Proceedings of the 8th Faculty of Science International Conference (FOSIC 2025), Delta State University, Abraka, Nigeria. 12th – 14th November, 2025. Pp. 262 - 269

MEASUREMENT OF SCATTERED AND LEAKAGE RADIATION IN X-RAY FACILITIES FROM SELECTED CENTERS IN WARRI METROPOLIS, DELTA STATE.

Ovwasa, S. O.
Department of Physics, Delta State University, Abraka, Nigeria.
Email of corresponding author: ovwasa-obakpororo@delsu.edu.ng

ABSTRACT

Measurements were carried out to determine the amount of scattered and leakage radiation in x-ray facilities in Warri metropolis. A total of twenty (20) Sampled x-ray units were studied. A portable GQ GMC-600 digital Geiger Muller Counter capable of detecting α, β, γ and x-rays radiation with serial number 36311386254310 by GQ Electronics, well calibrated at National Institute of Radiation Protection and Research (NIRPR) was used for the measurements. The leakage radiation at 1m from the cathode side and 1m from the anode side were measured with close collimator blades while scattered radiation were taken with open collimator blades 1m from the iso center of a phantom approximately 30 cm x 30 cm x 25 cm (width x length x thickness) to simulate an average adult abdomen was used to position the radiation detector. Exposures were made with film to focus distance (FFD) of 100 cm using mAs and kVp of routine abdominal radiological examinations. The results show that 85% of the investigated x-ray units have cathode side leakage radiation higher than the anode side leakages, 5% anode side leakage radiation higher than the side cathode leakages and 10% having similar anode and cathode side leakage radiation. The mean leakage from individual x-ray unit ranges from 0.21 $mRhr^{-1}$ to 100.27 $mRhr^{-1}$ with an overall mean value of 25.67 $mRhr^{-1}$. It was observed that only one unit, A_{10}, had mean leakage radiation value of 100.27 $mRhr^{-1}$ which was above 100 $mRhr^{-1}$American Association of Physicist Medicine (AAPM) set limit, this therefore means there is no probability that the general public may experience cancer from exposure to these machines or immediate radiological health hazard arising from the leakage radiation from these x-rays' facilities.

Keywords: Dose, X-ray, ALARA, Risk, Leaking radiation.

INTRODUCTION

Ionizing radiation has proven to be a double-edged sword since discovery by Dr. William Roentgen in 1895. Radiation is a potent mutagen and carcinogen; however, it is also used in the diagnosis and treatment of human diseases. At present, radiation is not only indispensable in medical diagnoses and treatments but is widely used in fundamental research and practical applications in various fields of science and technology, thus contributing much to humans for elevating the quality of life. A report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2008) estimates that the annual number of all types of medical x- ray examination undertaken in the world, corresponding to an annual frequency of 360 examinations per 1000 individuals worldwide. In Nigeria, x-ray is the most frequently used ionizing radiation in medicine despite advances in magnetic resonance imaging and ultrasound techniques (Oluwafisoye et al., 2010). Majority of the people, including many intellectuals, have an excessive concern for the risk of radiation even for very minute quantities due to the health effects associated with ionizing radiation (ICRP, 2007; Mesfin et al., 2017; Mangset et al., 2019; Osward, 2021). It is well known that the exposure of ionizing radiation to biological tissue may trigger complex chains of biomolecular events and consequently biological damage which depends on the dose or dose rate. The loss of orbital electrons from an atom due to exposure leaves it positively charged. Other interactions lead to excitation of the atom rather than ionization, here, an outer valence electron receives sufficient energy to overcome the binding energy of its shell and moves further away from the nucleus to an orbit that is not normally occupied. These effects alter the chemical force that binds atoms into molecules and a regrouping of the affected atoms into different molecular structures can result. Ionizations and excitations can give rise to unstable chemical species called free radicals, they are chemically very reactive and seek stability by bonding with other atoms and molecules which may result to biological Changes of the cell or tissue or organ in question. The higher the dose (exposure), the higher the rate of biological damage done on the tissue or probability of biological damage on the tissue.

