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Effective Doses and Excess Lifetime Cancer Risks from Absorbed Dose Rates Measured in Facilities of Two Tertiary Institutions in Nigeria

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ABSTRACT: This study was aimed at examining the radiation absorbed dose rate, annual effective doses and excess lifetime cancer risks of halls of residence, Radiotherapy Unit and Radiology Department of UI, UCH and UNIMEDTH respectively. Results of measurements show that the mean absorbed dose rate for male and female hall are 0.33 ± 0.05476 and 0.17 ± 0.05074 μSv h^{-1} respectively. The mean overall absorbed dose rates calculated for facilities studied are 0.269 ± 0.0992 μSv h^{-1}, 0.121 ± 0.036 μSv h^{-1} and 0.123 ± 0.00931 μSv h^{-1} in UI, UCH and UNIMEDTH respectively. The mean annual effective doses recorded in both male and female halls in University of Ibadan ranges between 0.71 mSv y^{-1} and 2.67 mSv y^{-1}. The mean annual effective doses obtained from the facility of University of Medical Sciences Teaching Hospital, Ondo (UNIMEDTH) ranges between 0.17 and 0.44 mSv y^{-1}. In addition, the mean annual effective doses calculated from the measured absorbed dose rate in Radiotherapy Department of University College Hospital, Ibadan ranges between 0.20 and 1.22 mSv y^{-1}. As regards ELCRs, the mean values determined in various facilities examined are 6.07 x 10^{-3} (Male Halls, UI), 3.27 x 10^{-3} (Female Halls, UI), 0.57 x 10^{-3} (UNIMEDTH- NE), 0.99 x 10^{-3} (UNIMEDTH- EX), 0.65 x x 10^{-3} (Teletherapy, UCH) and 0.57 x 10^{-3} (Brachytherapy, UCH).The mean ELCRs of both halls examined are higher than the world average of 1.45 x 10^{-3} and the standard value of 0.29 x 10^{-3} by at least a factor of 1.97 units.

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Keywords: Excess lifetime cancer risk; absorbed dose rate; annual effective dose; radiotherapy

Radiation is part of human existence and it is found almost everywhere (indoor, outdoor, rocks, Deep Ocean and intestinal track). It occurs naturally in the environment as a result of attempt by unstable elements to attain stability through emission of certain nuclear components. This is seen in the emission due to certain elements such as U-238, Th-232 and K-40 found in the earth crust. Radiation in the environment can also take its source from the cosmic rays whose origin is the outer space amidst galaxies. This usually affects high altitudes and spacecrafts. Another source of radiation found in the terrestrial environment originates from human and industrial activities. Human activities leading to the release of radiation to the environment could be from nuclear accident (Chernobyl), testing of atomic bomb, operation of nuclear reactor and certain therapeutic and diagnostic X-ray machines. A greater percentage of radiation dose received by man is from natural sources (Chongakar *et al.*, 2003) and about 3.9 % are man-made. The naturally occurring background radiation comes from the decay of some primordial elements resulting from uranium-238, thorium-232 and potassium-40 (Jibiri and Famodimu, 2013).

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Background radiation distribution varies with geological make-up of the underlying rocks of the region, ongoing and past human activities in a given location. Since radiation cannot be detected by human senses, the knowledge of its presence and extent in an environment are important. It is essential to determine the level of radiation in human environment. This knowledge helps to determine the likely health effects such that informed decisions in the health sector can be made by local, international regulatory bodies and the institutions concerned with public health. Measurement of level of radiation is important when radiological or nuclear activity is carried out in an environment. This enables one to ascertain the safety indices of such environment. Benrhardson *et al.,* (2012) observed that a serious events involving unwanted exposure to ionizing radiation will make it necessary to estimates the doses to the exposed individuals and the public in an attempt to support decision making. Example of such measurement was carried out in the Eastern Belarus affected by a major surface contamination of radionuclides from Chernobyl accident (Bernhardson *et al.,* 2012). As a result of environmental assessment of dose in the region, it was classified as an area of strict radiation control (Balonov, 2007), and the inhabitants were offered the opportunity to resettle to others of less radiation contamination. In addition, environment where radiological activities such as treatment and diagnosis are carried out are expected to be regularly monitored to prevent unwanted radiation in the environment due to leakages of equipment and other radiation sources. This study was aimed at examining the indoor dose rate, annual effective doses and excess lifetime cancer risks (ELCR) in two Teaching Hospitals and halls of residence of a university in Southwestern Nigeria.

