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Radiological Risk Assessment Among Occupational Health Workers in Selected Radiological Centres in Warri City, Nigeria

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ABSTRACT

Background and Objective: The exposure of patients and workers handling radiological equipment in Nigerian hospitals is becoming of increasing concern to both experts in the field of radiation and the regulatory agency in the country. This study, therefore, evaluates the occupational health workers associated with the use of some radioactive ladened equipment in selected radiological centres in Warri City Delta State, Nigeria to ascertain the exposure levels to both operators and patients within the environment. **Materials and Methods:** The BIR data were collected *in situ* from four selected radiological centres for indoors and outdoors exposure using a well-calibrated Gamma scout, Geiger counter multi-radiation meter and a GPS meter were used. **Results:** The measured average exposure assessment for indoors are well above ambient level but are within for outdoors. The radiological risk parameters evaluated revealed elevated values and in some cases above international permissible limits. The averaged ELCR for all the centres obtained were found to be higher than the recommended world average mean value of 0.29×10^{-3} ($mSvy^{-1}$). The overall obtained results of the study area do not constitute any immediate radiological health effect on the workers, patients and the public. **Conclusion:** The mean excess lifetime cancer risk (ELCR) for occupational health workers for all the radiological centres was 0.66 μSvy^{-1} which is relatively higher than the worldwide average of 0.29 μSvy^{-1}. These evaluated values may not cause immediate health issues to the health workers, but the accumulation of these doses may be detrimental.

KEYWORDS

Background radiation, dose-rate, hazard indices, hospital, Warri city

INTRODUCTION

Over the years, the deployment of radiation-induced equipment and its application have become an important tool in medical diagnosis and therapy. About 50-75% of medical decisions depend on x-ray diagnosis and the early diagnosis of some diseases depends completely on x-ray examinations[1]. However, if x-rays are not shielded such that they only interact with intended parts of the body, then they are a potential health hazard to the health workers, patients and members of the public[2]. Duration, distance shielding, exposure time reduction, increasing distance from the source and patient shielding make up

https://doi.org/10.21124/tss.2025.01.09

Received: 17 Aug., 2024
Accepted: 12 Dec., 2024
Published: 31 Mar., 2025

the trio of radiation protection actions. It has been proven that occupational workers are of great importance in protecting patients, personnel and members of the public from the potential hazards of radiation[3,4]. Protection practices are aimed at keeping all-radiation risks as low as is reasonably achievable. Every year in Nigeria, several radiological examinations are carried out for diagnostic purposes. However, some of the procedures do not have a record of doses received by the health workers and the employed exposure parameters used for such procedures are not documented, therefore, radiation dose management is hindered. The report of the UNSCEAR 2000 concluded that occupational health workers' exposure due to medical radiation is likely to be increasing worldwide, particularly in countries where medical services are in their early stages of development[5]. The ICRP recommends that medical activities involving ionizing radiation should fulfil two basic principles: Justification and optimization. In Nigeria and other parts of the world, research works have been done on the background ionizing radiation in and around radiological diagnostic and therapy equipment and facilities in the hospitals. The general results showed a significant difference between the indoor and outdoor BIR and the annual effective dose at the radiological units for both indoor and outdoor[6-9]. Abdullahi *et al.*[8] carried out a measurement of radiation dose on medical workers in selected Hospitals in Dhaka Bangladesh and the results show that the average estimated dose for all subjects' ranges from (0.01-2.42) $mSvy^{-1}$. Among these workers, those in the radiology department received the most substantial estimated dose.

It is observed in Nigeria in recent times that the import and deployment of medical facilities and equipment for diagnostic and therapeutic purposes are on increase in the last five years due to the improved health care policy of the state government. This can also be correlated with the increasing population of the city dwellers due to the rural-urban migration and the attended market force of demand and supply of health care needs. However, cognisant attention has not been accorded to the need for the safety and protection of both patients and workers in these facilities. The need to monitor the BIR levels and the radiation dose received by the duo in and around the building warehousing and some of these equipment has arisen. This study observes the occupational health workers associated with the use of radioactive equipment.

