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Radiological Risk Estimates Due to Background Exposures in Selected Hospitals in South – East Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author GOA designed the study. Author IEN performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors GOA and IEN managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Radiation is present everywhere on the Earth and humans are exposed to it without being aware of it. Exposure to natural ionizing radiation is inevitable as long as we live on Earth. An *in-situ* measurement of indoor and outdoor exposure dose rates of Federal Medical Center Umuahia (FMC Umuahia) and Federal Medical Center Owerri (FMC Owerri) were measured with well calibrated radiation meters (Radalert-100 and Digilert-200). The average indoor and outdoor exposure rates for Federal Medical Center Umuahia were 0.014±0.003 and 0.014±0.003 mRh^{-1}, while that for Federal Medical Center Owerri were 0.012±0.002 mRh^{-1} and 0.013±0.002 mRh^{-1}. The values show that the exposure rates for Federal Medical Center Owerri is within the range of the World threshold value of 0.013 mRh^{-1}, while that of FMC Umuahia is higher. The average indoor and outdoor absorbed dose rate measured at federal medical centre (FMC) Owerri are 106.7 and 104.7 $nGyh^{-1}$ respectively while the average indoor and outdoor absorbed dose for Federal medical center (FMC) Umuahia are 120.1 and 116.8 $nGyh^{-1}$ respectively. These values exceeded the

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world average of 89 $nGyh^{-1}$. Also the results for average excess lifetime cancer risk (ELCR) calculated for indoor and outdoor for the hospitals show that ELCR for both indoor and outdoor exposures were all higher than the world acceptable value of $0.29x10^{-3}$, but the annual effective dose levels for the hospitals both indoor and outdoor were all below the 1 $mSvy^{-1}$ maximum permissible limit for the public set by the International Commission on Radiological Protection (ICRP). Therefore there is need for the management of the hospitals to monitor radiation levels in other to take necessary precautions to avoid radiation levels getting to unacceptable levels.

Keywords: Radiation monitoring; radiation hazard; radiation safety; survey meter; ELCR.

1. INTRODUCTION

Ionizing radiation sources is harmful for the occupational workers, patients and also for the environment. So it is essential to monitor the radiation to ensure the health and safety of the Occupational workers, general public and also to protect the environment from the harmful effect of ionizing radiation. The assessment of the radiation doses in humans from natural sources is of special importance because natural radiation are the largest contributor to the collective doses received by the world population. The natural radiation sources include: cosmic radiation, radioactive materials present in the earth's crust, building materials and in air. Annual effective dose equivalent (mSv) from natural sources is estimated to be 2.4 mSv from external sources and 1.6 mSv from internal sources [1]. Background radiation consists of three primary types: Primordial, Cosmo genic and anthropogenic. Primordial radionuclides are present in the earth's crust and found throughout the environment. Cosmo genic radionuclides are produced when cosmic radiation interacts with elements present in the atmosphere and are deposited through both wet and dry deposition. Anthropogenic sources of radiation result from human activities, but are considered background because their presence is ubiquitous [2].

Exposure from natural background radiation to humans is natural, continuous and inescapable feature of life on earth. One of the main contributors are terrestrial radioactive materials which originate from the formation of the earth and are present everywhere in the earth's crust and in the human body [3]. Background ionizing radiation which originally was attributed to cosmic sources has over the years increased due to technological advancement. Radiation from hospitals and medical research institutes has been of great concern due to the known effects of high doses of radiation. Exposure of patients to radiographic examinations and radiation therapy has contributed to increase in background radiation and radiation dose to patients and occupational workers [4].

Studies on health effects due to ionizing radiation have produced substantial evidences that exposure to high levels of radiation can cause illness or even death. It can also cause retardation in children of mothers exposed to radiation during pregnancy [5]. Exposure to ionizing radiation can cause injuries and clinical symptoms; which may include a chromosomal transformation, cancer induction, free radical formation, bone necrosis and radiation catractogenesis [6]. Several studies have been carried out in Nigeria to measure the natural background radiation levels of hospitals. Okoye and Avwiri [4] carried out a study on the radiation levels at Braithwaite Memorial Specialists Hospital, Port Harcourt. The indoor exposure dose rate ranged from 0.14± 0.02 μSvh^{-1} to 0.16± 0.01 μSvh^{-1}. Also James et al. [6] studied the background radiation levels at Kwali General Hospital Abuja. The exposure dose rates were all lower than the standard value of 0.133 µSv/h or 0.013 mR/h.

