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EVALUATION OF EFFECTIVE DOSE AND EXCESS LIFETIME CANCER RISK FROM INDOOR AND OUTDOOR GAMMA DOSE RATE OF UNIVERSITY OF PORT HARCOURT TEACHING HOSPITAL, RIVERS STATE.

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ABSTRACT

An in-situ measurement of indoor and outdoor radiation dose rate at the University of Port Harcourt Teaching hospital was done using well calibrated radiation meter (Radalert-100). The minimum and maximum indoor gamma dose rate were found to be 121.8 ±4.02 nGyh^{-1} and 200.1±5.06 nGyh^{-1} respectively while the minimum and maximum outdoor gamma dose rates were 87.0 ±2.07nGyh^{-1} and 200.1± 4.07nGyh^{-1}. The study also revealed that the average annual effective dose rate is 0.31±0.002 mSvy^{-1} and 0.92 ±0.02 mSvy^{-1}for outdoor and indoor measurements respectively. In addition, the excess lifetime cancer risk (ELCR) calculated for indoor exposure ranges from 1.68 × 10^{-3} to 3.22 × 10^{-3} with an average value of 0.83 × 10^{-3}. For outdoor exposure ELCR varies from 0.46 × 10^{-3} to 1.09 × 10^{-3} with a mean value of 2.289 × 10^{-3}. The average values for indoor and outdoor gamma doses were found to be greater than the world population weighted average for indoor gamma dose rate of 89 nGyh^{-1}. The result shows that ELCR for both indoor and outdoor exposure were higher than the world acceptable value of 0.29 × 10^{-3},though the annual effective dose levels in all of the locations (indoor and outdoor) were below the 1mSvy^{-1} maximum permissible limit for the public set by International Commission on Radiological protection (ICRP). Therefore, the management of University of Port Harcourt teaching hospital should undertake a routine maintenance of diagnostic equipment(x-ray machines, CT scanners) may have to avoid leakage which may have contributed to the enhancement of background radiation of the hospital.

Key words: Dose rate, absorbed dose, background radiation, effective dose, ELCR, radiological,

INTRODUCTION

Background ionizing radiation which was originally attributed to cosmic sources has over the years increased due to advances in technology apart from terrestrial radiations from the environment. Radiation from hospitals and medical research institutes has been of great concern because of the known effects of exposure to high doses of radiations (Okoye, *et al.*, 2012). Background radiations of hospitals may be enhanced due to radiological activities that involve the use of ionizing radiations in medical imaging and treatments.

Human beings are always exposed to radiation in their environment without knowing it and the exposure to natural background radiation is unavoidable event in human environment (Ononugbo and Nwii, 2015). Several studies on impact of ionizing radiation on human health have produced substantial evidence that exposure to high level of radiation can cause radiation sickness or even death (Muhammad et al., 2014). Health hazards associated with exposure to ionizing radiation includes; direct chromosomal transformation, indirect free radical formation, cataractogenesis, cancer induction, bone necrosis (Norman, 2008).

Exposure to natural radiation from the environment is higher than the ones from man induced sources (technology) put together (UNSCEAR, 2010) and the International Atomic Energy Agency (IAEA) estimated that dose contribution to the environment shows that 80% of the background radiation received by man is derived from natural sources while the remaining 20% is from the artificial sources. The global average natural dose of background ionizing radiation to humans is about 2.40mSvy^{-1} (UNSCEAR, 2008). Main source of these background radiations is radon and its progenies, contributing 1.2 mSv per year. After radon, next highest percentage of background radiation comes from cosmic and terrestrial sources respectively. Terrestrial radiations coming from rocks and soil (containing radionuclides of different concentration) vary depending upon geographical locations.