MATERIALS AND METHODS

Study area: Warri City in Delta State comprises various towns, villages, from the different local governments areas that made up the city. The city is known for its commercial, industrial and socio-economic activities in Nigeria. It shares boundaries with Ughelli/Agbarho, Sapele, Okpe, Udu and Uvwie although most of these places, notably Udu, Okpe and Uvwie, have been integrated into the larger cosmopolitan. Most of the social, economic and industrial activities in Delta State occur in Warri City and its environs thus, Warri is regarded as the commercial capital of Delta state. The city is strategically located along the border between the eastern and western regions of Nigeria, thereby serving as a transit and conference town[9]. The city lies within latitude: 5°31'2.53"N and longitude: 5°45'0.22" E. The Warri and its environs consist of both State and Private Hospitals that serve the medical needs of its people. The city is the fourth-most populated city in Nigeria[10]. The study was carried out in four radiological hospitals which include: General Hospital Warri (GHW), General Hospital Ekpan (GHE), Lily Hospital (LH) and Lonia Clinic and Maternity (LCM), they are all specialized radiographic centres. The study was conducted between May 2020 and July 2021, which represent 1 year.

Experimental method: An *in-situ* approach of background ionizing radiation measurement was employed to enable the source samples to maintain original environmental characteristics. A digital radiation meter (Gamma scout and Geiger counter multi-radiation meter) containing a Geiger Muller characterization property of detecting (α-, β- and γ-) rays. The meter was pre-set for γ rays' measurement within a temperature of (-10-50°C and a Geographical Positioning System (GPS) was used to measure the precise location of sampling following standard best practice[4]. Measurements were obtained between 1300 and 1600 hrs of time because the radiation meter has a maximum response to environmental radiation within these hours either (indoors) or (outdoor) investigation according to the Ezekiel[10].

The data were cumulatively collected and analysed using the gamma scout software for graphical representation/correlation outlines and also using existing analytical methods to derive the radiological hazard indices such as: Equivalent dose, absorb dose, annual effective dose, equivalent organ dose and excess lifetime cancer risk attributed to the objectives of the study.

Equivalent dose rate (ED): For the whole-body equivalent dose, we used the National Council on Radiation Protection and Measurement's recommendation for both indoor and outdoor evaluation:

$$1\text{mRh}^{-1} = \left[\frac{0.96 \times 24 \times 365}{100}\right] = 84.096\ \text{mSvy}^{-1} \tag{1}$$

Absorbed dose rate (ADR): Ionizing radiation deposits energy when it penetrates the human body or an item. An absorbed dose is the amount of energy absorbed as a result of radiation exposure. The gray unit is used to measure the absorbed dosage (Gy). A dose of one gray is equivalent to a unit of energy (joule) deposited in a kilogram of a substance as described by Agbalagba *et al.*[3]:

$$1\text{uRh}^{-1} = \left[\frac{1.001 \times 24 \times 365}{1000}\right] = \left\{8.7\ \text{nGyh}^{-1}\right\} \tag{2}$$

This implies that:

$$1\text{mRh}^{-1} = 8.7\ \text{nGyh}^{-1} \times 10^{3} = 8700\ \text{nGyh}^{-1} \tag{3}$$

Annual effective dose equivalent (AEDE): The annual effective dose equivalent estimations are calculated from absorbed dose rate with a conversion factor of 0.7 SvGy^{-1} recommended by UNSCEAR 2000 of absorbed dose in the air to an effective dose an adult receives and an occupancy factor of (20% outdoor) and (80% indoors) exposure[11]:

$$\text{AEDE (indoor) mSvy}^{-1} = \text{Absorbed dose nGyh}^{-1} \times 8760\ \text{h} \times \frac{0.7\ \text{sv}}{\text{Gy}} \times 0.8$$

$$\text{AEDE (outdoor) mSvy}^{-1} = \text{Absorbed dose nGyh}^{-1} \times 8760\ \text{h} \times \frac{0.7\ \text{sv}}{\text{Gy}} \times 0.2$$

Excess lifetime cancer risk (ELCR): The impact of these doses on a health worker is evaluated from excess lifetime cancer risk (ELCR). This deals with the probability of developing cancer or a radiological illness over a lifetime at a given exposure level. It is presented as a value representing the number of extra cancers/illnesses expected in a given number of people on exposure to a carcinogen at a given dose. In addition, the ELCR was determined from the annual effective dose rate with a duration of life (DL) estimated as 70 years. The risk factor (RF, 5%) for public exposure is considered to produce a stochastic effect[12].