The aim of this study is to measure the background ionizing radiation of the selected hospitals and quantify its associated radiological risks. The values from the selected hospital will be compared and the indoor and outdoor exposure dose rates will be correlated to ascertain the relationship between them.

2. MATERIALS AND METHODS

A GPS based gamma survey was carried out using two radiation meters. The Digilert-200 and Radalert-100 radiation meters were used in this study to measure the background ionizing radiation of the sampling locations. They are health and safety instruments that measure the alpha, beta and gamma radiations in the environment. Both detectors count ionizing events and display the results on the liquid crystal display (LCD). Three readings each were taken with the two meters and the average value taken. Measurements were taken indoor and outdoor at different departments of the selected hospitals. Data obtained for the exposure dose rates in mR/h was converted into absorbed dose rate (nGy/h) using the conversion factor [5]. The calculations for the radiation parameters were calculated using Microsoft Excel software and the exposure rate measured was converted to absorbed dose using the following relation (Rafique et al. [7].

$$1\ \mu R/h = 8.7 nGy/h = 8.7 \times 10^{-3}\ \mu Gy / (1/8760)y = 76.212\ \mu Gy/y \quad (1)$$

3. RESULTS

The *in-situ* measurement of background ionizing radiation and the calculated values of the absorbed dose, annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) of the three hospitals are presented in Tables 1-4, while Figs. 1 and 2 represent the correlation of the indoor and outdoor exposure dose rate.

3.1 Annual Effective Dose Equivalent (AEDE)

The absorbed dose rate values were used to calculate the annual effective dose equivalent received by patients and staff of the three hospitals. In calculating the AEDE, a dose conversion factor of 0.7 Sv/Gy and the occupancy factor indoor and outdoor was 0.75(18/24) and 0.25(6/24) respectively. It has been estimated that people spend approximately 18 hours indoors and 6 hours outdoors. The annual effective dose equivalent is determined using the equations [8].

$$\text{AEDE (indoor) (mSv/y)} = \text{Absorbed dose rate (nGy/h)} \times 8760\ h \times 0.7\ Sv/Gy \times 0.75 \quad (2)$$

$$\text{AEDE (outdoor) (mSv/y)} = \text{Absorbed dose rate (nGy/h)} \times 8760\ h \times 0.7 Sv/Gy \times 0.25 \quad (3)$$

The mean annual effective dose equivalents for the two hospitals are as follows: FMC Umuahia - 0.56 mSv/y (indoor) and 0.019 mSv/y (outdoor), FMC Owerri - 0.50 mSv/y (indoor) and 0.17mSv/y (outdoor).

3.2 Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk is calculated based on the calculated values of the AEDE using the following equation [9,7].

$$\text{Excess Lifetime Cancer Risk (ELCR)} = \text{AEDE} \times \text{Average duration of life (DL)} \times \text{Risk Factor (RF)} \quad (4)$$

Where AEDE, DL and RF are the annual effective dose equivalent, duration of life (70y) and the risk factor (Sv^{-1}) fatal risk per Sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses values of 0.05 for the public [7,5].

ELCR for the hospitals are as follows: FMC Umuahia – 1.97 x 10^{-3} (indoor) and 0.65 x 10^{-3} (outdoor), FMC Owerri - 1.76 x 10^{-3} (indoor) and 0.59 x 10^{-3}. The ELCR values for the hospitals exceeded the worldwide average value of 0.29 x 10^{-3} [7].

