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Assessment of Radiation Leakage from Diagnostic Rooms of Radiology Department of a Teaching Hospital in Kano, Northwestern Nigeria

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ABSTRACT

Diagnostic x-radiation is an essential part of present-day medical practice being the largest contributor of irradiation to the general population. Therefore, routine checking of x-ray tubes leakage is very important to ensure that leakage radiation at a one-meter distance from focus is less than 1mR/h. The measurement of background radiation was performed during normal departmental working hours: early in the morning before the machines were switched on, and after the machines were switched on. Exposures were performed using different exposure factors and the fall out radiation in both control and uncontrolled areas were also recorded. The highest equivalent dose rate was recorded in the uncontrolled area of room 2, where the mean dose rate was 26.21 µSv/h (in changing room) and 11.67 µSv/h (behind the door), respectively. It follows the dose rate measured in the uncontrolled area of room 1, where the mean dose rate was 6.33 µSv/h (behind the door), 2.96 µSv/h (in changing room B), and 1.56 µSv/h (in changing room A), respectively. The lowest radiation dose was measured in both controlled and uncontrolled areas of CT-scan, where the mean dose rate was 0.17 µSv/h and 0.16 µSv/h, respectively, simply because the room doors and wall are adequately lead-lined and protected. All values obtained in this study are within the permissible limit, except that for uncontrolled areas in x-ray rooms 1 and 2, where radiation dose rates were higher than the reference limit for public exposure.

KEYWORDS

Radiation, X-ray, Leakage, Effective Dose, Controlled area, Uncontrolled Area.

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INTRODUCTION

The application of ionizing radiation in medicine has greatly improved human health preservation through the diagnosis and treatment of diseases. Ionizing radiation also has wide applications in industries, agriculture, environmental monitoring, and water resources management and therefore forming an important tool for mankind **(Kiragga, 2018).** The largest contributor of irradiation to the general population comes from the diagnostic x-radiation. Although individual irradiations are usually low, there is a concern of possible excess cancer risk when large populations are irradiated. Unnecessary irradiations to patients from radiological procedures can be significantly reduced with rather small or no decrease in the value of medical diagnostic information. This can be achieved by using well-designed x-ray equipment which is installed, used, and maintained by trained personnel, and by adopting standardized procedures **(Chaloner, 1994).** It cannot be ignored that the diagnostic x-ray procedures contribute to maximum population dose as compared to other man-made radiation sources. Therefore, the x-ray beam must be constricted to outside (both controlled and uncontrolled areas) of x-ray departments by protecting them with high shielding materials, such as lead **(Bari *et al*., 2015).**

Since the discovery of radiation, more than a century of radiation research has yielded extensive information on the biological mechanisms by which radiation can affect health. It is known that radiation can produce effects at the cellular level, causing their death or modification usually because of direct damage to deoxyribonucleic acid (DNA) strands in a chromosome. Based on their occurrence observation, health effects following a radiation exposure are defined here as either early or delayed health effects. Generally, early health effects are evident through the diagnosis of clinical syndromes in individuals, and delayed health effects, such as cancer, through epidemiological studies by observation of the increased occurrence of pathology in a considered population **(UNEP, 2016).**

The routine checking of x-ray tubes, diaphragm assemblies, and cones over several years has frequently revealed gross leaks of radiation. These have been due to the omission or shifting of the lead protection in the tube housing, or to the incorrect alignment of the diaphragm and cone assembly, or the use of materials of inadequate protective value **(Ardran & Kemp, 1956). The** Monitoring of radiation doses received by staff in the radiology department is of great importance **(Okaro *et al*., 2010).** The purpose of a radiation monitoring program is to identify all sources of radiation exposure within an operation so that timely detection of changes in radiation parameters which may lead to increase the exposures and to produce sufficient information for optimization purpose **(Samer *et al*., 2014).**

Based on International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA) recommendations for the annual limit of effective dose to members of the general public that are in uncontrolled areas such as patients, visitors to the facility, and employees who do not work routinely with radiation sources, shielding designs should limit exposure to an effective dose that does not exceed 1 mSv per single year. Radiologists are occupationally exposed to a low level of ionizing radiation during normal working. However, the dose level should not exceed 1mSv in a single year, with the maximum possible limit of 20 mSv per year. As the dose level exceeds the specified limit, the probability of occurring cytogenetic abnormalities and fatal cancer risk for the clinical staff performing diagnostic procedures would increase **(Bari *et al*., 2015).**

As a result of radiological examinations, the exposure of radiation workers and the public due to scattered and leakage radiation is always increasing. Currently, there is no study conducted on the assessment of radiation leakage in the radiology department of Aminu Kano Teaching Hospital, from Kano, Northwestern Nigeria. Hence, there is a need to survey to ensure that the amount of leakage radiation from the x-ray tube and the annual exposure limit to both radiation workers and members of the public coming to the department is within the permissible limit recommended by the ICRP.