Excess lifetime cancer risk (ELCR) is given as:

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF} \tag{4}$$

Where:

DL = Duration of life (estimated to be 70years)

RF = Risk factor (s/v) i.e., fatal cancer risk per-server

RESULTS AND DISCUSSION

The results of the measured BIR exposures levels and calculated hazard indices of (equivalent dose rate, absorb dose rate, annual equivalent dose rate and excess lifetime cancer risk) for the four radiography centres are presented in Table 1-3. Table 1 presents the results of the measured BIR outdoor values and the different estimated hazard indices. As Table 2 present the results of the measured BIR indoor ambient values and the different estimated hazard indices while Table 3 is the summary of the measured indoor BIR levels during the examination of the patient or when the machines are in operations and their corresponding hazard indices for the four radiography centres of the four hospitals.

The outdoor data obtained from the *in situ* measurement for the four radiological centres as presented in Table 1 shows that the exposure rate ranged from 0.004-0.009 mRh^{-1} with a mean value of 0.008±0.004 mRh^{-1} while the ambient indoor exposure rate ranged from 0.007-0.0101 mRh^{-1} with a mean value of 0.006±0.002 mRh^{-1}. The BIR level for both outdoor and indoor exposure before examination for the four radiological centres are below the world average level of 0.013 mRh^{-1} and values reported in kinds of literature in outdoor environment[10,13]. However, the values obtained in the indoor environment during radiological examinations were found to be higher about the world ambient and recommended permissible level for the public in GHW, GHE and LCM, except for Lily Hospital which is below the recommended dose limit. The relatively high values measured during examinations operations for GHW, GHE and LCM may be attributed to faulty equipment, poor shielding sheet, poor structural faults, or lack of proper radiation monitoring during the examination of patients.

Table 1: Mean assessment summary of the outdoor BIR's exposure levels of GHW, GHE, LH and LCM

Hospital	Av. BIR levels (mRh^{-1})	ED ($mSvy^{-1}$)	ADR ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR (μSvy^{-1})
General Hospital Warri (GHW)	0.0079±0.006	0.69±0.26	69.07±26.48	0.34±0.13	1.19±0.44
General Hospital Ekpan (GHE)	0.008±0.003	0.77±0.32	76.6±32.04	0.38±0.16	1.31±0.55
Lily Specialist Hospital (LH)	0.009±0.003	0.75±0.24	74.9±24.74	0.37±0.13	1.29±0.42
Lonia Clinic and Maternity (LCM)	0.009±0.004	0.81±0.36	80.1±35.50	0.39±0.17	1.38±0.59
Total mean value	0.008±0.004	0.75±0.27	75.16±27.87	0.37±0.15	0.31×10^{-1}
World standard	0.013	1.00	59.01	0.07	0.29×10^{-3}

BIR: Background ionizing radiation, ED: Equivalent dose rate, ADR: Absorbed dose rate, AEDE: Annual effective dose equivalent dose and ELCR: Excess lifetime cancer risk

Table 2: Mean assessment of the Indoor BIR's exposure levels of GHW, GHE, LH and LCM before the examination

Hospital	Av. BIR levels (mRh^{-1})	ED ($mSvy^{-1}$)	ADR ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR (μSvy^{-1})
General Hospital Warri (GHW)	0.007±0.004	0.69±0.09	62.4±9.06	0.30±0.04	1.09±0.16
General Hospital Ekpan (GHE)	0.004±0.002	0.35±0.07	35.4±7.69	0.17±0.04	0.60±0.13
Lily Specialist Hospital (LH)	0.009±0.003	0.84±0.07	84.1±7.82	0.41±0.04	1.44±0.13
Lonia Clinic and Maternity (LCM)	0.004±0.001	0.38±0.07	44.1±6.97	0.18±0.03	0.64±0.12
Total mean value	0.006±0.002	0.56±0.07	59.95±7.89	0.30±0.04	0.10×10^{-1}
World standard	0.013	1.00	59.01	0.34	0.29×10^{-3}

