MEASUREMENT OF SCATTERED RADIATION DOSES AND ESTIMATION OF SOME ORGAN DOSES IN X-RAY ROOMS OF THREE HOSPITALS IN YENAGOA, BAYELSA STATE, SOUTH-SOUTH, NIGERIA

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Abstract: The increase in patients undergoing radiological examination has aroused a great deal of interest in quantifying the risk associated with the radiological examination. Determination of the radiation dose to the organs is very difficult and direct measurement is not possible. The scattered radiation in the x-ray rooms of three selected hospitals in Yenagoa, Bayelsa State has been investigated. A radiation survey meter, Radalert was used to measure the scattered radiation in different places in the x-ray rooms of the hospitals. Model equations were used to estimate the radiological parameters associated with exposure to the scattered radiation in the rooms. The measured scattered radiation for the three hospitals falls between (0.226 - 0.655) mRh^{-1} with a mean of 0.290 mRh^{-1}. The corresponding absorbed dose rates ($nGyh^{-1}$). Equivalent dose rates ($mSvy^{-1}$), annual effective dose rates ($mSvy^{-1}$) and excess lifetime cancer risks falls between (1966 - 5699), (0.019 - 0.055), (0.003 - 0.011) and 1.27×10^{-4} - 3.66×10^{-2} respectively. The estimated organ dose for the three hospitals falls between (0.002 - 2.180) $mSvy^{-1}$. Comparing the result with permissible limits set by ICRP, 1991, the annual effective dose values for the study are less than the occupational limit of 20 $mSvy^{-1}$ and slightly higher than the public limit of 1 $mSvy^{-1}$. Hence, the workers, residents living close to the locations of the hospital, and the patients are within the safe limits.

Keywords: Measurement, Estimation, Scattered radiation, Organ dose, X-ray rooms

Introduction

Radio-sensitivity is the relative vulnerability of cells, tissues, organs, organisms, or other substances to the detrimental action of radiation (Agbalagba *et al*., 2016). It has generally been found that cell radio-sensitivity is directly and inversely proportional to the rate of cell division and degree of cell differentiation respectively (Agbalagba *et al*., 2016). This means that dynamically dividing cells or those not fully mature are mostly at risk from radiation. The most radio-sensitive cells are those which, have a high division rate, and a high metabolic rate, are of a non-specialized type, and are well-nourished (Rubin and Casarett, 1968). The susceptibility of various organs in the human body varies due to their densities and general estimation dose exposure without specific estimation of organ dose which may result in not having an idea of the organs in the body that may be at higher risk when exposed to ionizing radiation.

To appropriately estimate and evaluate the effect of radiation from diagnostic procedures, it is important to know the effective dose as well as the dose to individual body organs (Yamashita, 2021). The effective dose takes into account that different body parts or organs react differently to radiation exposure (Ibikunle *et al*., 2015). The medical community and regulatory agencies are aware of the effects of low-dose ionizing radiation and also that of high dose (Aborisade *et al.*, 2018). It is careful to note that most of the radiation studies are expressed in fluoroscopy time, dose area product (DAP), or air kerma (AK). There is little or no research study on the accurate dose a particular body cell, organ, or tissue can take and also to know how much effect the scatter radiation can have on other parts of the body other than the targeted cells. Scatter radiation is the source of most personnel's occupational exposure and it is significant, as observed by some research on radiation dose distribution (Bienert *et al.*, 2016; Khaled *et al*., 2016). There is an increase in patients undergoing radiological examination in which x-ray is most times the foremost option (Martins *et al.*, 2020). This increase has aroused great interest in determining the risk associated with the radiological examination (Bienert *et al*., 2016; Aborisade 2021). Hence the need for this study will be of benefit to the radiologist, medical staff, patients, and even the public to note the effect which radiation exposure could be, to the body organs and the body as a whole. According to the limits of exposure to radiation for personnel mandated by the International Commission on Radiological Protection (ICRP, 1996), the effective radiation dose should not exceed 100 mSv in five years and the effective dose in a single year should not exceed 50 mSv (Martins *et al.*, 2020).

The purpose of this study is to measure the scattered radiation dose in x-ray rooms in three hospitals within Yenagoa and estimate the associated radiological parameters as a result of exposure to the scattered radiation in the x-ray rooms. To the best of the knowledge of the researcher, there has not been any such study in the hospital.