MATERIALS AND METHODS

A prospective cross-sectional study was carried out between June 2019 to November 2019 using a radiation survey meter. The background radiation of all the radio-diagnostic rooms in the radiology department of Aminu Kano Teaching Hospital was measured, which includes: Three-conventional x-ray machines (Two located at the main new radiology complex and one at the old radiology complex), one-ceiling mounted x-ray machine (located at the accident and emergency complex), one-digital radiography machine (DR), one-mammography machine, one-angiography machine, two-fluoroscopy machines (one at the new radiology complex and the other at Abdullahi Bayero complex, (ERCP) and 2-CT scans. However, one CT scanner is located at the main radiology complex, and the other (New CT) is located at Muhammadu Sunusi Radiodiagnostics, (MRSD)Complex. However, the design and layout of the old radiology complex, Accident and emergency unit, MRSD complex, ERCP were not captured in figure 1.

The study was conducted during normal departmental working hours. Early in the morning, before the machines were switched on, and after the machines were switched on, exposures were performed, and the fall out radiation was also recorded. The equivalent radiation dose rate was measured in specific locations selected according to rooms design as indicated in figure 1. These locations include: dose at one-meter distance from the x-ray tube, control panel, changing room, just behind the door and at the corridor outside the x-ray room (door closed). Three different exposure factors, for the most commonly anatomical structures examined in each unit were selected. For instance, in conventional x-ray room A, the factors selected were 110 peak kilovoltage, (kVp) on 25 milliampere second (mAs), 75 kVp on 12.5 mAs and 60 kVp on 4 mAs, which represent the exposure factors for lumbosacral, chest and extremities examination, respectively.

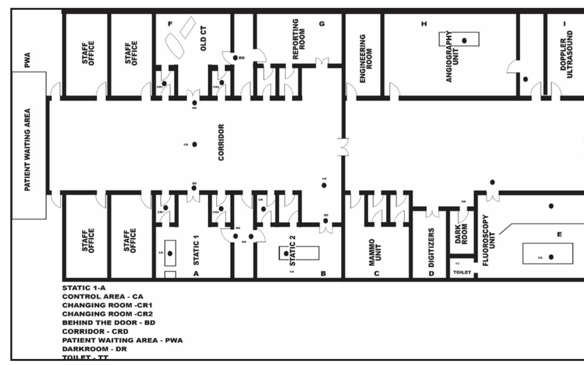

Fig. (1): Design and layout of the radiology department.

The radiation dose was monitored using a portable dosimeter, namely Thermo scientific FH 40 G Multi-purpose digital survey meter. The device is a wide range digital Geiger counter suitable for nearly all measurement tasks arising in radiation protection through optional plug and play probes available for neutron measurement, alpha and beta contamination reading and even to detect artificial gamma and x-rays. Therefore, it was suitable for the current survey to detect and measure secondary radiation from x-ray at the control area, exact position of working radiographers, and uncontrolled area such as patient waiting area, changing room, dark room/digitizer and radiographer's office. Data recorded were analyzed using statistical package social sciences (SPSS), version 23.0, and the mean average exposure, standard deviation values were obtained.

RESULTS AND DISCUSSION

The various dose rate measured for different designated diagnostic rooms based on control area (CA), changing room one (CR1), changing room two (CR2), Behind the door (BD), Corridor (CRD), patient waiting Area (PWA), Darkroom (DR), Toilet (T) for different exposure factors were presented in tables below.

Table 1 below shows the dose rate values for location A (Static 1) when machine is operated at 60 kVp on 4 mAs, 75kVp on 12.5 mAs and 110 kVp on 25 mAs respectively.

