International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 2 Feb. 2023, pp: 776-781 www.ijaem.net ISSN: 2395-5252

Analysis of Protective Shielding Parameters for Diagnostic X-Ray Rooms in Some Selected Hospitals in Kogi State, North Central Nigeria.

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Date of Submission: 15-02-2023 Date of Acceptance: 25-02-2023

ABSTRACT
The analysis of protective shielding parameters of diagnostic X-ray units at Federal Medical Center Lokoja, Kogi State Specialist Hospital, Lokoja and General Hospital Okene, have been carried out using a radiation meter (inspector Exp). Operating potential, workload and use factors of each diagnostic X-ray machine have been evaluated and used for the determination of primary and secondary structural shielding parameters. The primary and secondary protective barriers for General Hospital Okene, Kogi State Specialist Hospital, Lokoja and Federal Medical Center Lokoja are found to be 11.0 ± 0.11 x 10^1mm and 9.0 ± 9 x 10^{-2}mm, 6.0 ± 6.0 x10^{-1}mm and 6.0 ± 6.0 x 10^{-2}mm and 7.0 ± 7.0x10^{-1}mm and 6.0 ± 6.0 x 10^{-2}mm respectively. These results show that the wall thickness around the X-ray rooms at General Hospital Okene (300 ± 3.0 x10^{-1}mm) and Federal Medical Center Lokoja (300 ± 3.0 x 10^{-1}mm) and at Kogi State Specialist Hospital, Lokoja (270 ± 2.7 x10^{-1}mm) are seen to be adequate as protective structural shield when compared with International recommended standard value of 74 ± 7.4 x10^{-1}mm even for the highest peak voltage of 150kVp.
Key Words: X-ray, Shield, Protective shielding parameters, Diagnostic X-ray rooms.

I. INTRODUCTION:

The discovery of X-ray by Wilhem C. Roentgen in the year 1895, stood as a major achievement in the Science of medical practice and the beginning of the study of medical and industrial Physics. X-rays are produced in X-ray tubes and this is achieved when electrons produced by thermionic emission from tungsten filament are accelerated across a high potential difference collide with a target (Awodele&Okunade, 2001). In an X-ray machine, sufficient intensity of electron flow when high voltage power supply of 50KVp is applied producing diagnostic X-rays for clinical diagnosis and treatment. Clinical examination are normally performed at about 50 - 60KVp. Abdominal and chest examinations are normally performed at about 70 – 80KVp and 100KVp (Benjamin, 2002).

Though diagnostic X-rays serve as a powerful tool in medical practice for diagnostic and therapeutic purposes. It exposure represents the greatest manmade contribution to the collective dose imparted to the population. It is generally assumed that medical exposure equals approximately half the exposure from the natural sources of ionizing radiation. It is generally considered that its exposure equals approximately half the exposure from the natural sources of ionizing radiation. It is generally known that over exposure to X-rays is capable of producing various damaging health effects and even death at higher exposure levels. There is therefore a need to minimize its exposures. External radiation in radiology can be reduced by limiting the duration of exposure, increasing distance between source and patients and placing a shielding material between the radiation source and the patients (Cember& Johnson, 2009). Since X-ray radiation exposure from X-ray machines is considered as an external radiation, it can easily be minimized using source and structural shielding in and around diagnostic and therapeutic X-ray rooms. This work is therefore aimed at determining the shielding parameters of diagnostic X-ray rooms in some hospitals in Kogi state, with a view to determine the adequacy or other wise of the primary and secondary protective shielding of the X-ray rooms.

Basic Theoretical Consideration

The physical parameters that determine the primary and secondary structural shielding of X-ray radiology rooms include; workload, use factor, operating potential and occupancy factor. These parameters are related by the equation (1) below (Zuk, 2002).

$$K = \frac{Pd^2}{WUT} \dots\dots\dots\dots\dots\dots\dots\dots\dots . (1)$$

Where K is the exposure per unit workload at unit exposure, P IS the maximum permissible exposure in R/week for the controlled area, d is the distance (m) from the target to the primary area, W is the workload (mA –min /week), T is the occupancy factor, and U is the use factor.

Workload is the amount of X-rays emitted per week and is expressed in mA-min/week.