Materials and Method

Description of the study area

The study areas are three hospitals (A, B, and C) located in Yenagoa, Bayelsa State, Niger Delta region of Nigeria. The city lies between latitude $4^0$55'N and $5^0$05'N and longitude $6^0$15'E and $6^0$20'E (Nwankwoala and Oborie 2014). Bayelsa State is well known for oil and gas exploration activities. Activities associated with such industries may, in one way or the other affect the health status of residents in the area. The possibility of residents undergoing x-ray investigations cannot be ruled out due to common medical needs for x-ray investigations.

Measurement of scattered radiation doses in X-ray rooms

A digital handheld radiation survey meter, RADALERT 100X was used. In some modes, when radiation levels increase over certain preset levels, the Radalert 100X uses auto-ranging, automatically changing to the X1000 scale. Whenever X1000 is shown above the numeric display, multiply the displayed reading by 1000 to determine the radiation level. The regular range of operation is 0.0 - 1100 μSvh^{-1} or 0.0 - 110 mRh^{-1}. When the maximum level for the current mode is reached, the Radalert 100X beeps for three seconds pauses for three seconds and repeats that pattern. The display shows RANGE: Full. The beeping pattern and the Range Full icon continue until the level decreases or the Radalert 100X is turned off. Measurement was carried out in mRh^{-1} in five randomly selected points in the x-ray room during normal working hours of the hospitals when the x-ray machine was on and readings are taken when the survey meter becomes stable. The study is not without limitations because of the unavailability of some information about the x-ray machines in the hospital due to the sensitivity of the study.

Evaluation of hazard indices associated with exposure to scattered radiation from the x-ray machines

Equivalent dose rate

To estimate the whole body's equivalent dose rate (EDR) over one year, the National Council on Radiation Protection and Measurements Recommendations were used (Agbalagba, 2017).

$$1mRh^{-1} = \frac{0.96 \times 24 \times 365}{100}\ mSvy^{-1} \quad (1)$$

Absorbed dose rate

The data obtained for the external exposure rate in μGyh^{-1} were also converted to absorbed dose rates nGyh^{-1} using the conversion factor (Ekong *et al*., 2019).

$$1\mu Rh^{-1} = 8.7\ nGyh^{-1} = \frac{8.7 \times 10^{-3}}{\left(\frac{1}{8760y}\right)}\ \mu Gyy^{-1} = 76.212\ \mu Gyy^{-1} \quad (2)$$

Annual effective dose equivalent (AEDE)

The computed absorbed dose rates were used to calculate the annual effective dose equivalent (AEDE). A dose conversion factor of 0.7 SvGy^{-1} recommended by UNSCEAR was used for the conversion coefficient from the absorbed dose rate in the air to the effective dose received by adults (Taskin *et al.*, 2009).

AEDE nSvy^{-1} = absorbed dose nGyh^{-1}× 8760 h × 0.7 SvGh^{-1}× 0.2 (3)

Excess Lifetime Cancer Risk (ELCR)

This is the possibility of an individual to be able to develop cancer in a lifetime due to exposure to low-level radiation. It is obtained using the computed values of the annual effective dose equivalent multiplied by the average duration of life (DL) and the risk factor (RF) (Taskin *et al.*, 2009).

ELCR = AEDE × DL × RF (4)

Where AEDE is the annual effective dose equivalent, DL is the average duration of life which is 70 years, RF is the risk factor which is 0.05 for public exposure.

The Effective Dose Rate (Dorgan) in my-1 to Different Body Organs and Tissues.

The effective dose is obtained by multiplying the equivalent dose by a tissue weighting factor that corresponds to the type of tissue exposed to radiation. If more than one organ is exposed to radiation, then all effective doses to all exposed organs are added together to obtain an overall effective dose. To obtain the effective dose for the organs (Agbalagba, 2017)

D_{organ} (mSvy^{-1}) = O × AEDE × F (5)

Where, O is the occupancy, 0.8, AEDE is the annual effective dose equivalent, and F is the conversion factor for organ dose from ingestion.