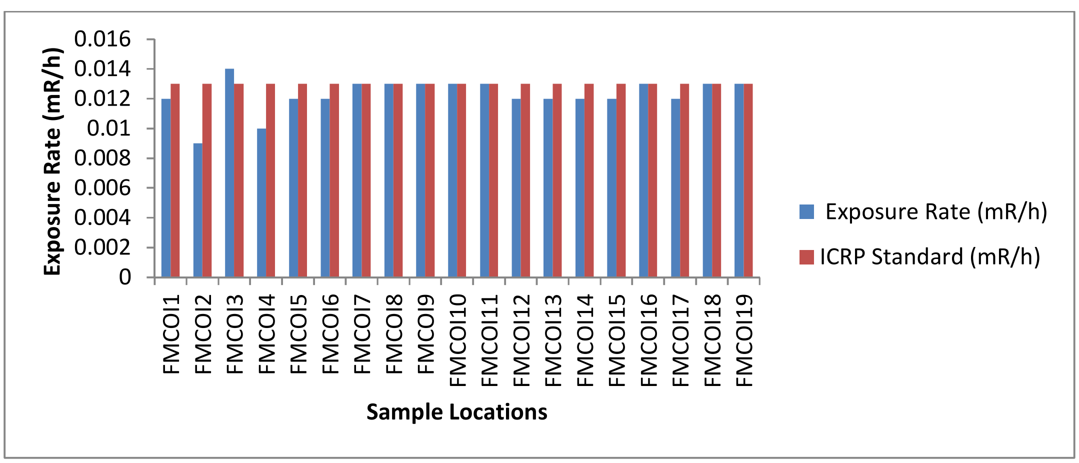

Fig. 1. Comparison of exposure rate of FMC Owerri indoor and ICRP standard

Table 1. Outdoor radiation exposure rates measured at FMC Owerriand its parameters

S/N	Location	GPS reading	Exposure rate (mR/h) outdoor	Absorbed dose (nGy/h)	AEDE (mSv/y) outdoor	ELCR X 10^{-3}
1	Public Relations Unit	N05°30.148' E007°01.372'	0.011±0.002	95.7	0.15	0.53
2	Block A	N05°30.167' E007°01.362'	0.013±0.004	113.1	0.18	0.63
3	Family Planning	N05°30.169' E007°01.343'	0.011±0.003	95.7	0.15	0.53
4	Radiology	N05°30.196' E007°01.338'	0.011±0.002	95.7	0.15	0.53
5	Gate By Dental Clinic	N05°30.189' E007°01.457'	0.012±0.001	104.4	0.17	0.60
6	Dump Site	N05°30.216' E007°01.437'	0.012±0.001	104.4	0.17	0.60
7	Medical Oxygen Plant	N05°30.220' E007°01.422'	0.014±0.003	121.8	0.19	0.67
8	Fuel Depot	N05°30.189' E007°01.404'	0.012±0.003	104.4	0.17	0.60
9	Generator House	N05°30.214' E007°01.379'	0.01 4±0.003	121.8	0.19	0.67
10	Block B	N05°30.203' E007°01.375'	0.014±0.006	121.8	0.19	0.67
11	Statistics Office	N05°30.127' E007°01.329'	0.010±0.002	87.0	0.14	0.49
12	Accident And Emergency	N05°30.118' E007°01.334'	0.011±0.004	95.7	0.15	0.53
13	Emergency Pediatrics Unit	N05°30.145' E007°01.291'	0.011±0.002	95.7	0.15	0.53
14	Histopathology Dept.	N05°30.096' E007°01.214'	0.012±0.002	104.4	0.17	0.60
15	Car Park By Accident And Emergency	N05°30.128' E007°01.305'	0.013±0.003	113.1	0.18	0.63
16	Ward 11	N05°30.084' E007°01.271'	0.011±0.001	95.7	0.15	0.53

S/N	Location	GPS reading	Exposure rate (mR/h) outdoor	Absorbed dose (nGy/h)	AEDE (mSv/y) outdoor	ELCR X 10^{-3}
17	Ward 10	N05°30.082' E007°01.268'	0.010±0.001	87.0	0.14	0.49
18	Ward 7	N05°30.086' E007°01.279'	0.013±0.002	113.1	0.18	0.63
19	Ward 6	N05°30.089' E007°01.291'	0.013±0.004	113.1	0.18	0.63
20	Main Theatre	N05°30.093' E007°01.302'	0.011±0.002	95.7	0.15	0.53
21	Servicom	N05°30.090' E007°01.333'	0.013±0.003	113.1	0.18	0.63
22	Children Out Patient	N05°30.118' E007°01.336'	0.013±0.004	113.1	0.18	0.63
23	Doctor's Lounge	N05030.104' E007001.375'	0.014±0.002	121.8	0.19	0.67
24	Pharmacy	N05°30.125' 25E007°01.389'	0.012±0.002	104.4	0.17	0.60
25	Laundry	N0265°30.123' E007°01.405'	0.010±0.001	87.0	0.14	0.49
26	Labor Ward	N05°30.131' E007°01.435'	0.011±0.003	95.7	0.15	0.53
27	House Officers Quarters	N05°30.081' E007°01.453'	0.011±0.002	95.7	0.15	0.53
28	Special Care Complex	N05°30.098' E007°01.449'	0.013±0.003	113.1	0.18	0.63
29	Main Gate	N05°30.088' E007°01.473'	0.013±0.002	113.1	0.18	0.63
	Mean		**0.013±0.002**	**104.7**	**0.17**	**0.59**