Exposure to ionizing radiation during diagnostic radiological procedures is not without damage to living cells (ICRP, 2007). The as Low as Reasonably Achievable (ALARA) principle means that every reasonable effort must be made to keep radiation doses to staff and the public below the required limits of radiation. The benefits of exposure should therefore outweigh the risk of exposure to ionizing radiation also keeping all exposures to the barest minimum. The dose received from a single exposure may not be problem but the cumulative dose resulting from subsequent exposures increases the risk of developing stochastic effects (ICRP, 1991). Protecting patients from unnecessary exposures thus reducing the radiation burden to the radiation worker and the public, this can be achieved by quantifying the scattered radiation dose by a patient during an exposure. This is however not simple because the energy and quantity of photons used, the size of patients and the vulnerability of exposed tissues must be factored into any estimate (Medical/Health physicists often undertake extensive calculations to accurately estimate the dose of radiation received by a specific patient during a radiograph. The ALARA principle is a safety principle, recommended by national and international radiation protection agencies for radiation workers, to address the growing concerns of radiation induced somatic and heritable mutations. (ICRP, 1991).

Ionizing radiation does have detrimental effects hence the need to reduce exposure during x-ray examination as low as possible. The effects of ionizing radiation may either be stochastic or deterministic. A stochastic effect is one where the probability of occurrence increases with radiation dose but the severity of the result does not vary with dose; examples include the development of cancer and leukemia and hereditary and genetic effects. Stochastic stands for something that occurs by chance and is random in nature; there is no threshold for stochastic effects. By contrast a deterministic effect is one where the severity depends upon radiation dose; examples include skin burns, infertility, and hair loss and cataract formation. There is a threshold for deterministic effects; these effects occur once the threshold radiation is crossed. (ICRP, 2007). Most diagnostic procedures may not result to deterministic effects, however, there is a probability of stochastic effect, which with the potential for biological effects increases with multiple exposures. It is therefore the small doses encountered in diagnostic procedures, contributing to the stochastic effects, which are a matter of concern. Its therefore essential and mandatory to reduce the radiation dose to patients to the barest minimum. To determine the extent to which the ALARA principle is being adhered to, radiology departments usually conduct, amongst other things, the assessment of scatted and leakage radiation which are important components of quality assurance programs and it is a sort of subjective evaluation of safety and standard of good radiological practice. The determination of scatted and leakage radiation are useful and well-established methods for quality control of radiological facilities.

In diagnostic radiology, quality assurance means the planned and systematic actions that provide adequate confidence that a diagnostic x-ray facility will produce consistently high-quality images with minimum exposure of the patients. The determination of what constitutes high image quality will be made by the facility producing the images. The basic strategy for quality assurance in diagnostic radiology was formulated by the WHO (WHO,2023) and involves various activities, including managerial and technical activities. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (Part, 2011) provide requirements to establish a quality assurance programmed for medical exposures. These principles are further developed in Safety Guide No. RS-G-1.5 (IAEA, 2000). Quality assurance actions include both “quality control” techniques and “quality administration” procedures which includes policies and procedures ensuring overall safe practices are observed in an x-ray department as well as, in keeping with minimum exposure to both patients and personnel. In 1977, the American Association of Physicists in Medicine (AAPM) published a quality assurance protocol aimed at providing guidance involved in the implementation of a quality assurance (QA) program in diagnostic radiology. Since the time of that writing, diagnostic radiology has undergone fundamental changes that have directly influenced the requirements of such a program (AAPM, 2002).

MATERIALS AND METHODS

Description of the study area

Study Area: Since most social, economic, and industrial growth in the state occurs in Warri rather than Asaba, the state capital, Warri is acknowledged as the commercial hub of Delta State. Because of its strategic location near the border between Nigeria's Eastern and Western regions, the city functions as a transit and convention town. Many oil and gas firms, including the Warri Petrochemical Company, have their facilities (tank farms, gas plants, oil and gas wells, maintenance workshops, and offices) in the city due to the availability of hydrocarbons (oils and gas) in the city and nearby areas. Warri city's dense population is a result of these factors as well as the presence of a naval base and army barracks. According to Agbalagba (2017), the city has around a million inhabitants, making it the fourth most populous in Nigeria.