Results and Discussion

The section presents the result of the study in tabular and pictorial forms. Tables 1-3 present the values of the measured and estimated radiological parameters while Tables 4-6 present the estimated organ doses for the study. Pictorial representations of the result are also presented

Table 1: Measured scattered radiation and estimated radiological parameters for Hospital A

	Average Scattered Radiation (mRh^{-1})	Equivalent Dose (EDR) mSvy^{-1}	Absorbed Dose Rates (D_R) (nGyh^{-1})	Annual Effective Dose Rate (AEDE) mSvy^{-1}	Excess Life Time Cancer risk ELCR (10^{-2})
1	0.635	0.053	5525.0	0.010	3.55
2	0.655	0.055	5699.0	0.011	3.66
3	0.533	0.045	4811.0	0.009	2.98
4	0.494	0.042	4298.0	0.008	2.77
5	0.450	0.038	3915.0	0.007	2.52
Mean	**0.553**	**0.047**	**4849.0**	**0.009**	**3.09**

The scattered radiation from the x-ray machine ranged from (0.450– 0.635) with a mean of 0.553 mRh^{-1} while the equivalent dose ranged from (0.038 - 0.055) mSvy^{-1} with a mean of 0.047 mSvy^{-1}. The estimated absorbed dose rate falls Between 3915 nGyh^{-1} and 5699 nGyh^{-1} with a mean of 4849.0 nGyh^{-1}. The annual effective dose rate is less than the permissible limit of 1 mSv/y and the corresponding excess life time cancer estimated is above the permissible limit of 2.9 × 10^{-4} recommended by UNSCEAR, 2000.

Table 2: Measured scattered radiation and estimated radiological parameters for Hospital B

	Average Scattered Radiation SR (mRh^{-1})	Equivalent Dose Rates (EDR) (mSvy^{-1})	Absorbed Dose Rates D_R (nGyh^{-1})	Annual Effective Dose Rates (AEDE) mSvy^{-1}	Excess Life time Cancer Risk (ELCR) 10^{-4}
1	0.226	0.019	1966.0	0.0036	1.27
2	0.339	0.029	2924.0	0.0054	1.89
3	0.337	0.028	2932.0	0.0054	1.88
4	0.328	0.027	2854.0	0.0052	1.84
5	0.319	0.026	2775.0	0.0051	1.79
Mean	**0.309**	**0.026**	**2695.0**	**0.0050**	**1.74**

Similarly for the second hospital, the estimated radiological parameters viz a viz equivalent dose rates, absorbed dose rates, annual effective dose rates, and the excess life time cancer risk with the mean values of 0.026 $mSvy^{-1}$, 2695.0 $nGyh^{-1}$, 0.005 $mSvy^{-1}$ and 1.74×10^{-4} respectively, are all less than the recommended permissible limits for the estimated radiological parameters. The measured scattered radiation in the vicinity of the x-ray machine ranged from (0.226 - 0.339) mRh^{-1} with a mean of 0.309 mRh^{-1} which is also less than the permissible limit for the public.

Table 3: Measured scattered radiation and estimated radiological parameters for Hospital C

S/N	Average Scattered radiation SR(mRh^{-1})	Equivalent Dose Rates (EDR) ($mSvy^{-1}$)	Absorbed Dose Rates D_R($nGyh^{-1}$)	Annual Effective Dose Rates (AEDE) $mSvy^{-1}$	Excess Life time Cancer Risk (ELCR) 10^{-3}
1	0.579	0.019	5037.0	0.0093	3.24
2	0.578	0.029	5029.0	0.0093	3.23
3	0.561	0.028	4881.0	0.0090	3.14
4	0.408	0.027	3550.0	0.0065	2.29
5	0.400	0.026	3480.0	0.0064	2.24
Mean	**0.505**	**0.026**	**4395.0**	**0.0081**	**2.82**

Again, for the third hospital, the measured mean scattered radiation values ranged from 0.40 - 0.579 mRh^{-1} with a mean of 0.505 mRh^{-1}. Similarly, the other estimated radiological parameters viz: equivalent dose rates, absorbed dose rates, annual effective dose rates, and excess lifetime cancer risks ranged between (0.019 - 0.029) $mSvy^{-1}$, with the mean of 0.026 $mSvy^{-1}$, (3480 - 5037) $nGyh^{-1}$ with the mean of 4395 $nGyh^{-1}$, (0.0064 - 0.0093) $mSvy^{-1}$ with the mean of 0.0081 $mSvy^{-1}$ and (2.24 - 3.24) $\times 10^{-3}$ respectively. Hence, the staff, patients, and the members of the public in the vicinity of the x-ray machines are not at risk of any lethal exposure to ionizing radiation when the x-ray machines are in use and not in use.