Table 2. Outdoor radiation exposure rate measured at FMC Umuahia and its parameters

S/N	Location	GPS readings	Exposure rate (mR/h) outdoor	Absorbed dose (nGy/h)	AEDE (mSv/y) outdoor	ELCR X 10^{-3}
1	Car Park	N05°31.324' E007°29.626'	0.015±0.005	130.5	0.21	0.74
2	Gate (Main)	N05°31.354' E007°29.625'	0.014±0.004	121.8	0.19	0.67
3	Mortuary	N05°31.386' E007°29.635'	0.015±0.003	130.5	0.21	0.74
4	Accident And Emergency	N05°31.287' E007°29.636'	0.012±0.003	104.4	0.17	0.60
5	Community Medicine	N05°31.230' E007°29.615'	0.013±0.03	113.1	0.18	0.63
6	Special Out Patient Dept.	N05°31.256' E007°29.632'	0.014±0.003	121.8	0.19	0.67
7	ENT/Dental Clinic	N05°31.260' E007°29.609'	0.013±0.002	113.1	0.18	0.63
8	Pediatrics Department	N05°31.229' E007°29.640'	0.011±0.002	95.7	0.15	0.53
9	Antenatal/Gynae Clinic	N05°31.217' E007°29.630'	0.010±0.002	87.0	0.14	0.49
10	New Complex Laboratory	N05°31.232' E007°29.655'	0.014±0.003	121.8	0.19	0.67
11	Kirk Ward/Dots Center	N05°31.139' E007°29.645'	0.014±0.003	121.8	0.19	0.67
12	A.R.T. Unit And Heart To Heart	N05°31.164' E007°29.663'	0.015±0.002	130.5	0.21	0.74
13	Postnatal Ward	N05°31.156' E007°29.680'	0.015±0.003	130.5	0.21	0.74
14	By School Of Midwifery Post	N05°31.151' E007°29.734	0.017±0.007	147.9	0.23	0.81
15	By School Of Nursing Post	N05°31.209' E007°29.793'	0.013±0.003	113.1	0.18	0.63
16	Shops Area	N05°31.303' E007°29.744'	0.013±0.003	113.1	0.18	0.63

S/N	Location	GPS readings	Exposure rate (mR/h) outdoor	Absorbed dose (nGy/h)	AEDE (mSv/y) outdoor	ELCR X 10^{-3}
17	By Generator House	N05°31.343' E007°29.686'	0.012±0.004	104.4	0.17	0.60
18	Medical Library	N05°31.375' E007°29.656'	0.014±0.002	121.8	0.19	0.67
19	Physiotherapy	N05°31.325' E007°29.657'	0.013±0.003	113.1	0.18	0.63
20	NHIS Offices	N05°31.323' E007°29.667'	0.012±0.002	104.4	0.17	0.60
21	Mental Health	N05°31.303' E007°29.668'	0.012±0.002	104.4	0.17	0.60
22	New Admin. Block	N05°31.321' E007°29.682'	0.011±0.002	95.7	0.15	0.53
23	Orthopedic	N05°31.243' E007°29.686'	0.017±0.005	147.9	0.23	0.81
24	Batley Ward	N05°31.293' E007°29.708'	0.016±0.003	139.2	0.22	0.77
25	Inner wheel Park	N05°31.280' E007°29.718'	0.012±0.003	104.4	0.17	0.60
26	Children's Ward B	N05°31.264' E007°29.723'	0.013±0.003	113.1	0.18	0.63
27	Children's Ward A	N05°31.275' E007°29.719'	0.013±0.002	113.1	0.18	0.63
28	Radiology	N05°31.231' E007°29.717'	0.012±0.002	104.4	0.17	0.60
29	New Surgical Ward	N05°31.252' E007°29.755'	0.014±0.004	121.8	0.19	0.67
30	Main Theatre	N05°31.255' E007°29.731'	0.013±0.002	113.1	0.18	0.63
31	Nursing Services Department	N05°31.261' E007°29.732'	0.014±0.004	121.8	0.19	0.67
	Mean		**0.014±0.013**	**116.8**	**0.19**	**0.65**

Table 3. Indoor radiation exposure rate measured at FMC Umuahia and its parameters