Table (1) : *Dose rate values measured for diagnostic room A.*

STATIC 1	MEASURED DOSE RATE (µSv/h)			MEAN ± SD
	60 kVp,4 mAs	75kVp ,12.5 mAs	110 kVp on 25 mAs	
Control Area	0.18	0.18	0.56	0.31 ± 0.22
Changing Room (1)	0.19	0.19	4.30	1.56 ± 2.37
Changing Room (2)	0.19	0.28	8.40	2.96 ± 4.71
Behind the Door	0.50	5.50	13.20	6.33 ± 6.41
Corridor	0.27	0.29	0.98	0.34 ± 0.10

Table 2 below shows the dose rate values for location B when machine is operated at fixed 200 mA on 70 kVp 6 ms, 102 kVp 12 ms, and 133 kVp 32 ms respectively.

Table (2) : *Dose rate values for Diagnostic room B.*

STATIC 2	MESURED DOSE RATE (µSv/h)			MEAN ± SD
	70 kVp, 6 ms	102 kVp, 12 ms	133 kVp, 32ms	
Control Area	0.18	0.20	0.23	0.20 ± 0.03
Changing Room	16.40	23.54	38.70	26.21 ± 11.39
Behind the Door	0.21	13.01	21.80	11.67 ± 10.86
Corridor	0.20	0.58	0.61	0.46 ± 0.23

Table 3 below shows the dose rate values for Muhammadu Sunusi Radiodiagnostic Complex (new CT) when the machine is operated at 120 kVp on 125 mAs, 100kVp on 166 mAs and 100 kVp on 225 mAs respectively.

Table (3) : *Dose rate values for MSRD COMPLEX (new CT).*

MSRD COMPLEX (new CT)	MESURED DOSE RATE (µSv/h)			MEAN ± SD
	120 kVp, 125 mAs	100kVp, 166 mAs	100 kVp, 225 mAs	
Control Area	0.16	0.17	0.18	0.17 ± 0.01
Changing Room	0.16	0.17	0.17	0.17 ± 0.01
Behind the Door	0.15	0.15	0.17	0.16 ± 0.01
Patient Waiting Area	0.15	0.15	0.16	0.16 ± 0.01

Table 4 below shows the dose rate values for different locations within the Accident and emergency unit when the machine is operated at fixed 200 mA on 50 kVp 0.2 s, 70 kVp 0.3 s, and 90 kVp 0.4 s respectively.

Table (4) : *Dose rate values for Accident and Emergency Unit.*

Accident & Emergency unit	MEASURED DOSE RATE (µSv/h)			MEAN ± SD
	50 kVp 0.2 s	70 kVp 0.3 s	90 kVp 0.4 s	
Control Area	0.81	3.36	4.94	3.04 ± 2.08
Dark Room	0.15	0.16	0.23	0.18 ± 0.04
Toilet	0.17	0.23	0.32	0.24 ± 0.08
Call Room	0.16	0.16	0.18	0.17 ± 0.01
Behind the Door	0.14	0.14	0.15	0.14 ± 0.01

Table 5 below shows the dose rate values for old radiology complex for different locations when machine is operated at fixed 200 mA on 70 kVp 0.2s, 80 kVp 0.4s, and 90 kVp 0.6s respectively.

Table (5) : *Dose rate values for Old radiology Complex.*

OLD RADIOLOGY COMPLEX	MEASURED DOSE RATE (µSv/h)			MEAN ± SD
	70 kVp 0.2 s	80 kVp 0.4 s	90 kVp 0.6 s	
Control Area	0.19	0.37	0.87	0.48 ± 0.35
Changing Room	0.17	0.22	0.23	0.21 ± 0.03
Dark Room	0.17	0.20	0.33	0.23 ± 0.09
Behind the Door	0.15	0.16	0.19	0.17 ± 0.02
Patient Waiting Area	0.15	0.15	0.17	0.16 ± 0.01

Table 6 below shows the dose rate values for Abdullahi Bayero, Endoscopic retrograde cholangiopancreatography, (ERCP) when machine is operated at 68 kVp on 3.2 mAs, 70kVp on 6.4 mAs and 75 kVp on 75 mAs respectively.