Occupancy factor (T) is the fraction of time that a maximally present individual is present in the area while the beam is on and the barrier protecting the area is being irradiated. Use factor (U) is the fraction of primary beam workload that is directed to a particular barrier. Operating potentials (kVp), is the value in kilovolts of the potential difference of the pulsating X-ray generator (Akodele and okunade, 2001).

Problem Statement/Justification

It is generally known that over exposure to X-rays is capable of producing various damaging health effects and even death at higher exposure levels. Many patients that patronize the X-ray facilities in the state lack the adequate knowledge of the health implications of the over exposure to the radiation from the X-ray machines. Even most of the hospitals that have installed this machine within their premises do not follow some technical safety precautions needed for its construction. Therefore there is need to take some radiation measurements around the X-ray machines in some selected hospitals to ensure the safety of the users and people living around the machine.

Objectives of the study

The research proposal aimed at:

i. Determining the shielding parameters of diagnostic X-ray rooms in some hospitals in Kogi state, with a view to determine the adequacy or other wise of the primary and secondary protective shielding of the X-ray rooms.

II. LITERATURE REVIEW

It is common knowledge that medical exposure procedures such as diagnostic radiology, nuclear medicine, and radiotherapy remain the largest source of man-made exposure to ionizing radiation (Stephen, 2012). This makes the role of quality assurance (QA), an important tool in medical exposure procedures, especially a center-based QA program developed and supervised by a medical physicist who is qualified in this area of expertise by education, training, and experience. The medical physicist offers professional guidance to the technologists and other staff to execute the program

The focus is on X-ray diagnostic radiology since it is the commonest mode of medical exposure in Nigeria compared to nuclear medicine and radiotherapy procedures. Worthy of note is the fact that most of the issues under consideration are similar conditions in many developing countries. And the fact that X-ray generators at a controlled high voltage between cathode and anode, and a controlled current to the cathode produce maximum X-ray; thus, changing both the current (mAs setting) and the high voltage (kVp setting) will alter the output of the X-ray tube thereby bringing human expertise to play in radiation exposure to the patient.

The main goal of any diagnostic quality assurance program is to reduce radiation doses to patients; staff and the public to as low as reasonably achievable (ALARA) while still maintaining high-quality diagnostic images of patients (IAEA 1990). This can be achieved using an adequate diagnostic QC program involving periodic checks of all major components in the respective diagnostic imaging and optimum QA program for any individual diagnostic facility.

Quality assurance actions include both quality control (QC) techniques and quality administration procedures. QC is normally part of the QA program and quality control techniques are those techniques used in the monitoring (or testing) and maintenance of the technical elements or components of an X-ray system. Due to the expansion of diagnostic imaging procedures in medicine coupled with rapid technological advances, the availability of qualified and trained personnel is crucial if the desired quality is to be achieved (Stephen et al, 2012).

In Nigeria, the Nigeria Nuclear Regulatory Authority (NNRA) has the mandate to supervise all QA activities in the country. This body has some guidelines on the minimum instrumentation requirements for all imaging modalities, personnel training requirements, etc. Nevertheless, a good QA program (guidelines) is not a guarantee for the assurance of the radiation safety of patients, staff, and the public without

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implementation. What is urgently needed is an in-house radiation safety program, which is very essential in every diagnostic imaging facility and must also be under the direction of a qualified expert in radiation protection.

This paper seeks to assess the compliance level to the various components of quality assurance of the selected diagnostic radiology department. The results of which will serve as a benchmark to the X-ray technicians/radiographers and also assist NNRA to carry out their oversight function to ensure compliance with the Basis Safety Standard (BSS) in the use of radiation facilities and achieve safe use of radiation in Nigeria.

X-ray System

The second most common type of radiation source used in industrial radiography is the X-ray. Unlike gamma radiation which is emitted from radioactive material, X-rays of sufficient intensity for industrial radiography are produced by a machine that can be turned on and off at will. X-ray sets in hospitals and clinics are probably the best-known source of artificial radiation.

Effects of Radiation

Early human evidence of harmful effects of radiation to man as a result of its exposure existed long enough. The early radiologists and special occupational workers experience skin burn, erythema, and epilation amongst them (Cember, 2004). Today, repetition is common among cancer patients who undergo prolonged radiation therapy. The experience from prolonged X-ray produced on for example skin burn directly on the individual exposed is called somatic effects while those that are transferred to the victim's offspring are called genetic effects. These radiation effects can be classified into two categories according to Cember (2004), which are Probabilistic and Deterministic.