S/N	Location	Exposure rate (mR/h) indoor	Absorbed dose (nGy/h)	AEDE (mSv/y) ind.	ELCR x 10^{-3}
1	Accident And Emergency	0.017±0.005	147.9	0.69	2.42
2	Family Planning Clinic	0.012±0.003	104.4	0.49	1.72
3	Community Health	0.015±0.003	130.5	0.61	2.14
4	Special Out Patient Dept.	0.014±0.005	121.8	0.57	2.00
5	ENT Clinic	0.013±0.004	113.1	0.53	1.86
6	Pediatrics Dept.	0.013±0.004	113.1	0.53	1.86
7	Antenatal/Gynae Clinic	0.014±0.006	121.8	0.57	2.00
8	New Complex Laboratory	0.015±0.003	130.5	0.61	2.14
9	Anesthetists Call Room	0.015±0.001	130.5	0.61	2.14
10	Physiotherapy	0.016±0.004	139.2	0.65	2.28
11	New Admin. Block	0.013±0.004	113.1	0.53	1.86
12	Orthopedic	0.012±0.002	104.4	0.49	1.72
13	Batley Ward	0.013±0.002	113.1	0.53	1.86
14	Radiology General Office	0.018±0.003	156.6	0.73	2.56
15	CT Scan Room	0.013±0.004	113.1	0.53	1.86
16	CT Operation Room	0.011±0.004	95.7	0.45	1.58
17	Radiology Reception	0.016±0.004	139.2	0.65	2.28
18	CT Work Station	0.012±0.003	104.4	0.49	1.72
19	X-Ray Film Collection Room	0.026±0.018	226.2	1.05	3.68
20	New Surgical Ward	0.013±0.003	113.1	0.53	1.86
21	Main Theatre	0.015±0.003	130.5	0.61	2.14
22	X-Ray Room 1	0.009±0.002	78.3	0.37	1.30
23	Surgery Dept.	0.011±0.004	95.7	0.45	1.58
24	Pharmacy	0.010±0.002	87.0	0.41	1.44
25	X-Ray Room Children Emergency	0.011±0.003	95.7	0.45	1.58
26	Children Emergency	0.012±0.005	104.4	0.49	1.72
	Mean	**0.014±0.003**	**120.1**	**0.56**	**1.97**

Table 4. Indoor radiation exposure rate measured at FMC Owerri and its parameters

S/N	Location	Exposure rate (mR/h) indoor	Absorbed dose (nGy/h)	AEDE (mSv/y) indoor	ELCR X 10^{-3}
1	X- ray Room1	0.012±0.003	104.4	0.49	1.72
2	Digital X - ray Room	0.009±0.002	78.3	0.37	1.3
3	Reporting Room	0.014±0.002	121.8	0.57	2
4	Mammogram Room	0.01±0.003	87	0.41	1.44
5	X- ray Room2	0.012±0.003	104.4	0.49	1.72
6	X - ray Room 1	0.012±0.003	104.4	0.49	1.72
7	Male Ward	0.013±0.001	113.1	0.53	1.86
8	Female Ward	0.013±0.003	113.1	0.53	1.86
9	Obstetrics Ward	0.013±0.003	113.1	0.53	1.86
10	Post - Natal Ward	0.013±0.002	113.1	0.53	1.86
11	Pre - Natal Ward	0.013±0.002	113.1	0.53	1.86
12	Dental Clinic	0.012±0.003	104.4	0.49	1.72
13	Labour Ward	0.012±0.004	104.4	0.49	1.72
14	Special care complex	0.012±0.002	104.4	0.49	1.72
15	Male Surgical	0.012±0.002	104.4	0.49	1.72
16	Ward 7	0.013±0.003	113.1	0.53	1.86
17	Female Surgical	0.012±0.002	104.4	0.49	1.72
18	Ward 10	0.013±0.002	113.1	0.53	1.86
19	Accident and Emergency	0.013±0.002	113.1	0.53	1.86
	Mean	**0.012±0.002**	**106.7**	**0.50**	**1.76**