Table 1: Description of the studied facilities.

S/N	EQUIPMENT NAME	MANUFACTURES	MODEL	MACHINE SERIAL NUMBER	DATE OF MANUFACTURE	CODES
1	COMET	COMET AG BERN SWITZERLAND	MULTISTATE 94-118	MS-1		A1
2	TOSHIBA	TOSHIBA ELECTRON TUBES AND DEVICES CO. LTD STOCHIGI JAPAN	E/876X	14H235	AUGUST 2014	A2
3	HYUN-DAI M EDICAL X-RAY	HYUN DAI MEDICAL X-RAY CO. LTD. 297-3 PAJU-CITYKYONGGI-DO KOREA	BMX1100	12MU81002	MARCH 2012	A3
4	DHANWANTARI MEDICAL SYSTEM	DHANWANTARI MEDICAL SYSTEM	DIAGNOSTE-100	-	2012	A4
5	SIEMENS POLIMOBILE 2	SEIMENS GERMANY	8463468 X 1706	03055 S 02	2015	A5
6	PHILIPS	PHILIPS GERMANY	SUPER ROTALIX ROT 350 10	15532		A6
7	COMET CH 3097	COMET SA SUISSE LIEBEFELD SWITZALAND	DI 9-30/50-125	42-6628		A7
8	GE MACHLETT	GEC MEDICAL EQUIPMENT LIMITED	MACHLETT			A8
9	GENERAL ELECTRIC	GENERAL ELECTRIC COMPANY JAPAN	46-270615P1H	056-8	DECEMBER 1992	A9
10	GENERAL ELECTRIC	GENERAL ELECTRIC COMPANY USA	46-12368633	287874182	1993	A10

Measurement of leakage radiation

The following are the materials used for this research; GQ GMC -600 PLUS radiation survey meter, digital laser tape.

METHODS

Twenty (20) different X-ray facilities in Warri Delta State were used for the measurements. Radiation detector, GMC 600 PLUS with serial number 36311386254310 by GQ Electronics, calibrated by National Institute of Radiation Protection and Research (NIRPR) with calibration certificate number: NIPPR/JUTH/22/231 was utilized. The lowest tube current (50 mA) station was picked that is appropriate for the ionization survey meter's reaction time. The greatest tube potential (80 kVp) permitted was selected. During the survey, the total heat capacity of the anode and the x-ray tube housing should not be exceeded. The radiation detector was positioned using the digital tape on the surface of an imagined sphere with a radius of one meter and a focal spot at its center. Exposure were built with close collimator blades or block the collimator port with at least 10 half-value layer (HVL) equivalent of lead. The leakage radiation at the designated sites was then measured. The instantaneous dose rate (IDR) data were acquired in μSv/hr directly from the display screen of the radiation detector. After then, the results were changed from micro-Sievert per hour (μSv/hr) to milli-roentgen per hour (mR/hr).

RESULTS AND DISCUSSION

The results of the physical evaluation were carried out and measurement of the background radiation were obtained as well as the leakage radiation carried out on the facilities in selected x-ray center, Tables 2 and 3, respectively, displayed the scattered and leakage radiation measurements. A bar graph showing the leakage and scattered radiation data compared to the maximum allowable leakage limit, 100 mRhr^{-1} established by the AAPM. Table 2 displays a line graph that illustrates the relationship between the leakage radiation pattern from the anode and cathode sides of the twenty x-ray units under investigation, while Table 3 displays the scattered radiation as measured in this investigation.

Table 2: x-ray room background (BG) and leakage radiation at 1 m from the studied x-ray machines.