Methodology and Materials

The radiation meter (inspector, Exp S.E international summer town USA) was used for measurements of radiation in all the three selected hospitals to determine the exposure of X-ray machine at 1m from the source. X-ray machine to be used for this work are the 3phase diagnostic X-ray machines situated at the X-ray departments of the mentioned hospitals. A graduated measuring tape of 7.5 long. The following radiological parameters were recorded for each film used for the measurement of various distances.

The work was carried out for 5 weeks in each of the hospitals; the patient examination records containing types of examinations each day, peak tube voltage (kVp), Thickness of patients, tube current I and exposure time (t) and the number of films used were obtained. At General Hospital Okene, a total of 184 patients were examined for three weeks, 135 patients examined at Kogi State Specialist Hospital, Lokoja, and Federal medical Center Lokoja recorded 400 patients for the three weeks.

The following distances were measured; primary distance (d_{pm}), leakage distance (d_{leak}), scatted distance (d_{sca}), and the wall thickness with the aid of a tape. The primary distance (d_{pri}) was measured from the X-ray tube focal spot to 0.3m beyond the wall which acts as the primary barrier. The distance from the source to the scattered (d_{sca}) was also measured from the closest surface of the patient (scattering material) to 0.3m beyond the primary barrier. The tube leakage distance was measured from the X-ray tube to 0.3m beyond the primary barrier. The exposure per week contributed by the primary exposure (Xp), scattered exposure Xs, and the leakage exposure Xl were computed.

III. RESULTS AND DISCUSSION

The experimental results were obtained after some detailed computations from the measured radiographic parameters/shielding distances, at various hospitals and presented in tables 1 to 4.

Table 1: Measured Radiographic parameters at the various hospitals

Hospital / Measured parameters	Gen. Hospital Okene	Kogi State Spec. Hospital	Fed. Medical Center Lokoja
Tube Voltage (kVp)	100	100	100
Exposure rate (mR/hr)	7.409 ±0. x 10^{1}	0.856±1.3x10^{-1}	109.9±1.7x10^{-1}
Exposure Time, T(s)	1	1	1
mAs	60	48	30
Field size (cm^2)	1350	1395	1350

Table 2: measured Shielding distances obtained at the various hospitals

Hospital / Measured distances	Gen. Hospital Okene	Kogi State Spec. Hospital	Fed. Medical Center Lokoja
Primary distance d_{pri} (m)	2.47	2.3	2.1
Secondary distance d_{sec} (m)	1.02	0.79	0.93
Leakage distance d_{leak}(m)	2.47	2.3	2.1
Scattered distance d_{sca}(m)	1.27	1.39	1.07
Source image distance, SID (m)	1.45	1.51	1.17
Film to coat distance (m)	0.42	0.40	0.33
Wall thickness	$0.3 \pm 3x10^{-2}$	$0.27 \pm 2.7x10^{-2}$	$0.3 \pm 3x10^{-2}$

Table 3: The shielding parameters of the X-rays rooms of the three Hospital investigated

Hospital / Shielding Parameters	Gen. Hospital Okene	Kogi State Spec. Hospital	Fed. Medical Center Lokoja
Tube Workload (mA-min/wk)	633	46.34	60
Use factor	0.067	0.4	0.5
Occupancy factor	1	1	1
X-ray tube output(k) at 1m from source (mR/mA-min)	$4.14 x10^{-4}$	$4.5 x10^{-4}$	$9.2 x10^{-3}$
Exposure towards primary Barriers (mR/wk)	0.60	0.30	0.77
Exposure towards secondary barriers. (mR/week)	0.58	0.5	0.74
Exposure per unit workload towards pri. Barriers (k) at unit distance. (R/wk)	0.001	0.03	0.015
Exposure per unit workload towards Sec. barriers (k) at unit distance. (R/wk)	0.004	0.013	0.03
Required primary shielding barrier of concrete thickness (mm)	$11.0 \pm 0.11x10^{1}$	$6.0 \pm 6x10^{-1}$	$7.0 \pm 7x10^{-1}$
Required secondary shielding barrier of concrete thickness (mm)	9.0 ±9x10-1	$5.0 \pm 5x10^{-1}$	$6.0 \pm 6x10^{-1}$