MATERIALS AND METHODS

The Global Positioning System (GPS) was used to measure the location of the rooms examined in this study. The study locations (University of Ibadan) has a mean elevation of 200 meters above sea level and lies between latitudes N7^{o} 26^{l} and N7^{o} 21^{l} , and longitudes E 3^{o} 53^{l} , and E 3^{o} 54^{l} . University of Ibadan (UI) is found in southwestern Nigeria and northern part of Ibadan metropolis along Oyo-Ilorin road (Egunyinka *et al.,* 2009). It falls within the basement complex of geological setting of southwestern Nigeria characterized mainly by the metamorphic rock types of Precambrian age, but with few extrusion granite and porphyrites of Jurassic age (Jibiri and Okorie, 2006). The main forms of rocks found in UI are gneiss, quartzites and magnetite which originate from igneous and sedimentary rocks. The basement rocks are covered by superficial deposits which vary in thickness with location (Oresanya, 1984). The deposits are covered with laterites and clay topsoil.

Measurement of indoor dose rates was carried out in two University Teaching Hospitals and halls of residence of a University. The Teaching Hospitals include: (1) University College Hospital (UCH-Radiotherapy Department) and (2) University of Medical Sciences Teaching Hospital (UNIMEDTH-Radiology Department), Ondo (Lat:7.08^{o} N, Long.:4.79^{o} E). Dose rates were measured in females and males hostels in University of Ibadan. Female hostels monitored include Queen Elizabeth Hall (7.44^{o} N, 3.89^{o} E), Queen Idia Hall (7.48^{o}N, 3.89^{o} E), New Postgraduate Hall (7.48^{o} N, 3.89o E), St Anne Hall (7.46^{o} N, 3.89^{o} E), Obafemi Awolowo Hall (7.43^{o} N, 3.89^{o} E). The male hostels investigated within the University of Ibadan are Indy Hall (7.43 N, 3.89^{o} N), Tedder Hall (7.44^{o} N, 3.90^{o} E), Sultan Bello Hall (7.44^{o} N, 3.89 E), Zik Hall (7.44 ^{o} N, 3.89^{o} E), Obafemi Awolowo Hall (7.43^{o} N, 3.89^{o} E), Kuti Hall (7.43^{o} N, 3.89^{o} E), Mellanby Hall (7.44^{o} N, 3.89^{o} E) and New PG Hall (7.48^{o} N, 3.89^{o} E).

Measurement of Radiation: Measurements were carried out in both Radiology Department of University of Medical Sciences Teaching Hospital (UNIMEDTH), Ondo and Radiotherapy Department of University College Hospital (UCH), Ibadan. This was done with the aid of calibrated RADTRACE Survey Meter (RF000217) obtained from Radiotherapy Department of UCH. The range of measurement of the equipment is 10 μSvh^{-1} and 100 $mSv\ h^{-1}$. It has energy range of 48 keV to 2 MeV ± 4%. A sensitive calibrated digital Survey meter, RADOS Technology (RDS-30) was used to measure the scattered radiation in the halls of residence of University of Ibadan (UI). The meter has an accuracy of ± 5% of the reading in ceasium-137 exposure. During investigations, measurement of exposures in female and male halls were done in three different locations at a height of 1 meter above the floor in each room. A total of eight male and five male halls of residence are included in this study.

At UNIMEDTH, the Radiology Department housed both a conventional X-ray machine and a Computed Tomography (CT) unit. The RADTRACE dose rate meter was used to measure the scattered radiation around the facility. Nurses' Office, Reporting Room, Radiographers' Office, Toilet, Burns Unit, Intensive Care Unit (ICU), Reception and Main Entrance were examined. Other areas examined include: Control Room, Digitizer Room and Corridor (with exposures and without exposure). Also, dose rate were measured in the Teletherapy Suite of UCH Radiotherapy

Department in the following locations: Entrance Door, Control Room, Reception and Cubicle when exposures were being carried out and when there was no treatment done. The Teletherapy unit houses the external beam machine and Brachytherapy machine. Measurement was also done in the Brachytherapy suite (Treatment Room, Control Room and Sitting Room) with exposure and without exposures.