X-RAY MACHINE	BACKGROUND μSυhr^{-1}	LEAKAGE RADIATION (mRhr^{-1})		
		CATHODE SIDE UNIT	ANODE SIDE UNIT	MEAN
A_1	0.28	6.12	4.82	5.47
A_2	0.24	0.39	0.32	0.36
A_3	0.25	37.79	37.12	37.46
A_4	0.20	91.97	91.97	91.97
A_5	0.32	0.21	0.21	0.21
A_6	0.21	7.01	6.64	6.83
A_7	0.25	6.82	6.63	6.73
A_8	0.24	20.11	17.68	18.90
A_9	0.26	4.07	3.13	3.60
A_{10}	0.19	100.84	99.70	100.27
A_{11}	0.18	11.55	11.39	11.47
A_{12}	0.29	9.85	9.03	9.44
A_{13}	0.28	42.03	47.12	44.58
A_{14}	0.28	84.03	68.06	76.05
A_{15}	0.29	32.11	31.55	31.83
A_{16}	0.31	12.03	11.46	11.75
A_{17}	0.29	16.33	13.76	15.05
A_{18}	0.29	7.83	6.15	6.99
A_{19}	0.28	16.03	12.11	14.07

A_{20}	0.26	22.07	18.65	20.36
MINIMUM	**0.18**	**0.21**	**0.21**	**0.21**
MAXIMUM	**0.32**	**100.84**	**99.70**	**100.27**
MEAN	**0.26**	**26.46**	**24.88**	**25.67**

Table 3: Measured Scattered radiation at 1m from the studied x-ray machines.

X-RAY MACHINE	**SCATTERED RADIATION**		
	SR1 ($\mu Sv hr^{-1}$)	SR2($\mu Sv hr^{-1}$)	MEAN ($mSv hr^{-1}$)
A1	284.45	281.59	0.283
A2	9.62	9.69	0.010
A3	588.61	589.01	0.589
A4	4064.63	4061.16	4.063
A5	9.32	9.37	0.009
A6	257.31	252.73	0.255
A7	201.60	201.69	0.202
A8	623.28	623.44	0.623
A9	155.69	155.19	0.155
A10	1537.23	1541.13	1.539
A11	384.55	384.55	0.385
A12	295.16	295.20	0.295
A13	1011.71	1014.55	1.013
A14	1501.18	1521.01	1.511
A15	651.00	651.29	0.651
A16	320.11	324.12	0.322
A17	320.91	318.97	0.320
A18	197.54	197.54	0.198
A19	240.89	241.06	0.241
A20	490.29	488.95	0.490
MINIMUM	9.32	9.37	0.009
MAXIMUM	4064.63	4061.16	4.063
MEAN	657.25	658.11	0.658