Comparing the measured radiological parameters with similar work done by Ioannis *et al.*, 2015, the values of the scattered radiation in their study (0.048) $mSvh^{-1}$ is greater than that of the measured values for the three hospitals (0.0051{0.505mRh^{-1}}, 0.0031{0.309 mRh^{-1}} and 0.0055{0.555 mRh^{-1}}) $mSvh^{-1}$ for the first, second and third hospitals selected for the study. Owusu *et al.*, 2018 also reported a scattered radiation dose rate in the range of (0.10 - 0.12) $mSvh^{-1}$ which is again greater than the measured values in the study.

Oladele and Arogunjo, 2018 reported an annual effective dose rate of (0.63 - 1.17) $mSvy^{-1}$ in a Diagnostic Radiology department in Ondo State, Nigeria. Their estimated value for the annual effective dose rate is higher than that of the three selected hospitals for the study (0.009, 0.005, and 0.0081) $mSvy^{-1}$.

Dyel *et al.*, 2018, reported an annual dose rate of 2.31 - 7.72 $mSvy^{-1}$ of scattered radiation in some selected hospitals in Jos Metropolis and the value is greater than the one reported in the present study.

Statistically, there is a strong and positive correlation between the scattered radiation in the x-ray rooms for all the hospitals and the annual effective dose rates for the staff and everyone that visits the hospitals. Hospitals A, B, and C have correlation coefficients of 0.96, 0.99, and 0.99 respectively. Figure 1, is a representation of the correlation coefficient value that existed between scattered radiation and annual effective dose rates of the users of hospital A. There also exists a low correlation (0.01) between the scattered radiation and the organ doses as indicated in Figure 2. This shows that the organ doses are accrued due to the focus voltage of the x-ray machine and less the scattered radiation.

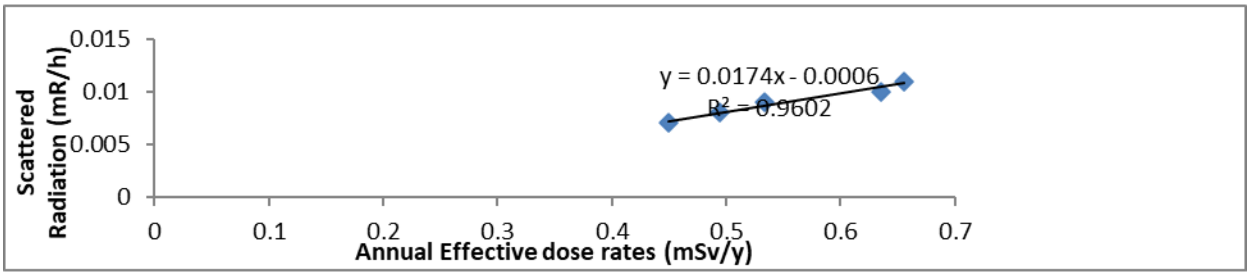

Figure 1: Plot of Scattered Radiation Vs Annual effective dose rates showing the positive correlation between the two radiological parameters

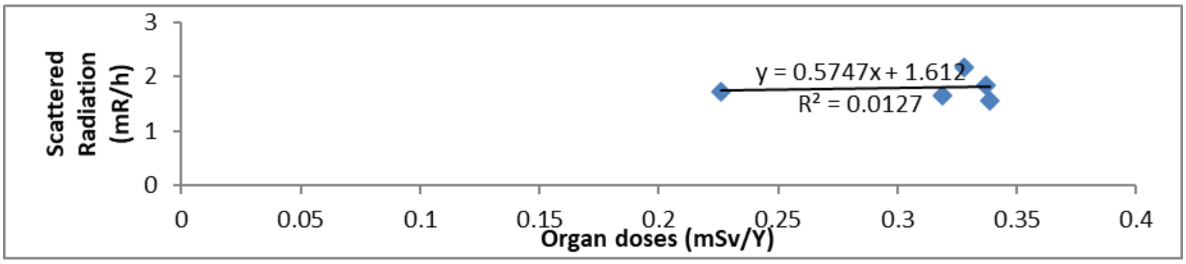

Figure 2: Plot of Scattered Radiation Vs Organ dose showing the low correlation between the two radiological parameters

Table 4: Estimated Annual Effective Dose rate (mSvy^{-1}) to Organs of the human body at Hospital A.