In Nigeria, studies have been conducted in various part of the country to measure the natural background radiation level around government hospitals. Measurement of background ionizing radiation level at Braithwaite Memorial specialist hospital, Port Harcourt revealed that Indoor annual equivalent dose ranged from 0.14±0.01μSvhr^{-1} to 0.16±0.01μSvhr^{-1} (Okoye and Avwiri, 2013). It was also reported that the indoor equivalent dose of 2.063mSvyr^{-1} was recorded at Skane Radiological centre Jos, while the outdoor of the same diagnostic center recorded 1.84mSvy^{-1}(Jwanbot *et al*., 2012). In Plateau State Specialist hospital, indoor equivalent dose of radiation was 2.44msvyr^{-1} and outdoor radiation dose equivalent was 2.002mSvyr^{-1} (Jwanbot *et al*., 2012). All these studies did not consider the cancer risk associated with exposure to background ionizing radiation within and around teaching hospitals. This present work aims at measuring the indoor and outdoor background radiation level of University of Port Harcourt Teaching Hospital (UPTH) in Rivers State and from obtained data, we shall estimate the excess lifetime cancer risk from the absorbed dose of radiation of the general public. The result of this survey will serve as baseline data for future research.

MATERIALS AND METHODS

The study area is the environment of University of Port Harcourt Teaching Hospital (UPTH). It lays between latitude N04º53'58″, longitude E006º55'43″. It involves the surroundings of the hospital (outdoor) and inside of the hospital (indoor). Rivers state lies on the coastal plain of the eastern Niger Delta. Its surface geology consists of fluvial sediments. These include the recent sediments transported by Niger River distributaries and rivers such as Andoni, Bonny and New calabar. These materials deposited as regolith overburden of 30m thickness are clays, peat, silts sands and gravels. The hospital is equipped with medical imaging equipment like x-ray machine, CT scanner Ultra sound scanner and so on. X-ray machine generates radiation during its normal operation.

A GPS based *in-situ* gamma survey was conducted using a portable nuclear radiation monitor, Radalert-100 (manufactured by

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S.E. International Inc., USA). It is used for low level gamma surveys and consists of 2.5cm ×2.5cm NAI (TI) Scintillator. Its' sensitivity is 17500 cpm/ µSv/h, based upon Cs- 137 gamma. The detector has energy dependent response and gamma dose rate were measured at the distance of one meter above the ground. A Radalert - 100 nuclear radiation monitoring meter containing a Geiger-Muller tube capable of detecting α, β, γ and x-rays within the temperature range of -10^{0}C to 50^{0}C were used to measure the radiation levels, while a geographical positioning system (GPS) was used to measure the precise location of sampling point and before each measurement, equipment were characterized for environmental measurement.

The tube of the radiation monitoring meter was raised to the standard height of 1.0 m above the ground (Ononugbo et al., 2011) with its window facing the site to be measured and then vertically downward, while the GPS readings taken at that spot. The GM-tube generates a pulse of electrical current each time radiation passes through the tube and causes ionization and each pulse is electronically detected and registered as a count. Readings were obtained between the hours of 1300 and 1600 hours, because the exposure rate meter has a maximum response to environmental radiation within these hours (Ononugbo *et al*., 2011).

For each location three measurements spanning over 2 minutes were carried out and these measurements were then averaged to single value. Data obtained for the external exposure rate in µR/h was converted into absorbed dose rate (nGy/h) using the conversion factor (Muhammad *et al*., 2014):

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

RESULTS

Indoor and outdoor Radiation environment

The indoor exposure dose rates were measured at the centers of each room of different sections of the University Teaching hospital, Port Harcourt and at the several locations in the rooms at varying heights using hand held radiation survey meters (Radalert-100) and global positioning system (GPS). Outdoor dose rates were also measured outside/surrounding of the same hospital. Table 1 shows the result of outdoor exposure dose rates and the calculated effective doses and excess lifetime cancer risk due to exposure to outdoor radiations while Table 2 shows the result of indoor exposure dose rates and the calculated effective doses and excess lifetime cancer risk due to exposure to indoor radiations. The outdoor exposure dose rate measured ranges from 0.012± 0.001 mRh^{-1} to 0.023±0.002 mRh^{-1}. Also the indoor exposure dose rate measured ranges from 0.012±0.001 mRh^{-1} to 0.023±0.002 mRh^{-1}. Both indoor and outdoor exposure dose rates measured in the University of Port Harcourt Teaching Hospital, exceeded the ICRP, 2003 standard value of 0.013mRh^{-1} except at two points of the hospital: the reception and in front of laundry department.