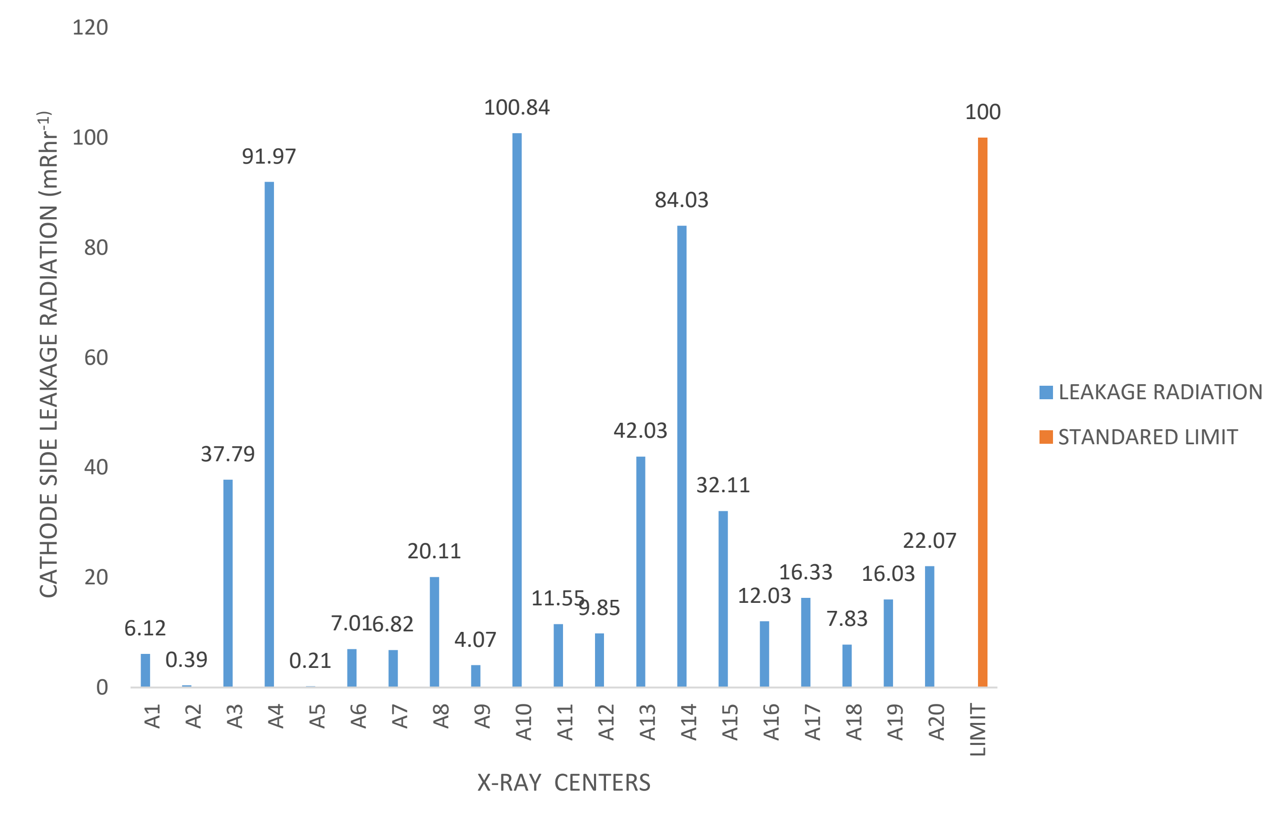

Figure1: Comparison of the cathode side leakage radiation to standard limit.