BIR: Background ionizing radiation, ED: Equivalent dose rate, ADR: Absorbed dose rate, AEDE: Annual effective dose equivalent dose and ELCR: Excess lifetime cancer risk

Table 3: Mean assessment summary of the Indoor BIR's exposure levels of GHW, GHE, LH and LCM during the examination

Hospital	Av. BIR levels (mRh^{-1})	ED ($mSvy^{-1}$)	ADR ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR (μSvy^{-1})
General Hospital Warri (GHW)	0.61±0.33	56.05±33.76	5500.2±384.4	26.40±14.38	96.72±60.67
General Hospital Ekpan (GHE)	0.59±0.25	51.54±22.18	5119.1±403.7	25.1±10.82	87.88±68.97
Lily Specialist Hospital (LH)	0.007±0.002	5.7±0.47	56.9±19.58	0.28±0.09	0.97±0.34
Lonia Clinic and Maternity (LCM)	0.62±0.25	54.43±29.9	5420.1±281.5	26.59±10.70	93.05±37.48
Total mean value	0.45±0.20	40.65±21.57	4024.07±297.29	19.5±8.99	0.66×10^{-2}
World standard		50	(59.00-84.0)	20	0.29×10^{-3}

BIR: Background ionizing radiation, ED: Equivalent dose rate, ADR: Absorbed dose rate, AEDE: Annual effective dose equivalent dose and ELCR: Excess lifetime cancer risk

The Equivalent Dose (ED) rate for outdoor exposure presented in Table 1, column 4 ranged from 0.69-0.81 mSvy^{-1} with a mean value of 0.75±0.27 mSvy^{-1}. From Table 2, column 4 the ED for indoor exposure ranged with an average mean value of 0.35-0.84 mSvy^{-1} with a mean value of 0.56±0.07 mSvy^{-1}. The results of the ED during examination operations from Table 3 shows that the equivalent dose rate for GHW, GHE, LH and LCM has an average mean value of 56.06, 51.54, 0.573 and 54.427 mSvy^{-1}, respectively with a mean value of 40.65±21 mSvy^{-1}. For the four radiological centres under study indoor and outdoor before medical radiological examinations, indicates that the centres were below the permissible dose limit of 1.0 mSvy^{-1} three recommendations of the International Commission on Radiological Protection[14]. Figure 1 shows a comparison of the equivalent dose rate for the outdoor and indoor estimated values for the four radiological centres when there before radiological examinations of patients. The Figure 1 clearly shows that the values are all well below the world recommended permissible level for occupational workers in radiological sectors like hospitals[15]. The results of the ADR in the four radiological centres for outdoor exposure and indoor exposure before the examination as presented in Table 1 and 2 shows a mean ADR value of 75.16±27.87 nGyh^{-1} while the indoor mean value is 59.95±7.89 nGyh^{-1}. This indicates that the mean ADR value for the four radiological centres value estimated is 4024.07±297.29 nGyh^{-1}. The mean values obtained in this study are all above the world permissible dose average of 59.01 nGyh^{-1}. The values obtained indoors during examination operations are higher than the values published in some parts of the world as reported in the UNSCEAR, (2000) report [5,10]. These countries include Turkey (135.70 nGyh^{-1}), Portugal (102 nGyh^{-1}), Italy (105 nGyh^{-1}), Japan (187 nGyh^{-1}) and China (100 nGyh^{-1}).