The Annual Effective Dose Equivalent (AEDE)

Measured absorbed gamma dose rates were used to calculate the annual effective dose equivalent (AEDE) received by patients and staff of the hospital surveyed. For calculating AEDE we have used dose conversion factor of 0.7 Sv/Gy and the occupancy factor for indoor and outdoor was 0.75 (18/24), and 0.25 (6/24) respectively. Peoples of study area spent almost 6 h in outdoor and 18 h in indoor environment. The annual effective dose is determined using the following equations (Muhammad et al., 2014).

$AEDE_{(outdoor)}$ (mSv/y) = Dose rate (nGy/h) x 8760h x 0.7Sv/Gy x 0.25 ……(2)

$AEDE_{(indoor)}$ ($mSvy^{-1}$) = Dose rate (nGy/h) × 8760h × 0.7 × 0.75 ………………….,(3)

In the UNSCEAR 1993 report the Committee used 0.7 Sv/Gy for the conversion coefficient from absorbed dose in air to effective dose received by adults. Estimated values of annual effective dose equivalent for outdoor exposure AEDE ranges from 0.16 mSv to 0.36 mSv while the indoor annual effective dose equivalent ranges from 0.48mSv to 0.92 mSv. The indoor AEDE in all the sections of the teaching hospital exceeded the worldwide average of the annual effective dose 0.48 mSv (Muhammad *et al.*, 2014) while the outdoor AEDE values are within the world safe value.

Excess Lifetime Cancer Risk (ELCR)

Based upon calculated values of AEDE, Excess Lifetime Cancer Risk (ELCR) is calculated using Equation (3).

Excess lifetime cancer risk (ELCR) = AEDE x Average duration of life (DL) x Risk factor (RF) ………………………. (3)

where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and Risk factor (http://en.worldstat.info/Asia/ Pakistan) and risk factor (Sv^{-1}), fatal cancer 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 exposure. Estimated excess lifetime cancer risk (ELCR) from outdoor annual effective dose ranges from 0.56 x 10^{-3} to 1.26 x 10^{-3} while for indoor ELCR ranges from 1.68 x 10^{-3} to 3.22 x 10^{-3}. All the ELCR calculated exceeded the worldwide average value of 0.29 x 10^{-3} (Taskin *et al*., 2009).

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Table 1: Outdoor Exposure dose rate Measured and the associated Risk parameter in UPTH

S/N	Sample point	Sample code	Geographical location	Exposure Rate mR/h	Absorbed Dose (nGy/h)	AEDE mSv/y	ELCR x 10^{-3}
1	Entrance of GOPD	EOD	N04º53'58.7″ E006º55'38.4	0.017±0.001	147.9	0.23	0.81
2	physiotherapy	PHY	N04º53'006″ E006º55'38.1″	0.019±0.003	165.3	0.25	0.88
3	A & E	A &E	N04º53'38.1″ E006º55'39.2	0.023±0.002	200.1	0.31	1.09
4	Medical Library	MDL	N04º54'02.2″ E006º55'40.2″	0.019±0.002	165.3	0.25	0.88
5	Full stored oxygen	FSO	N04º54'01.6″ E006º55'41.4″	0.020±0.003	174.0	0.27	0.95
6	Anesthesiology dept	DOF	N04º54'01.6″ E006º55'42″	0.022±0.002	191.4	0.29	1.02
7	Laundry department	LD	N04º54'02.1" E006º55'42	0.012±0.003	104.4	0.16	0.56
8	Anatomic pathology unit	APU	N04º54'03.9" E006º55'41	0.019±0.001	165.3	0.25	0.88
9	Around mortuary dump site	AMDS	N04º54'06.1" E006º55'40	0.016±0.002	139.2	0.21	0.74
10	Around generator plant	AGP	N04º54'05.2" E006º55'42.8"	0.017±0.001	147.9	0.23	0.81
11	Incinerator house	IH	N04º54'04.6" E006º55'44.0"	0.018±0.003	156.6	0.24	0.84
12	Generator house	GH	N04º54'02.6" E006º55'47.0"	0.020±0.002	174.0	0.27	0.95
13	Oxygen plant	OP	N04º54'00.6" E006º55'46.3"	0.019±0.002	165.3	0.25	0.88
14	Dietetic department	DP	N04º53'59.3" E006º55'45.7"	0.017±0.001	147.9	0.23	0.81
15	Near Dietetic department	NDP	N04º54'56.3" E006º55'44.7"	0.018±0.003	156.6	0.24	0.84
16	Opposite mothers room	SCBU	N04º53'56.5" E006º55'44.9"	0.010±0.001	87.0	0.13	0.46
17	Junction	JOU	N04º53'54.7" E006º55'43.9"	0.016±0.001	139.2	0.21	0.74
18	Pediatric department	PED	N04º53'54.0" E006º55'46.5"	0.019±0.003	165.3	0.25	0.88
19	Children emergency	CE	N04º54'56.3" E006º55'44.7"	0.017±0.002	147.9	0.23	0.81
20	Main entrance	ME	N04º53'58.0" E006º55'42.1"	0.017±0.012	147.9	0.23	0.81