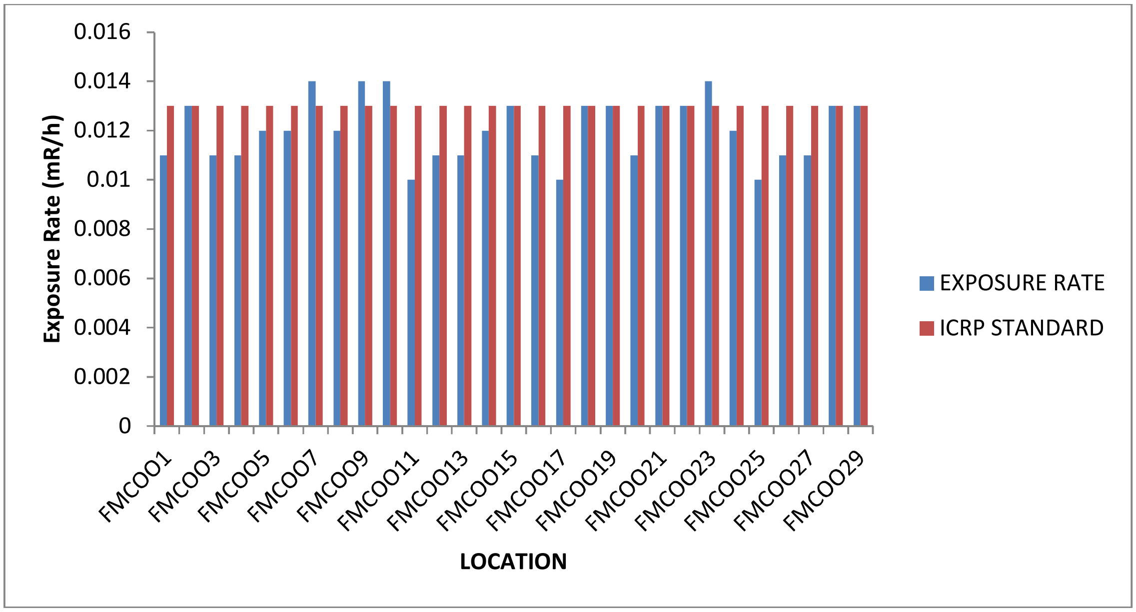

Fig. 2. Comparison of exposure rate of FMC Owerri outdoor and ICRP standard

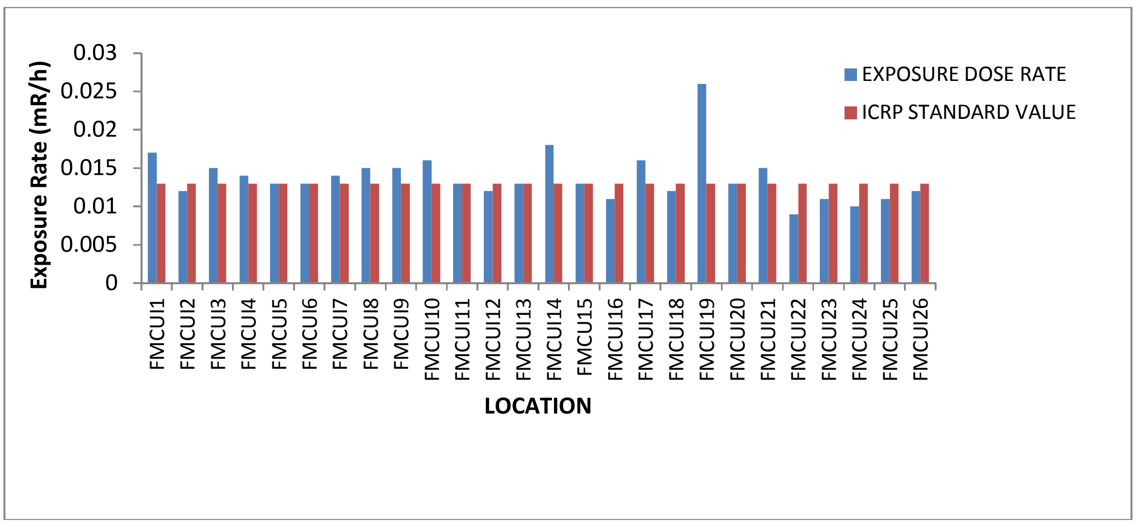

Fig. 3. Comparison of exposure rate of FMC Umuahia indoor and ICRP standard

4. DISCUSSION

The results got show variations in the values of indoor and outdoor radiation levels. This can be ascribed to the differences in radionuclide concentrations from the roof, walls, air and scattered radiation from imaging rooms. The exposure rate for FMC Umuahia, ranged from 0.016 to 0.026 mR/h with a mean of 0.014 mR/h (indoor) and 0.010 mR/h to 0.017mR/h with a mean of 0.013 mR/h (outdoor).At FMC Umuahia 45% of the locations (outdoor) had exposure dose rates equal to or above the standard value of 0.013 mR/h, while 55% were below. 42% of values indoor were equal to or above the standard value, while 58% were below. This is shown in Figs. 3 and 4. The highest measurement of 0.026 mR/h was recorded by the door of the X – ray room when a procedure was going on. This could be due radiation leakage from the door. It is therefore necessary to make sure the door to the X- ray room is closed tightly to avoid radiation leakage. The exposure values show that the radiation levels indoor are higher than those outdoor. This can be mean that radiation is leaking from diagnostic rooms due to inefficiency of walls or doors of the rooms [8]. Surprisingly the X –ray room had the lowest reading of 0.009mR/h. This compares to results obtained by Okoye and Avwiri, [4], where the radiology department had a mean exposure value lower than the general average of the hospital.