Computation of Effective Dose and Excess Lifetime Cancer Risk: An attempt was made to determine the radiological implications of indoor annual effective doses $A_E\left(\frac{mSv}{y}\right)$. This was calculated from the measured absorbed dose rate, $D\left(\frac{mSv}{h}\right)$ as seen in equation (1).

$$A_E(indoor) = D\left(\frac{mSv}{h}\right) x(24\ x\ 365)\ x\ f\ x\ 10^{-3} \quad 1$$

Where $f = 0.75$, the occupancy factor for residential hall (Rafique *et al.*, 2014).

For a workplace such as UNIMEDTH and Teletherapy Department which requires eight hours work-hour per day, the occupancy factor is assumed to be f = 0.33. By using equation (1) with occupancy factor of 0.33, the indoor annual effective doses were estimated. Additionally, excess lifetime cancer risk (ELCR) was calculated (equation 2) from indoor annual effective doses.

$$ELCR = A_E\ x\ D_L\ x\ R_F \quad 2$$

Where A_E is the indoor annual effective dose, D_L is average duration of life - for Nigerians, D_L = 55.44 years (Microtrends, 2022). The value R_F is the fatal cancer risk factor per sievert (Sv^{-1}). For stochastic effects, ICRP 60 uses value of 0.05 as the risk factor for the public (ICRP, 1990).

RESULTS AND DISCUSSION

Tables 1 and 2 show the number of halls of residence, blocks and rooms examined in both male and female halls in University of Ibadan (UI). A total of 101 rooms were examined in male and 45 rooms in female halls. This consists of 30 and 21 blocks of rooms for male hall and female halls respectively. Table 3 is the indoor absorbed dose rate (μSvh^{-1}) measured at various halls examined in University of Ibadan. The mean value of indoor dose rates ranges between 0.217 ± 0.0536 μSvh^{-1} (Zik Hall) and 0.406 ± 0.05911 $\mu Sv\ h^{-1}$ (PG Hall). The range of mean indoor absorbed dose rate (μSvh^{-1}) measured in Female Halls is between 0.1068 ± 0.0289 (Queen Elizabeth Hall) and 0.2275 ± 0.015 μSvh^{-1} (Female PG Hall).

Table 1: Number of blocks and rooms examined in male halls of residence

S/N	Hall of Residence	No. of blocks	No. of Rooms
1	Indy Hall (IH)	4	16
2	Tedder Hall (TH)	4	13
3	Bello Hall (BH)	4	11
4	Zik Hall (ZK)	4	15
5	Awo Hall (AH)	3	13
6	Kuti Hall (KH)	5	14
7	Melambi Hall (MH)	4	12
8	New PG Hall	2	7
Total	8	30	101

Table 2: Number of blocks and rooms examined in female halls of residence

S/N	Hall of Residence	No. of blocks	No. of Rooms
1	Queens E Hall (QEH)	9	21
2	Queens I Hall (QIH)	3	13
3	St Annes Hall (SAH)	1	1
4	PG Hall (PGH)	2	4
5	Awo F Hall (AFH)	6	6
Total	5	21	45

The difference in the dose rate can be attributed to the difference in the age of the two buildings. Both Zik Hall and Queen Hall (built about five decades ago) were built earlier than the PG Halls (male and female) with higher absorbed dose rates. The mean indoor dose rates for male and female halls of residences are 0.3337 ± 0.0547 and 0.16804 ± 0.05074 respectively. The mean dose rate found in the male halls is higher than the female hall by a factor of about 2 units. The mean overall indoor dose rate for all the halls in University of Ibadan is 0.2699 ± 0.0992 μSvh^{-1}. This overall mean for the thirteen halls is higher than the global population weighted average indoor gamma dose rate of 0.059 μSvh^{-1} in air (UNSCEAR, 2000) by a factor of 4.6 units. The overall mean found in this study is comparable with the mean value recorded in a study carried out in Abeokuta (Southwestern, Nigeria) by Okeyode *et al* (2019). Table 4 is the result of the mean indoor absorbed dose rate measured at the Radiology Department of University of Medical Sciences, Ondo City. The mean indoor absorbed dose rate measured in thirteen locations without exposures is 0.1083 ± 0.0208 μSvh^{-1}, while the mean absorbed dose rate measure within the facility when the machine was working is 0.175 ± 0.0423 μSvh^{-1}. The difference between the background absorbed dose rate and the dose rate due to exposure is 0.0667 μSvh^{-1}. This is an indication that there is an elevated absorbed dose rate when the machine is in use as expected. This suggests the need for appropriate shielding and to provide mechanism for radiation protection in the facility, essentially in the Control Room, Corridor and Reception where elevated absorbed dose rate was recorded during the operation of X-ray machines within the department.