The results of the AEDE for outdoor exposure from Table 1 indicate that GHW, GHE, LH and LCM have AEDE mean values of 0.084, 0.08, 0.08 and 0.09 mSvy^{-1}, respectively. For which all the exposure are above the ambient dose limit outdoor of 0.07 mSv, but within recommended permissible or tolerable limits of 1.0 mSvy^{-1}[11]. From the results presented in Table 2, the indoor exposure before examination indicates that GHW, GHE, LH and LCM have an exposure mean of 0.34, 0.19, 0.45 and 0.22 mSvy^{-1}, respectively. The values obtained in GHE and LCM are below the accepted permissible dose limit indoor of 0.34 mSvy^{-1}[16-18]. The results of the AEDE during examination operations of the four selected radiological centres as presented in Table 3, column 6 shows that GHW, GHE, LH and LCM have mean AEDE values of 26.388, 25.111, 0.279 and 26.589 mSvy^{-1}, respectively. Table 3 shows the indoor BIR exposure level during examinations, the exposure rate ranged from 0.152 mRh^{-1} to 1.060 mRh^{-1} with a mean value of 0.45±0.20 mRh^{-1} for the four radiological centres. The GHW, GHE and LCM in the study area are also higher than the permissible dose limit of 20 mSvy^{-1} for the occupational worker as recommended by ICRP 2007 and reported by Mora and Acuña[18]. Figure 2 shows the comparison of the mean AEDE of the four studied radiological centres with the world recommended permissible limit for occupational health workers and radioactive laden section permissible limit. It is obvious from the figure that all except Lilly Hospital exceeded the limit.

The results of the ELCR in the four radiological centres for outdoor indoor exposure before the examination as presented in Table 1 shows a mean value of 0.31×10^{-1}, while the indoor exposure before the examination as presented in Table 2 shows a mean value of 0.10×10^{-1}. The mean estimated excess lifetime cancer risk for indoor exposure during the examination from Table 3 shows that GHW, GHE, LH and LCM has an average mean value of 0.83×10^{2}, 0.88×10^{2}, 0.97×10^{-1} and 0.93×10^{2} mSvy^{-1}. The mean values obtained in this study area are all above the world permissible value of 0.29×10^{-3} documented by UNSCEAR, 2000[11,12]. These values indicate the probability of cancer incidence over a lifetime exposure of 70 years.

The linear distribution analysis from the equivalent dose to the AEDE for a single year from Table 3 indicates that, more sensitizations, training of health workers on the use of this radioactive equipment and replacement of obsolete equipment to be put in place to curb the risk of exposure to excess ionizing

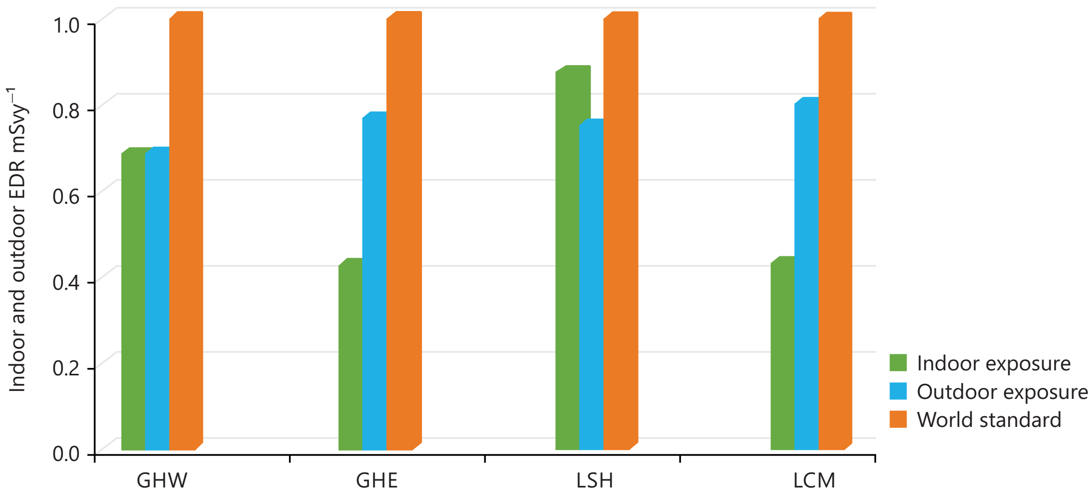

Fig. 1: Comparison of indoor and outdoor (ED) of the four radiological centres with world permissible dose limit