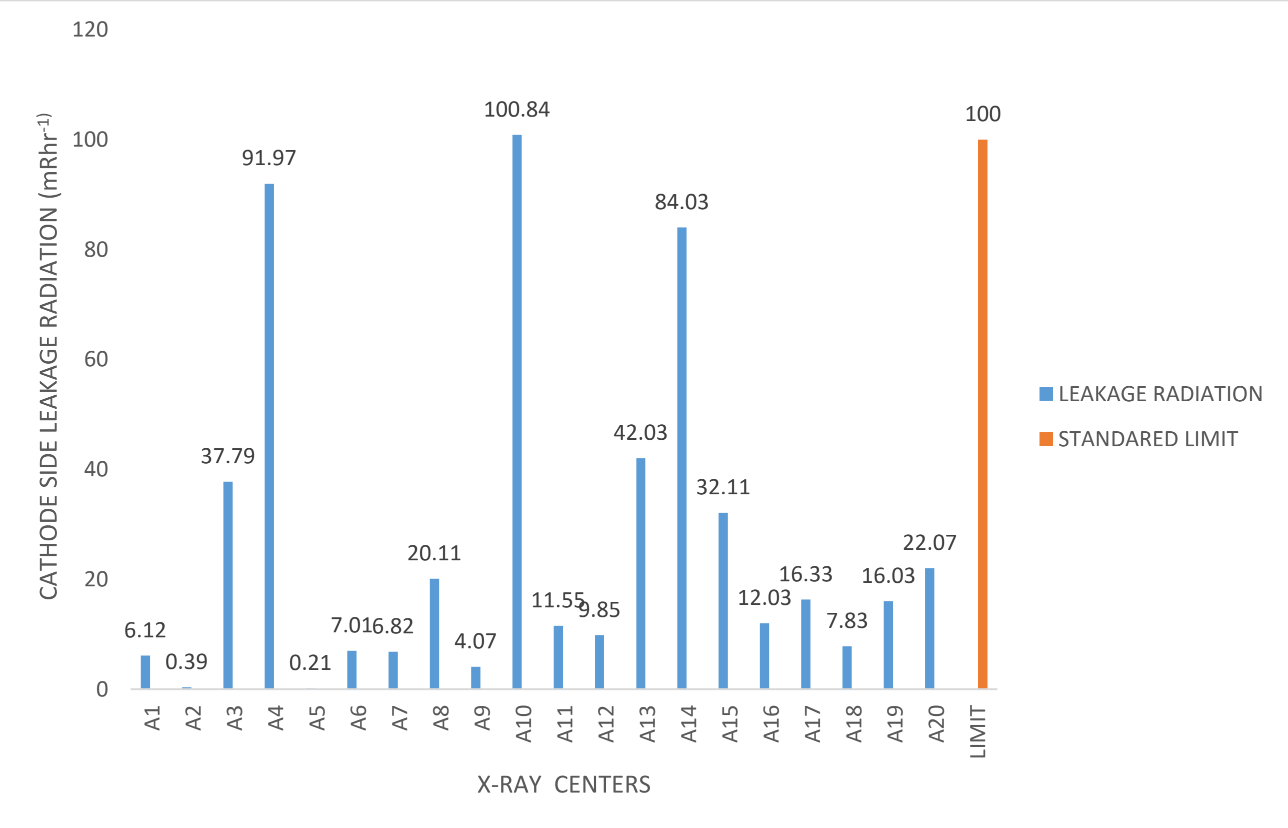

Figure 3: Comparison of the cathode side leakage radiation to standard limit.

Table 2 shows the background radiation (BG) obtained at the various x-ray room, shown alongside the leakage radiation from the cathode side and that of the anode side of the x-ray tube. The BG is a key factor required to rule out any external radiation influence on the obtained results from the leakage radiation test. The BG ranges from 0.18 μSυhr^{-1} (0.36mSυyr^{-1}) to 0.32 μSυhr^{-1}) (0.64 mSυyr^{-1}) across the studied facilities with a mean BG of 0.26 μSυhr^{-1} (0.52 mSυyr^{-1}). These values were below the ICRP recommended limit of 1mSυyr^{-1}. Hence, no external radiation source that would have influenced the scattered and leakage radiation investigations. Leakage radiation at 1 meter from the studied x-ray machines were also shown in Table 2, from the Table, the leakage radiation from the cathode side were ranging from 0.21-100.84 mRhr^{-1} with the overall mean values of 25.67 mRhr^{-1} corresponding to A_1 to A_{20} respectively. The peak from the cathode side was observed with facility A_{10} while A_5 was observed to have the minimum cathode side leakage. The cathode side leakage 0.21 mRhr^{-1} observed from A_5 is of no significant difference to the measured BG (0.020 mRhr^{-1}) from the x-ray room when compared to the very significant difference observed at A_{10} having a BG of 0.019 mRhr^{-1} to a cathode side leakage of 100.84 mRhr^{-1}. The x-ray unit A_2 also shows a relatively low cathode side radiation leakage 0.39 mRhr^{-1}. The peak cathode side leakage radiation was closely followed by A_4 and A_{14} with cathode side leakage of 91.97 mRhr^{-1} and 84.04 mRhr^{-1} respectively. The mean cathode side radiation leakage from this study was 26.46 mR/hr and this is within standard limit. AAPM has set a standard for the maximum permissible leakage limit, 100 mRhr^{-1}, from any give x-ray tube. As shown in Figure 1, the comparison of all the cathode side radiation leakages from the studied x-ray facilities were represented. From the chart, only one x-ray machine, A_{10} failed this test, resulting to a 5% failure rate and 95% pass rate.

Leakage radiation was also determined at 1m from the anode side of the investigated x-ray units. The results were also revealed in Table 2, from the Table, the leakage radiation from the anode side were ranging from 0.21-99.70 mRhr^{-1} representing the anode side leakage radiation from A_1 to A_{20} respectively. This range of 0.21 - 99.70 mRhr^{-1} representing the minimum and maximum anode leakage radiation corresponding to A_5 and A_{10} respectively. A_5 has been shown to have minimum radiation leakage both at the cathode side and the anode side in like manner, A_{10} has been shown to have maximum radiation leakage both at the cathode side and the anode side. The mean anode side leakage radiation observed in this was 24.88 mRhr^{-1}, which was slightly lower than the cathode side leakage of 26.46 mRhr^{-1}. This also shows that 85% of the investigated x-ray units have cathode side leakage radiation higher than the anode side leakages, 5% anode side leakage radiation higher than the side cathode leakages and 10% having similar anode and cathode side leakage radiation. It was observed from this study that radiation leakage is most frequent at the cathode side of the x-ray tube. Figure 3. shows the comparison of the anode side leakage radiation to AAPM standard limit. From the comparison all the studied x-ray facilities represented in the chart were below 100 mRhr^{-1} hence a 100% pass rate was observed. The 100% pass rate at the anode side was expected considering the fact that the cathode side only have a 95% pass rate with a mean cathode side leakage radiation observed in this study of 26.46 mRhr^{-1} which was higher than that of the anode side mean leakage of 24.88 mRhr^{-1}.