Table 3: Indoor absorbed dose rate (μSv h^{-1}) at various halls examined in University of Ibadan

Type of Hall	Hall (n)	Mean (STD) μSv h^{-1}	Range μSv h^{-1}
UI Male Hostel	Indy (16)	0.3363 ± 0.0712	0.200 - 0.440
	Tedder (13)	0.3355 ± 0.0751	0.2130 - 0.478
	Bello (11)	0.3112 ± 0.0962	0.150 - 0.537
	Zik (15)	0.217± 0.0536	0.11 - 0.293
	Awo male (13)	0.3686 ± 0.145	0.285 - 0.833
	Kuti (14)	0.3481 ± 0.068	0.477 - 0.817
	Mellanby (12)	0.3459 ± 0.0551	0.276 - 0.467
	PG Hall-Male (7)	0.4064 ± 0.0591	0.327 - 0.510
	Male Hall Mean	**0.33363 ± 0.0548**	
UI Female Hostel	Queen Elizabeth (21)	0.1068 ± 0.0289	0.060 - 0.703
	Queen Idia Hall (13)	0.1076 ± 0.02198	0.080 – 0.160
	Awo-Female (6)	0.1983 ± 0.0117	0.190 – 0.220
	St Annes (1)	0.2000	
	PG - Female (4)	0.2275 ± 0.015	0.210 -0.240
	Female Hall Mean	**0.16804±0.0507**	

n = number of halls

Table 4: Indoor absorbed dose rate (μSv h^{-1}) at various locations examined in UNIMEDTH, Ondo

Type of Room	Room (no. of exposures -n)	Mean (STD) μSvh^{-1}	Range μSv h^{-1}
UNIMED TH	Control Room (NE) 5	0.100	
	Control Room (EX) 5	0.18 ± 0.0158	0.16 - 0.20
	Corridor (NE) 5	0.12 ± 0.01581	0.100 -0.14
	Corridor (EX) 5	0.214 ± 0.0089	0.200 – 0.22
	CT Room (NE) 5	0.100 ± 0.0044	0.100 – 0.11
	Reception (NE) 5	0.114 ± 0.1053	0.11 -0.12
	Reception (EX) 5	0.13 ± 0.085	0.12 – 0.14
	Waiting Room 5	0.114 ± 0.00547	0.11 – 0.12
	Nurse Room 5	0.104 ± 0.00547	0.100 - .11
	Dark and Rep. Room 5	0.084 ± 0.0054	0.08 – 0.09
	Radiographers Room 5	0.092 ± 0.004472	0.090 – 0.10
	Rest Room 5	0.09	
	Digitizer 5	0.168 ± 0.005	0.16 – 0.17
	Main Entrance 5	0.112 ± 0.00447	0.11-0.12
	Burnt Unit 5	0.100	
	ICU 5	0.11 ± 0.005	0.10 -0.11

Table 5 is the indoor absorbed dose rates measured at different locations in University College Hospital (Teletherapy and Brachytherapy Units), Ibadan. The overall mean exposure in the Teletherapy Unit is 0.123 ± 0.00936 μSvh^{-1}. This is greater than the population weighted global average. The mean indoor absorbed dose rate obtained from the Brachytherapy Unit when there was no exposure is 0.1075 ± 0.0106 μSvh^{-1}. The result of the mean indoor absorbed dose rate during exposures is 0.393 ± 0.2302 μSvh^{-1}. This is also greater than the population weighted global average.