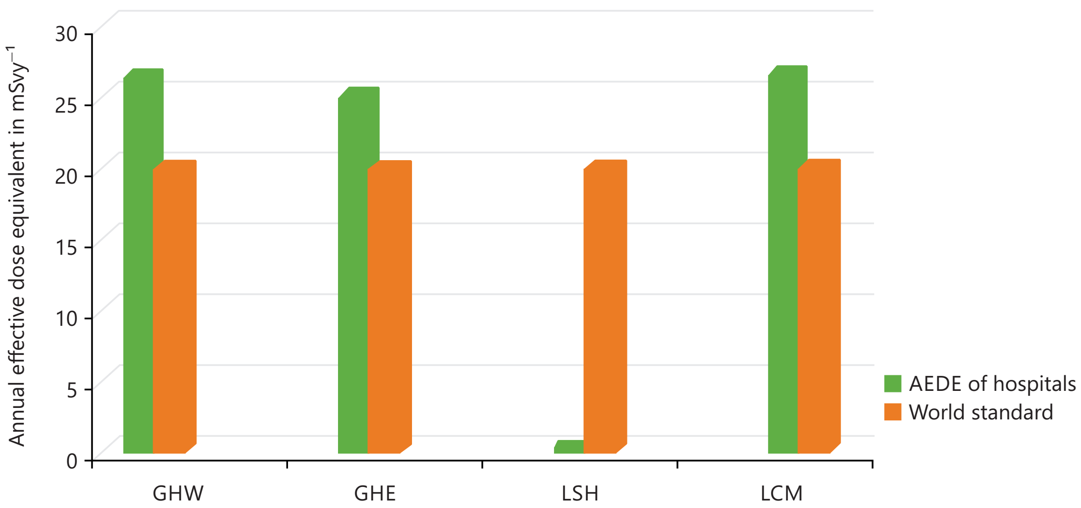

Fig. 2: Comparison of the AEDE for indoor exposure during examination operations for the four radiological centres with world permissible dose limit for occupational health workers

radiation and dose absorbed by occupational health workers and patients alike. Seeing that, these values may rise in a couple of years if drastic actions are not taken. Table 3 values also imply that any radiation exposure, no matter how small, involves some degree of risk. As a result of exposure to a high or long-term dose of ionizing radiation, human is always at risk. Where the dose absorbed determines the severity of the effect. The common effects associated with occupational health workers are leukaemia, skin cancer, genetic defects, sterility, erythema, tumours, tissue damage, cataracts etc. Some effects won't show immediately but in later years (10-20 years). These effects induced by radiation are transmitted from parents to their offspring etc. From Table 3, it is observed that the indoor annual effective dose for GHW, GHE and LCM are higher than the ambient level of 20 $mSvy^{-1}$ occupational reference limit when the x-ray machines and other radiological induced machines were energized, continuous exposure to this high radiation dose can lead to the effects mentioned above and eventually radiological induced illness.

The BIR results of the studied hospitals have shown that any defects in the structural design of the imaging room can lead to higher absorbed exposure levels[15]. The low BIR level recorded in Lily Specialist

Hospital may be attributed to the safety compliances enrolled by the hospital management. The measured values of the different study areas indicate that the outdoor and indoor exposures before examination of the various centres are not radiologically contaminated. The computed equivalent dose for a single year obtained during operational examinations for GHW, GHE and LCM are well above the standard occupational permissible equivalent dose limit of 50 ($mSvy^{-1}$) by the ICRP 2011, except for LSH which is below the occupational ambient dose limit, these values obtained call for concerns on the dose levels received during examination[13]. The results obtained for the equivalent dose rates are an indication that the background radiation levels of the various hospitals are high but may not pose any immediate radiological health challenges to an exposed occupational health worker or patients in general. These values of equivalent dose for indoor before examination operations are comparable to some values reported in previous studies in the western part of Nigeria and eastern part of Nigeria but higher than values reported in some countries of the world[7-9].