S/N	Body organ	Conversion factor	Organ Effective dose (mSvy^{-1})
1	Lungs	0.64	1.73
2	Ovaries	0.58	1.55
3	Bone marrow	0.69	1.84
4	Testes	0.82	2.18
5	Kidney	0.62	1.65
6	Liver	0.46	1.22
7	Whole body	0.68	1.83
Mean			**1.71**

The estimated organ doses for Hospital A as indicated in Table 1, has a mean of 1.71 mSvy^{-1} with the testes having the highest value (2.18 msvy^{-1}) and the ovaries having the lowest value (1.55 mSvy^{-1}). Similarly, Tables 5 and 6 present the maximum and minimum values of the estimated organ doses for testis (0.042mSvy^{-1}), liver (0.024 mSvy^{-1}), with the mean of 0.0033 mSvy^{-1}, testis (0.47 mSvy^{-1}) and liver (0.26 mSvy^{-1}) with the mean of 0.36 mSvy^{-1} respectively. The testis is the most exposed for the three hospitals.

Table 5: Estimated Annual Effective Dose rate (mSvy^{-1}) to Organs of the human body at Hospital B

S/N	Body organ	Conversion factor	Organ effective dose mSvy^{-1}
1	Lungs	0.64	0.032
2	Ovaries	0.58	0.029
3	Bone marrow	0.69	0.035
4	Testes	0.82	0.042
5	Kidney	0.62	0.032
6	Liver	0.46	0.024
7	Whole body	0.68	0.038
Mean			**0.033**

Comparing the result of the study with that of Ernest and Johnson, 2016 where the effective dose for the abdomen ranged from 5.4 - 19.8 mSvy^{-1} which is quite greater for the whole body reported in the present study. This may be due to the high dose required for the CT examination.

Figure 3 shows the bar chart for the estimated organ doses due to scattered radiation in the x-ray rooms of the three hospitals. Hospital A has the highest values of organ doses. This may be due to the higher operation dose for the x-ray machine in the hospital.

Table 6: Estimated Annual Effective Dose rate (mSvy^{-1}) to Organs of the human body at Hospital C

S/N	Body organ	Conversion factor	Organ effective dose mSvy^{-1}
1	Lungs	0.64	0.36
2	Ovaries	0.58	0.33
3	Bone marrow	0.69	0.39
4	Testes	0.82	0.47
5	Kidney	0.62	0.35
6	Liver	0.46	0.26
7	Whole body	0.68	0.40
Mean			**0.36**

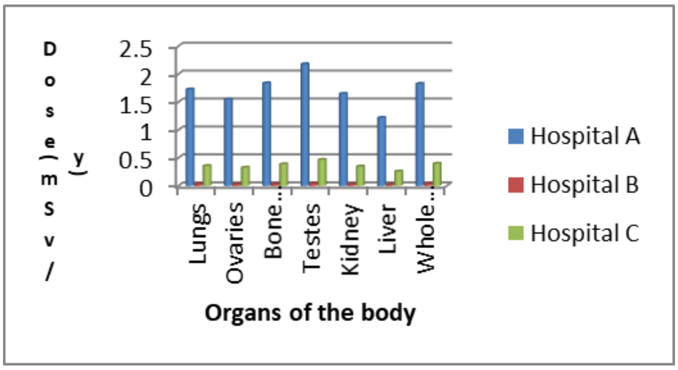

Figure 3: Bar chart of dose to organs in all three hospita

Conclusion

The measures scattered radiations in the x-ray rooms in the selected three hospitals in the study locations are contributes to the annual effective dose rates of the staff of the hospitals and other users of the hospitals. The value is highest 0.55 mRh^{-1}. The estimated radiological parameters associated with the exposure to the scattered radiation in the x-ray rooms are quite low and largely below the safe limits. This implies that the staff of the hospitals may not be present at any health risk since the values estimated for most of the radiological parameters are within the permissible limits set by various regulatory bodies.

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