Table 5: Indoor absorbed dose rate (μSv h^{-1}) at various locations examined in University College Hospital, Ibadan

Type of Room	Room (no. of exposures -n)	Mean (STD) μSv h^{-1}	Range μSv h^{-1}
Teletherapy(UCH)	Main Entrance 4	0.12 ± 0.008165	0.11 -0.13
	Control Room 4	0.12	
	Waiting Area 3	0.137 ± 0.00577	0.13 – 0.14
	Cubicle 3	0.116 ± 0.00578	0.11 -0.12
Brachytherapy(UCH)	Treatment Room (NE) 3	0.100	
	Treatment Room (EX) 3	0.59 ± 0.0306	0.56 -0.62
	Control Room (NE)	0.100	
	Control Room (EX)	0.45 ± 0.0115	0.400 – 0.47
	Brachy Waiting Room (NE)	0.09	
	Brachy Waiting Room (EX)	0.14 ± 0.005774	
	Brachy Chemo Room	0.135±0.55577	0.13-0.14
	Brachy Consulting Room	0.12	-
	Brachy Lab	0.100 ± 0.043	0.09-0.10

Figure 1 is the comparison of mean annual effective doses calculated for different halls in 146 rooms in male and female halls of University of Ibadan (UI). Almost all the effective doses for male and halls are found to be higher than 2 mSv y^{-1} except that of Zik hall. Meanwhile, the annual effective doses of all halls examined in female halls fall below 1.5 mSv y^{-1}. The highest effective dose is found to be 1.49 mSv y^{-1} in female hall while that of the male hall has the highest mean annual effective dose of 2.67 mSv y^{-1}.

Figure 2 is the result of mean annual effective dose (at UNIMEDTH) calculated from the indoor absorbed dose rate in the Control Room (0.37 mSv y^{-1}), Corridor (0.44 mSv y^{-1}) and Reception (0.27 mSv y^{-1}) during exposures (EX) and absence of exposure (NE): Control Room (0.21 mSv y^{-1}), Corridor (0.25 mSv y^{-1}) and Reception (0.23 mSv y^{-1}). The highest mean annual effective dose is found along the Corridor. In certain instances staff sit along the Corridor especially the Record Officers.

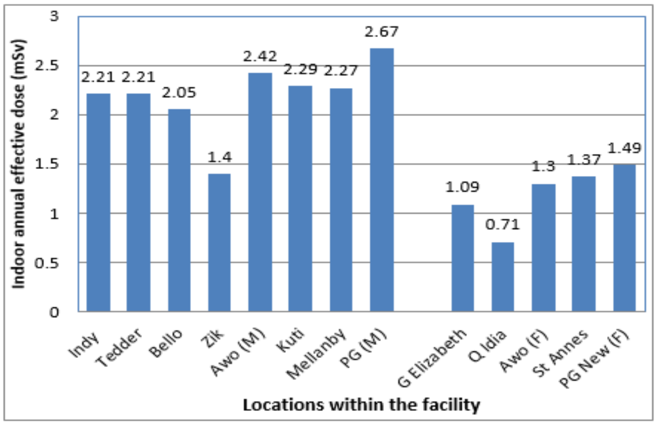

Fig 1: Comparison of Mean Annual Effective Doses in the residential halls of University of Ibadan