For FMC Owerri, the exposure rate ranged from 0.009 to 0.014 mR/h with a mean of 0.012 mR/h (indoor) and 0.010 mR/h to 0.014 mR/h with a mean of 0.013 mR/h (outdoor). 86% of these values (outdoor) were equal to or higher than the standard value of 0.013 mR/h, while 14% was lower. For indoor, 5% was higher while 95% was equal to or higher. This is shown in Figs. 1 and 2. The highest value (outdoor) of 0.014 mR/h was gotten close to the oxygen plant and the generator house. The result from the generator house can be due to leakages of petroleum products which has been associated with radionuclides [9]. While the highest value (indoor) was gotten from the X – ray reporting room while the lowest was gotten in the digital X – ray room.

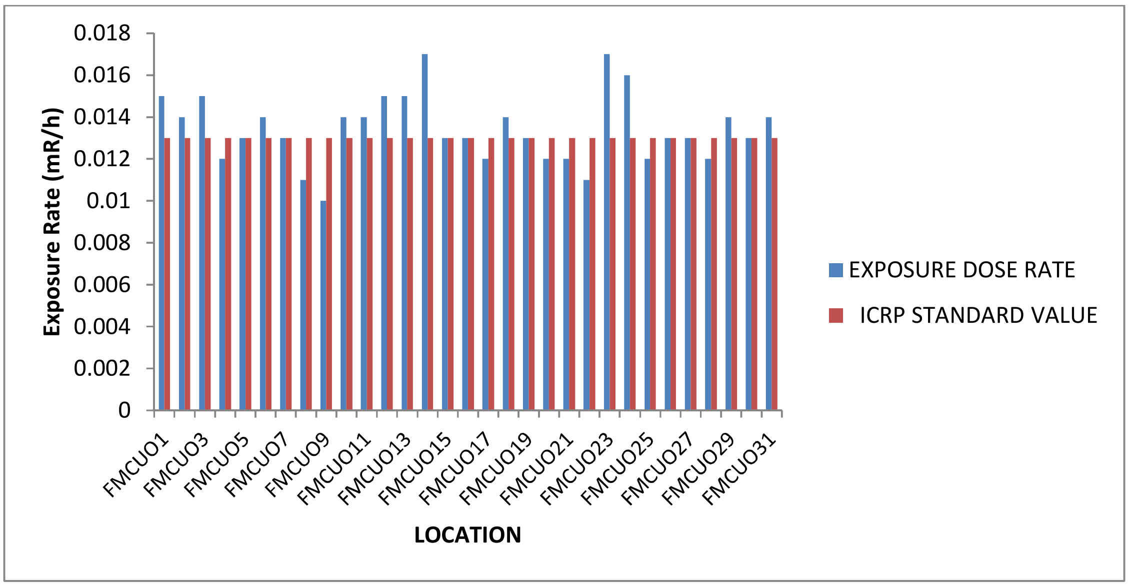

Fig. 4. Comparison of exposure rate of FMC Umuahia outdoor and ICRP standard

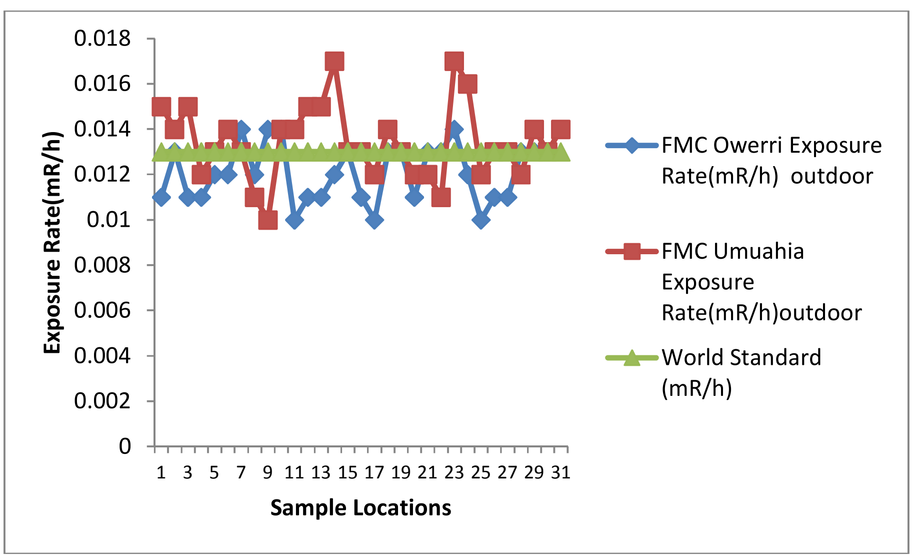

Fig. 5. Comparison of world standard exposure rate with that of FMC Owerri and FMC Umuahia (outdoor)