CONCLUSION

In many countries, there is a marked increase in medical x-ray installations and the number of examinations during the last decades. The scattered and leakage radiations have a significant effect in the quality of radiographic examinations and is very important for reduction of radiation doses to patient, personnel and members of the public. Scattered and leakage radiations tests were performed on twenty x- ray units among selected x- ray centers in Warri metropolis in Delta State. This study shows a leakage radiation test compliance rate was 95% and 5% non-compliance rate. Scattered radiation from this study was relatively higher with a mean of 0.658 mSυhr^{-1}, however, the amount of scattered radiation can significantly be reduced from the set exposure parameter. Conclusively, x-ray machine should have their scattered and leakage radiation check at interval at least annually to maintained consistency in which unnecessary and unwanted exposure are checked and corrected.

REFERENCES

AAPM (2002). Report No. 74: Quality Control In Diagnostic Radiology: Report of Task Group 12, Diagnostic X-ray Imaging Committee. Med. Phy. Pub.. Vernon Blvd. Madison, United States of America: 13-17.

Agbalagba O. E. (2017). Assessment of excess lifetime cancer risk from gamma radiations levels in Effurun and Warri city of Delta State, Nigeria. Journal of Taibah University for Science, 11, 367-380. Exposure to Ionizing Radiation, Safety Standards Series No. RS-G-1.5, International Atomic Energy Agency (IAEA), Vienna

IAEA (2000). International Atomic Energy Agency. Radiological Protection for Medical

ICRP (1991). International Commission on Radiological Protection. Recommendations of the International Commission Radiological Protection: ICRP 60 Annuals of ICRP (1-3).

ICRP (2007). International Commission on Radiological Protection. Radiological protection and safety in Medicine. ICRP Publication. Ann ICRP.

ICRP (2007). The 2007 recommendations of the International Commission on Ann ICRP. 37, No. 2-4, 1-332.

Mangset, W., Emmanuel, and Adesida, O., Samuel. (2019). Radiographic Reject Film Analysis in Radiology Department of a Teaching Hospital in Jos, Plateau State, Nigeria, AJMP is the official journal of the Federation of African Medical Physics Organizations (FAMPO), 1(1): 1-7.

Mesfin Zewdu, Elias Kadir and Melkamu Berhane (2017). Analysis and Economic Implication of x-Ray Fil Reject in Diagnostic Radiology Department of Jimma University Specialized Hospital, Southwest Ethiopia, Ethiop J Health Sci.. 2017 Jul; 27(4): 421-426.

Oluwafisoye, P., A,Olowookere, C, J., Jibiri, N. N., Bello, T. O., Alausa., S. K., and Efunwole, H.O., (2010). Quality Control and Environmental Assessment of Equipment Used in Diagnostic Radiology. International Journal of Recent Research and Applied Studies (IJRRAS), 2: 148-158.

Osward Bwanga. (2021). Causes of Reject and Repeat of Digital Radiographic images: A Literature Review to Guide the Practice of Radiography in Zambia, Medical Journal of Zambia, 48 (1): 38 - 45 (2021).

Part, N. G. (2011). Radiation protection and safety of radiation sources International Basic Safety Standards. Sources and effects of ionizing radiation Annex D. Health effects due to radiation from the Chernobyl accident. *http://www. unscear. org/unscear/en/publications. Html*

United Nations Scientific Committee (UNSCEAR) (2008). the Effects of Atomic Radiation,

WHO (2023). World Heath Organization recommend average duration of life in Nigeria. www.wikipedia.org/wiki/inverse-square_law.