the increase of radiation intensity of the environment and UMTH in general.

The low doses can be attributed to the large number of operations were made with light X-ray, hence the exposure of very low X-ray energies. This type of X-ray diagnostic is used for chest, legs, hands and children. The intensity of radiation is 0.65 – 0.74 mAs. Another aspect explaining this low dose is due to the design of machine. The X-ray machine got itself protection. Tube heads with protection up to ICRP Standards is incorporated. Thus, radiation comes in one direction, always incident on the patient only in contact with patient that radiation scattering occur. The most important factor for these low doses is based on the structural aspects of the X-ray rooms designed to keep all doses to the staff and patients. However, when the walls and the protective control are shielded, the surrounding area and the staff behind the control panel are protected against the scattered radiations.

Furthermore, the researcher has attempted through data collected to proffer solutions to questions asked and the analysis made as per the responses of the respondents on the questionnaires served. Personal data of the respondents such as sex, field of specialization, age, working experience, daily duration of work and nature of job are shown in Table 4. Table 4 shows that from a total of eight (8) respondents, three (3) specialized in Radiology, two (2) specialized in Radiography, one in Radiology/Radiotherapy, one in Radiography/Management and one failed to indicate his specialty. Two had ages (in years) above 45, four of them had ages ranged between 41-45, one each had age between 36-40 and 31-35 respectively and had a varying working experiences (in years); with the highest being forty-nine (49), followed by thirty one (31), twenty three (23), fourteen (14),

Three had nine each (9) and the least is seven (7). Their average daily working duration is 8 hours.

Table 5 gives information on the respondent's radiation protection adequacy. They do not use any personnel monitoring (PM) such as dosimeter, film badges; TLDs, etc. All indicated possessing protective clothing (PC). However, they do not have radiation protection supervisors.

Environmental radiation protection of the Radiology Unit is shown in Table 6 below. This shows that all the diagnostic rooms are shielded, nevertheless; there is the absence of the radiation survey to verify radiation leakage around the diagnostic rooms. In addition, they do not have radiation protection supervisors.

Table 4: Number of radiation workers monitored in Radiology Unit.

No. of respondents		Field of Specialization			Age (Yrs)				Professional Experience (yrs)			Work Duration Period (h/d)	Employed as an X-ray Worker
Male	Female	Radiology	Radiography	Others	31-35	36-40	41-45	> 45	< 20	< 30	> 45		
8	0	3	2	3	1	1	4	2	5	2	1	4	8

Table 5: Respondent's Radiation Protection.

No. of Respondents		Personnel Monitoring (PM)		Protective Clothing (PC)		Cubicles up to ICRP Standard		Aware of Limit Impose Dose	Having Radiation Supervisor
Male	Female	No. with PM	No. without PM	Examined	Not Examined	Yes	No		
8	0	0	8	1	7	6	2	8	0

Table 6: Environmental Radiation Protection.

No. of Respondents		No. of Shielded X-ray Room (by lead and concrete wall)	Radiation Survey (RS)		Having Radiation Supervisor
Male	Female		Exercising RS	Not Exercising RS	
8	0	8	0	8	0

Information from respondents revealed that not all the necessary radiation safety regulations were in practice such as using the personnel monitoring examination of protective clothing, etc. The absence of using personnel monitoring is contrary to the Universal Principles of X-ray worker/radiographer. The personnel monitoring (dosimeters, film badges, TLDs etc) are generally used for exposure control. That is, dose to personnel should be controlled and kept within established limit.

Table 7 showed a comparison of the mean annual dose in the Radiology Unit, University of Maiduguri Teaching Hospital with that of other countries of the world and with world.

Table 7: Comparison of the mean annual dose in the Radiology Unit, UMTH with that of other countries of the world and with world UNSCEAR data [20-21]

Country	Diagnostic radiology	Nuclear medicine	Radiotherapy
Australia	0.19	0.75	0.35
Brazil	2.58	3.50	3.95
Canada	0.35	1.96	0.80
Greece	3.86	2.27	2.00
Indonesia	1.75	1.20	1.63
India	0.42	1.36	1.34
Syria	4.40	3.16	1.37

Thailand	0.58	2.89	1.05
China	1.85	1.40	1.25
Lithuania	1.48	1.14	1.51
Pakistan	1.47	1.55	1.17
Kingdom of Saudi Arabia	0.66	1.56	0.28
Nigeria (Present Work)	0.02	-	0.02
UNSCEAR	1.34	1.41	1.33

4 Conclusions

This study revealed that the average radiation dose around Radiology Unit as 0.0225 mSv/y. This is negligible when compared with an effective dose equivalent of approximately 20 mSv/y for whole-body exposure and it is insignificant to pose any serious detrimental health effects to the workers in the Radiology Unit as recommended by the international commission on Radiological Protection. Therefore, the workers are not at any radiation risk due to their work. It is nevertheless desirable to limit the exposure of workers to the minimum value consistent with the medical requirements.

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