Table (6) : *Dose rate values for ERCP Unit.*

ERCP UNIT	MEASURED DOSE RATE (µSv/h)			MEAN ± SD
	68 kVp, 3.2 mAs	70kVp, 6.4 mAs	75 kVp, 75 mAs	
Control Area	0.18	0.20	0.22	0.20 ± 0.02
Toilet	0.19	0.23	0.25	0.22 ± 0.03
Behind the Door	0.17	0.18	0.19	0.18 ± 0.01
Patient Waiting Area	0.15	0.15	0.17	0.16 ± 0.01

From table 1, for exposures factors (60 KVp and

Table (7) : *X-ray Tube Leakage at One-Meter Distance in each Radio-Diagnostic Room.*

Location	Static 1 (μSv/h)	Static 2 (μSv/h)	New CT (μSv/h)	A&E (μSv/h)	Old Site (μSv/h)	ERCP (μSv/h)
Tube leakage	8.24	13.96	**	0.24	5.33	0.16

4 mAs and 75kVp on12.5 mAs), protected cubicle and changing room (2) have lowest radiation dose rates, while the changing room (1), corridor and just behind the door have higher radiation dose. At exposure of (110 kVp on 25 mAs) only protected cubicle has the lowest radiation dose rate, which might be due to distance of this place from the x-ray source, as well as to the efficiency of the lead-lining of the area. The radiation dose rate is the highest being 3 times higher comparatively with that measured for changing room 1, and almost 2 times higher versus the one measured for changing room 2 which might be due to their closeness to the x-ray source and probably some defects in a lead lining which protect the areas. When compared to other results from the literatures, it was found that the findings of this study are similar to those obtained by **(Bari *et al.,* 2015), (Samer *et al.*, 2014), and (Malimban *et al.*, 2018)**. The findings of our study contradict those obtained by **(Owusu *et al.*, 2018)**.

From table 2, for exposure factors (200 mA on 70kVp 6 ms), protected cubicle has the lowest radiation dose, which is at the level of background radiation. Dose rate just behind the main door and on corridor are slightly higher than the background radiation, while changing room has very high radiation dose. At this energy (200 mA on 102 kVp 12ms and 200 mA on 133 kVp 32 ms), dose rate in control cubicle is slightly higher than the background radiation but still within the acceptable limit, this is mainly due to distance of this place from the x-ray source as well as the design of the x-ray room. Changing room, just behind the door and corridor has very high radiation dose which is due to their closeness to the x-ray source and most likely some defects in the shielding material protecting the areas.

These findings are similar to those obtained in the studies conducted by **(Bari *et al.,* 2015), (Samer *et al.*, 2014), and (Malimban *et al.*, 2018)**. The study results contradict those of the study conducted by **(Owusu *et al.*, 2018)**.

From table 3 , at all considered exposure factors (120 kVp on 125 mAs, 100kVp on 166 mAs, and 100 kVp on 225 mAs), no radiation leakage was detected, as all the values recorded were within the level of background radiation. The reason may be the distance of these places from the x-ray machine, as well as the design of the x-ray room itself. This clearly showed that the CT Scan room is well designed and built, according to radiation protection criteria. These findings are similar to those of the study conducted by **(Owusu *et al.*, 2018)**, But they contradict the results obtained in the studies conducted by **(Bari *et al.,* 2015), (Samer *et al.*, 2014), and (Malimban *et al.*, 2018)**.

Table 4 shows that, for exposure factors (200 mA on 50 kVp 0.2 s and 200 mA on 70 kVp 0.3 s), dark room, toilet, call room and just behind the door have the lowest radiation dose, which is within the level of background radiation, probably due to the low factors selected. Dose rate in the control cubicle slightly rises, might be probably due to some defects/ inefficiency in the shielding material protecting this area. At this energy level (300 mA on 90 kVp 0.4 s), dose rate in call room and just behind the door are still low (within the level of background radiation), may be due to the distance from the x-ray sources, as well as to the efficiency of the lead material used in the wall or door of these areas. However, very high radiation dose was recorded in toilet and control cubicle, simply due to inefficiency of lead material lining the areas. It was found that the findings of this study are similar to those of the studies conducted by **(Bari *et al.,* 2015), (Samer *et al.*, 2014), and (Malimban *et al.*, 2018)**, and contradict the results obtained in the study conducted by **(Owusu *et al.*, 2018).**