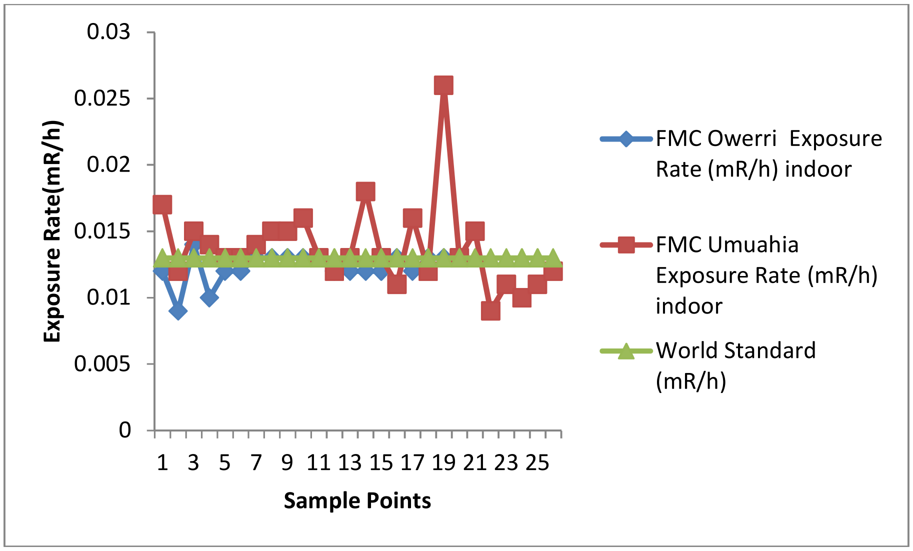

Fig. 6. Comparison of world standard exposure rate with that of FMC Owerri and FMC Umuahia (indoor)

Figs. 5 and 6 represent the comparison of the indoor and outdoor exposure dose rates for the two hospitals with the World Standard. The mean values for FMC Umuahia (outdoor) and FMC Owerri (indoor) and (outdoor) are within the ICRP standard of 0.013 mR/h, while FMC Umuahia (indoor) is higher. The correlation of the indoor and outdoor of the two hospital showed no correlation, which shows that the radiation indoor is not dependent on the radiation from outdoor. Therefore there is need to monitor radiation indoor to make sure they do not go above the standard to prevent radiation risks to staff of the radiology department.

5. CONCLUSION

The background exposure rate for FMC Umuahia and FMC Owerri were measured using two radiation meters and a global positioning system (GPS). The results obtained were used to calculate the associated radiation risk parameters which are used to estimate the associated health hazard indices. The following results were obtained:

1. The highest exposure rate of 0.026mR/h was recorded at the X – ray film collection room at FMC Umuahia. This might due to radiation leakage from the X – ray room. The measurement was taken by the door when a procedure was being carried out.
2. The indoor and outdoor absorbed dose rate obtained are 120.1 nGy/h and 116.8 nGy/h for FMC Umuahia respectively and 106.7 nGy/h and 104.7 nGy/h respectively for FMC Owerri.
3. The mean values of the absorbed dose rates for the hospitals are greater than the world population weighted average rate of 89 nGy/h [10].
4. Estimated mean indoor and outdoor annual effective dose equivalent are 0.56 mSv/y and 0.019 mSv/y respectively for FMC Umuahia and 0.50 mSv/y and 0.17mSv/y respectively for FMC Owerri.
5. Estimated mean indoor and outdoor ELCR are 1.97×10^{-3} and 0.65×10^{-3} respectively for FMC Umuahia and 1.76×10^{-3} and 0.59×10^{-3} respectively for FMC Owerri.

Generally the results showed high levels of background ionizing radiation. This might not pose an immediate health problems to patients and staff of the hospitals, but long term exposure might pose some radiological risk. Therefore regular monitoring is necessary.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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