Table 2: Indoor Exposure Rate measured and the associated Risk parameters at UPTH.

S/N	Sample point	Sample code	Geographical location	Exposure Rate mR/h	D (nGy/h)	AEDE mSv/y	ELCR x 10^{-3}
1	Reception	RME	N04°53'52.1" E006°55'43.1"	0.018±0.001	156.6	0.72	2.52
2	Radiological unit	RDU	N04°53'52.1" E006°55'43.1"	0.023±0.002	200.1	0.92	3.22
3	Haemodialysis unit	HDU	N04°53'52.1" E006°55'43.1"	0.016±0.001	139.2	0.64	2.24
4	Pharmacy	PSI	N04°53'52.1" E006°55'43.1"	0.017±0.003	147.9	0.68	2.38
5	Consulting & seminar room	C&SR	N04°53'52.2" E006°55'43.1"	0.014±0.002	121.8	0.56	1.96
6	Reception family medicie	GOPD	N04°53'51.2" E006°55'43.0"	0.016±0.003	139.2	0.64	2.24
7	Physiotherapy reception	PTR	N04°53'51.2" E006°55'43.0"	0.017±0.003	147.9	0.68	2.38
8	DOTS centre	DOT	N04°53'53.1" E006°55'42.1"	0.017±0.003	147.9	0.68	2.38
9	A & E Reception	AER	N04°54'02.3" E006°55'39.2"	0.012±0.002	104.4	0.48	1.68
10	Metabolic and hematology	MHC	N04°53'52.1" E006°55'43.1"	0.017±0.003	147.9	0.68	2.38
11	Pharmacy depart	PMD	N04°54'02.1" E006°55'40.2"	0.015±0.001	130.5	0.60	2.10
12	Library annex	LMA	N04°53'02.6" E006°55'48.1"	0.015±0.001	130.5	0.60	2.10
13	Anesthesiology department	AHD	N04°53'02.6" E006°55'47.2"	0.014±0.002	121.8	0.56	1.96
14	Surgery dept**.**	AHD	N04°53'02.6" E006°54'45.4"	0.017±0.003	147.9	0.68	2.38
15	Dental clinic	SUG	N04°53'02.6" E006°55'48.1"	0.015±0.001	130.5	0.60	2.10
16	GODP clinic	GOPDC	N04°53'02.6" E006°55'48.1"	0.015±0.001	130.5	0.60	2.10
17	Neuropsycholo	NSRG	N04°53'56.3" E006°55'45.7"	0.017±0.003	147.9	0.68	2.38
18	Orthopedic dept	OHD	N04°53'54.6" E006°55'46.5"	0.014±0.002	121.8	0.56	1.96
19	Endoscopy units	EDU	N04°53'54.2" E006°55'43.2"	0.015±0.001	130.5	0.60	2.38
20	Ward way	WDW	N04°53'02.6" E006°55'48.1"	0.021±0.004	182.7	0.84	2.94