From table 5, for exposure factors (200 mA on 70 kVp 0.2 s), no leakage radiation was detected, all the radiation dose values being within the level of background radiation, might be due to the low factors selected. for exposures done at (200 mA on 80 kVp 0.4 s), the dose rate in patient waiting area and just behind the door are still within the level of background radiation, which may be due to distance of these areas from the x-ray machine, as well as to the efficiency of lead material used in walls or doors of the room. Dose rate measured in the changing room and dark room rises slightly comparatively with the background radiation, while the protected cubicle has the highest dose rate (nearly double) due to it closeness to the x-ray sources and some defect in the protective shielding. At this energy (200 mA on 90 kVp 0.6 s), patient waiting area and just behind the door locations have the lowest dose, while changing room, dark room and protected cubicle has higher radiation dose rate compared to background radiation. The findings of this study are similar to those of the studies conducted by **(Bari *et al.,* 2015), (Samer *et al.,* 2014), and (Malimban *et al.*, 2018)**, and contradict the results of the study conducted by **Owusu *et al*. (2018)**.

Also, for table 6, for exposures done at (68 kVp on 3.2 mAs), no leakage radiation was detected, all the radiation dose rate values recorded being within the level of background radiation, may be due to the low factors selected. At exposure of (70kVp on 6.4 mAs), radiation dose rate at patient waiting area and just behind the door are still within the level of background radiation, which may be due to the low factors selected. The dose rate in toilet and protected cubicle rises slightly comparatively with the background radiation. At exposure of (75 kVp on 75 mAs), patient waiting area have the lowest dose rate, which is within the level of background radiation; this might be due to the low factors selected for the fluoroscopy machine. Even though the factors selected are low, dose rate in protected cubicle, toilet and just behind the door are slightly higher than the background radiation, these results indicating that the door leads to the room, toilet and protected cubicle were not efficiently lead lined. These findings are similar to those of the study conducted by **(Owusu *et al.*, 2018),** but contradict the results obtained in the studies conducted by **(Bari *et al.,* 2015), (Samer *et al.*, 2014), and (Malimban *et al.*, 2018).**

Generally, the similarity and variation in the aforementioned findings with other results obtained in other studies might be likely due to distance of the radiation source from the control and uncontrolled areas, structure of radio-diagnostic facility itself and most likely due to adequate shielding of the diagnostics rooms design.

Table 7 shows the result of x-ray tube leakage in all the unit except the new CT scan machine which was not assessed due to complex operating protocol of the installation. The result indicated that there was no tube leakage recorded in A&E and ERCP radio-diagnostic machines, showing that the tube housing in these machines are well lead-lined, designed and may result in low radiation dose at different location in these rooms. Also, tube leakage in old site, static 1, and static 2 are much higher but still within reference level, this may be due to the omission or shifting of the lead protection in the tube housing, or incorrect alignment of the diaphragm and cone assembly, resulting in high radiation dose rate measured at various locations in these rooms.

Considering all the radio-diagnostic rooms, higher equivalent radiation dose was recorded in changing room and just behind the door of the static 2 locations, the values being 26.21 μSv/h and 11.67 μSv/h, respectively. It follows the radiation dose rates measured just behind the door, changing room

(B) and changing room (A) of static 1, with values of 11.67 µSv/h, 2.96 µSv/h and 1.56 µSv/h, respectively. A higher effective dose rate was also found in the control cubicle of A&E room (4.94 µSv/h), may be due to inefficiency in the protected shielding of the area. The lowest equivalent dose rate was measured in the patient waiting area, just behind the door, changing room and protected cubicle of the CT-scan location, the values being 0.16 µSv/h, 0.16 µSv/h, 0.17 µSv/h and 0.17µSv/h, respectively; the reason is simply because the doors and walls of the room are adequately lead lined, protected and the distance from the machine.

In summary, the study findings give adequate quality control information to radiographers, medical physicists or service engineers and can be used as a guide to perform more comprehensive monitoring procedures to ensure that all radio-diagnostic facilities are functioning more effectively.

CONCLUSION

The radiation tube leakage for all the assessed diagnostic rooms were within the reference level, permissible limit and recommended limit for public exposure and radiation workers. Hence the need to carry out quality control test for tube leakage in order to identified which part of the tube housing more radiation penetrate so that corrective measures can be taken. No conflict of interest.

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