Table 4: computed exposure levels at the various hospitals

Hospital / Computed Exposures	Gen. Hospital Okene	Kogi State Spec. Hospital	Fed. Medical Center Lokoja
Primary exposure, Xp (mR/wk)	0.263	0.021	0.55
Incident Exposure X^{i}_{p} (mR/wk)	$1.5 x10^{-1}$	$1.1 x10^{-2}$	$5.7 x10^{-1}$
Scatter Exposure, Xs (mR/wk)	$7.9 x10^{-4}$	$5.75 x10^{-5}$	$2.9 x10^{-3}$
Tube leakage, Xl (mr/wk)	3.5	1.6	3.1

Table 5: Comparison of workloads and use-factors obtained in this work with those of other

Hospital / parameter	Gen. Hospital Okene	Kogi State Spec. Hospital	Fed. Medical Center Lokoja	Okunade/ Awodele	NCRP.49 (1970)
Workload (mA-min/wk)	633	46.34	60	95.22	1000
Use factor	0.67	0.4	0.5	0.43-0.73	1.00

The workload and the tube output at 1 meter from the source were calculated from each X-ray room for all the hospitals. The primary as well as secondary exposures which determine the required primary barrier for the X-ray rooms in the selected hospitals were determined. It was observed that the workload of 633mA-min per week for General hospitals, 46.34mA-min per week for Kogi State Specialist Hospital, Lokoja and 60mA-min per week for Federal Medical Center, Lokoja, are considerably lower than the suggested workload of 250mA-min per week, for a solo practice and 100mA-min per week for a busy radiographic rooms on the basis of the NCRP 49 (1970) recommendations the workload at where the workload is above the recommended value for Solo practice. It is General hospital Okene is higher but considerably less than 1000mA-min per week of the current recommendation of NCRP 49 for busy radiographic rooms.

The workload at General hospital,Okene is much greater than the other hospitals. This may be because this X-ray machine is the busiest of all.

From Table 5, it is observed that the results of General Hospital Okene in the present work are higher than those of Okunade/Awodele, but less than the NCRP 49 recommendations..

For the primary shielding calculation, the exposure per week (x) without shielding at a position 0.3m beyond the primary/secondary protective barriers in all the hospitals are less than the recommended exposure limit (Xlimit) per week of 2mR/week, (i.e 0.60 and 0.58 mR/weekfor General hospital Okene, 0.30 and 0.5mR/week for KogiStateSpecialist and 0.77 and 0.74mR/week for Federal Medical Center Lokoja, respectively. These exposure rates are also considerably low compared with the NCRP Report No. 116 (1993).

The results of the workload of this also lies between the workload range of 73 to 530mA-min. per week for orthopedic facilities and 500mA-min per week for shielding design purposes, recommended by Bushong and Glaze (1983). The workload at General Hospital Okene is more than those Okunade and Awodele(2001), but in good agreement and below the NCRP 49 (1970) recommendations of 1000mA-min per week.

Braestrup (1970) reported that, some results have shown that the weekly workload does not exceed 100mA-min even for every bush radiographic room, which agrees with the result of works at Federal Medical Center, Lokoja and Kogi State Specialist Hospital, Lokoja.

From the alternative formula by Zuk (2002) the primary barrier thickness needed in General hospital, Okene, Kogi State Specialist hospital, Lokoja, and Federal Medical Center Lokoja are 11.0 ±0.11 x10-1mm, 6.0±6.0x10-1mm and 7.0±7.0x10-1mm respectively. Also, 9.0±9.0 x10-1mm, 5.0±5.0 x10-1mm and 6.0±6.0 x10-1 mm for secondary barrier thickness respectively. While the thickness of the walls of the X-ray rooms at these hospitals are 300±3.0x101mm for General Hospital, Okene, 300±3.0 x101mm for Federal Medical Center Lokoja and 270±2.7 x101mm for Kogi State Specialist hospital lokoja. This further shows that the walls at these hospitals have adequate primary shielding, and will take care of the secondary protective shielding in all the hospitals investigated. This finally shows that the X-ray rooms in these hospitals do not necessarily need any additional primary structural shielding barriers.

IV. CONCLUSION

The result of all the three hospitals conform with the recommendations of the National Commission on Radiological and Protection (NCRP 70 and 116) protocols, since the protective shielding parameters obtained are much lower than the recommended maximum limits. The diagnostic X-ray rooms therefore have adequate structural shielding.

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