DISCUSSION

The indoor variations of gamma dose rates from outdoor dose rates might be due to differences in concentrations of radionuclides emitting gamma ray in air, walls ceilings and roofs of the buildings and scattered radiations from imaging room. Only sample point SCBU and A & E reception recorded lower values due to their distance away from radiological units. Wide

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variations were observed in indoor gamma dose rates quantified in different locations of the buildings ranging from104.4 nGyh^{-1} to 200.1 nGyh^{-1}. This is due to varying activities that employs radioactive source for its daily operation. For instance, x-ray machines and CT scanners that generate x-rays during an imaging procedure could enhance the background radiation level of the surrounding environment of the diagnostic unit. Other reasons could be the differences in natural ventilation rate of the building that would alter the concentration of gamma emitting radionuclide (Radon and Thoron) inside dwelling (James *et al.,* 2015). Mean outdoor and indoor gamma dose rates measured for this study were 1352.76 µGyy^{-1} (154.43 nGyh^{-1}) and 1238.45 µGyy^{-1} (141.38 nGyh^{-1}) respectively. The indoor gamma dose rate measured in this study is greater than those reported from other countries like USA (333 µGyy^{-1}), Italy(920.0 µGyy^{-1}), New Zealand (175 µGyy^{-1}), Japan (464 µGyy^{-1}), Poland (587 µGyy^{-1}), Germany (613 µGyy^{-1}), Australia (902 µGyy^{-1}) and United Kingdom (526 µGyy$^{-1)}$ (UNSCEAR, 2000). Gamma absorbed dose rate of indoor environment studied are appreciably higher than those of UNSCEAR estimates for population weighted average of world 84 nGyh^{-1} (UNSCEAR, 2000). Generally the estimated indoor absorbed dose of radiation obtained are slightly lower than the previous result from private diagnostic centers in Bori Rivers state (Ononugbo and Nwii, 2015), Plateau state specialist hospital (Jwanbot et al., 2012) and slightly higher that than results from Braithewaite memorial specialist hospital, Port Harcourt (Okoye and Avwiri, 2013), Kwali General hospital, Abuja (James et al., 2015). This variation may be due to radiation leakages from the imaging equipment of some hospitals and also operational practices of imaging and unlined walls of the imaging rooms.

The annual effective dose estimated from absorbed dose of indoor and outdoor dose rates fall within the safe limit of 1.0 mSv stipulated by the International Council for Radiation Protection (ICRP, 2003) and WHO (2008) for the general public. The excess lifetime cancer risk estimated from both indoor and outdoor annual effective dose, exceeded the world acceptable limit of 0.29× 10^{-3} (Taskin, 2009) at all the points. This implies that the patients and general public that uses the hospital might be exposed to high background radiations which might be detriment to their health for long term exposure.

Estimation of radiation hazards (absorbed dose, effective dose and excess lifetime cancer risk) from indoor and outdoor dose rates of University of Port Harcourt Teaching Hospital has been carried out using a GPS in-situ approach. Exposure dose rates measurement were done using a well calibrated radiation meter (Radalert-100) and a GPS at twenty locations within and outside the hospital. The study showed that the mean indoor and outdoor dose rates exceeded the safe standard value of 84.0 nGyh^{-1}. Though the annual effective dose estimated for both indoor and outdoor dose rate are within the safe limit of 1.0 mSv ,the excess lifetime cancer risk calculated from it were higher than the world acceptable value of 0.29× 10^{-3}.

The result showed that the background ionizing radiation of the study area has been enhanced due to radiological activities of the hospital which was evident on higher radiation risk estimated therefore, we recommend that proper and routine check and maintenance of X-ray units, the CT scanner and the mammographic unit be done to avoid leakages during operation. Also imaging rooms should be properly lined (shielded) and constant closing of the doors to reduce scattered radiation reaching the outside.

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