The absorbed dose rate of the study area for both outdoor and indoor exposure before examination operation and indoor during operational examination for the four centres were all found to be elevated above ambient levels, signifying radiological contamination of the environment and work unit. This is significant when discussing the radiological protection of the worker and the public. Though the present dose rates in the radiological centres are elevated, they are still below the levels that can initiate immediate health effects to the occupational workers[16-19]. However, continuous exposure may result in the accumulation of radiation doses which may present long-term health effects in the future[17-20].

The elevated annual effective dose equivalent recorded during examinations at GHW, GHE and LCM are attributable to poor level of dose administration, high voltage 7' usage of KVp and mAs of their radiographic machines when switched on and poor shielding engagement. The low AEDE level recorded in Lily Hospital can be attributed to the safety measures put in place in the administration of these doses and the use of low mAs and high KVp techniques. The estimated ELCR values obtained in this study for both outdoor and indoor exposure before examination operations were slightly elevated. This shows that the chances of contracting cancer by occupational health workers of this study area from GHW, GHE, LH and LCM who will spend all their service years in these working conditions will not likely come from exposure from background ionizing radiation. The averaged ELCR for all the centres obtained from this study are higher than the recommended world average mean value of 0.29×10^{-3} ($mSvy^{-1}$). The ADR for indoor exposure during examination operations for GHW, GHE and LCM in the study area are far higher than the recommended ambient dose limit of 59.00-84.0 $nGyh^{-1}$ except for Lily Hospital which is below the limit[14].

The elevation of the values of AEDE during an examination at GHW, GHE and LCM is attributable to poor level of dose administration, high voltage usage of KVp and mAs of the radiographic machines when switched on and poor shielding engagement. The low AEDE level recorded in Lily Hospital can be attributed to the safety measures put in place in the administration of these doses and the use of low mAs and high KVp techniques. The ELCR of the study area for both outdoor and indoor exposure before examination operation are slightly elevated. These values show that the chances of contracting cancer by occupational health workers of this study area from GHW, GHE, LH and LCM who will spend all their services year in these working conditions will not likely come from exposure from background ionizing radiation. The mean estimated excess lifetime cancer risk for indoor exposure during examination from Table 3 shows that GHW, GHE, LH and LCM has an average mean value of (0.83×10^{2}, 0.88×10^{2}, 0.97×10^{-1} and 0.93×10^{2}) $mSvy^{-1}$. The averaged ELCR for all the centres obtained from this study are higher than the recommended world average mean value of 0.29×10^{-3} ($mSvy^{-1}$)[19,20].

CONCLUSION

The radiological assessment shows that the study area does not constitute any immediate radiological health effect on the workers and the public due to BIR exposure and the chances of contracting cancer or any other radiological illness for workers of the study area are insignificant. Personal dose evaluation is carried out using film badges and thermo-luminescent badges to give robust information on the radiological status of each occupational health worker. Machines used for radiological examinations should be checked and monitored regularly to avoid the high level of the dose administered to limit the level of the background ionizing radiation exposure.

SIGNIFICANCE STATEMENT

This study discovered that the BIR level of radiographic rooms in radiological centres gets elevated when the machines are energized. The study was able to show that proper operational techniques and best practices in radiological centres can reduce the BIR level of the operational environment. This will benefit the operators of these machines, the owners of these hospitals, researchers and the government regulatory agency in charge of policymaking to guide hospital management. This study will help the researchers to uncover the critical areas of intervention that many researchers were not able to explore. Thus, a new theory on operational exposure may be arrived at.

ACKNOWLEDGMENTS

The author wishes to thank the entire staff and management of General Hospital Warri, General Hospital Ekpan, Lily Hospitals and Lonia Clinic and Maternity for creating an environment for the success of this study and their cooperation.

REFERENCES

1. Söderberg, M. and M. Gunnarsson, 2010. Automatic exposure control in computed tomography-an evaluation of systems from different manufacturers. Acta Radiol., 51: 625-634.
2. Rafique, M., S.U. Rahman, M. Basharat, W. Aziz and I. Ahmad *et al*., 2014. Evaluation of excess life time cancer risk from gamma dose rates in Jhelum Valley. J. Radiat. Res. Appl. Sci., 7: 29-35.
3. Agbalagba, E.O., M.S. Chaanda and S.U. Egarievwe, 2021. Assessment of solid mineral to soil radioactivity contamination index in selected mining sites and their radiological risk indices to the public. Int. J. Environ. Anal. Chem., 10.1080/03067319.2021.1940162.
4. Ajayi, O.S., C.G. Dike and K.O. Balogun, 2018. Elemental and radioactivity analysis of rocks and soils of some selected sites in Southwestern Nigeria. Environ. Forensics, 19: 87-98.
5. Sivakumar, S., A. Chandrasekaran, R. Ravisankar, S.M. Ravikumar and J.P.P. Jebakumar *et al*., 2014. Measurement of natural radioactivity and evaluation of radiation hazards in coastal sediments of East Coast of Tamilnadu using statistical approach. J. Taibah Univ. Sci., 8: 375-384.
6. Abdallah, Y.M.Y., M.M. Hemair and A.S. Algaddal, 2015. Valuation of radiation dose in lumbosacral examination. Int. J. Sci. Res., 4: 2422-2424.
7. Chukwuemeka, O.P. and G.O. Avwiri, 2013. Evaluation of background ionising radiation levels of braithwaite memorial specialist hospital Port Harcourt, Rivers State. Am. J. Sci. Ind. Res., 4: 359-365.
8. Abdullahi, A.G., A.K.M.F. Haque, M.G. Abdullahi, M.A. Hajara and S.G. Abdullahi, 2018. Measurement of radiation dose on medical workers in selected hospitals in Dhaka Bangladesh. CPQ Med., Vol. 1.
9. Blessing, O.B. and A.A. Muyiwa, 2018. Assessment of background radiation levels in selected diagnostic radiology department across Ondo state, Nigeria. Niger. J. Pure Appl. Phys., 8: 16-19.
10. Ezekiel, A.O., 2017. Assessment of excess lifetime cancer risk from gamma radiation levels in Effurun and Warri city of Delta state, Nigeria. J. Taibah Univ. Sci., 11: 367-380.
11. Aliyu, A.S., U. Ibrahim, C.T. Akpa, N.N. Garba and A.T. Ramli, 2015. Health and ecological hazards due to natural radioactivity in soil from mining Areas of Nasarawa State, Nigeria. Isot. Environ. Health Stud., 51: 448-468.
12. Taskin, H., M. Karavus, P. Ay, A. Topuzoglu, S. Hidiroglu and G. Karahan, 2009. Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey. J. Environ. Radioact., 100: 49-53.

13. Ademola, J.A. and U.C. Onyema, 2014. Assessment of natural radionuclides in fly ash produced at Orji River thermal power station, Nigeria and the associated radiological impact. Nat. Sci., 6: 752-759.
14. Monica, S., A.K.V. Prasad, S.R. Soniya and P.J. Jojo, 2016. Estimation of indoor and outdoor effective doses and lifetime cancer risk from gamma dose rates along the coastal regions of Kollam District, Kerala. Radiat. Prot. Environ., 39: 38-43.
15. Adhikari, K.P., L.N. Jha and M.P. Galan, 2012. Status of radiation protection at different hospitals in Nepal. J. Med. Phys., 37: 240-244.
16. Sharma, P., P.K. Meher and K.P. Mishra, 2014. Terrestrial gamma radiation dose measurement and health hazard along River Alaknanda and Ganges in India. J. Radiat. Res. Appl. Sci., 7: 595-600.
17. Ugbede, F.O. and I.D. Benson, 2018. Assessment of outdoor radiation levels and radiological health hazards in emene industrial layout of Enugu State, Nigeria. Int. J. Phys. Sci., 13: 265-272.
18. Mora, P. and M. Acuña, 2011. Assessment of medical occupational radiation doses in *Costa rica*. Radiat. Prot. Dosim., 147: 230-232.
19. Mokobia, C.E., T. Aniku and G. Avwiri, 2016. Evaluating the radiological health compliance of some beach environments in Delta State. J. Appl. Sci. Environ. Manage., 20: 513-519.
20. Brenner, D.J. and E.J. Hall, 2007. Computed tomography-An increasing source of radiation exposure. N. Engl. J. Med., 357: 2277-2284.