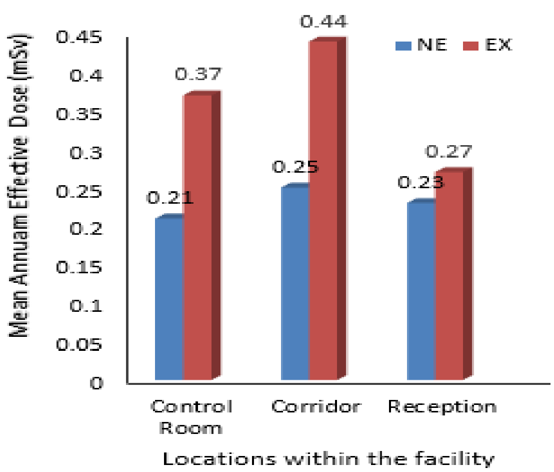

Fig 2: Comparison of Mean Annual Effective Doses in UNIMEDTH

Figure 3 shows that the annual effective doses recorded in other locations within Radiology Department in UNIMEDTH fall within the range of 0.17 and 0.35 mSv y^{-1}. The effective dose of Waiting Room and Main Entrance are comparable. Nurse Room (Nurse Rm), Burnt Room and ICU are also comparable. The lowest mean annual effective dose is found in the Dark Room (0.17 mSv y^{-1}), while Digitizer room has the highest value of 0.35 mSv y^{-1}. These fall below the recommended annual limit of 2 mSv y^{-1}.Results of mean annual effective doses in different locations within the Teletherapy and the Brachytherapy Units of the University College Hospital (UCH), Ibadan are shown in Figure 4. The figure shows that the mean annual effective doses range between 0.196 and 1.22 mSv y^{-1}. Results of annual effective doses of locations within the Teletherapy Units are comparable. In addition, results recorded in the following locations in the Brachytherapy units are comparable: Brachy Treatment Door (NE), Brachy Control Room (NE), Brachy Waiting Area (NE), Brachy Lab. Results of Brachy Waiting Area (EX), Brachy Chemical Room and Brachy Consulting Room are comparable and fall below the limit of 2 mSv y^{-1}. Additionally, results of Brachy Treatment Door (EX) and Brachy Control Room are found to be 1.22 mSv y^{-1} and 0.94 mSv y-[1] respectively. The Brachy Treatment Room has a relatively higher mean annual effective dose when the treatment is being carried out. This is however lower than the recommended annual dose limit. This calls for adequate shielding of the walls and doors of the treatment room. Other preventive mechanisms could be introduced especially during treatment. It is evident from the results of this study that annual effective doses recorded from background radiation level and during treatments process fall below the recommended annual dose limit. Table 6 is the results of mean lifetime cancer risk (ELCR-the difference between the lifetime risk for the exposed and the lifetime risk for the unexposed) calculated from mean annual effective dose. Results show that the mean ELCR for different facilities are $6.07 \times 10^{-3} \pm 1.05 \times 10^{-3}$ (Male Halls-UI), $3.27 \times 10^{-3} \pm 0.8272 \times 10^{-3}$ (Female Halls-UI), $0.51 \times 10^{-3} \pm 0.22 \times 10^{-3}$ (UNIMEDTH-NE, Ondo), $0.9977 \times 10^{-3} \pm 0.2418$ (UNIMEDTH-EX, Ondo), 0.65×10^{-3} (Teletherapy- UCH), and 0.57×10^{-3} (Brachytherapy-UCH).

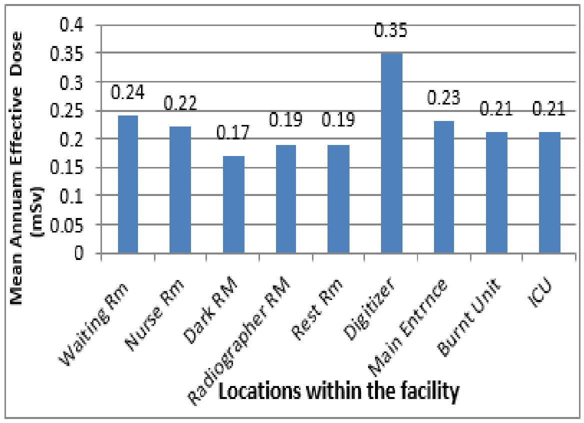

Fig 3. Comparison of Mean Annual Effective Doses in UNIMEDTH

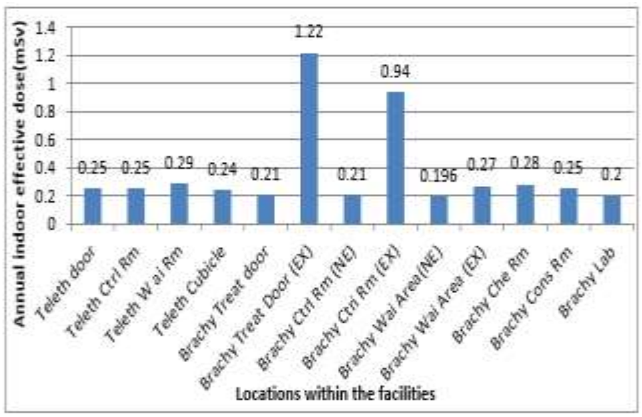

Fig 4: Comparison of annual indoor effective doses at different locations Teletherapy and Brachytherapy units of UCH

Table 6: Mean excess life time cancer risks calculated from indoor exposures for different facilities examined

Location/Facility (n)		Minimum ELCR (x 10^{-3}) (SD)	Maximum ELCR (x 10^{-3}) (SD)	Mean ELCR (x 10^{-3}) (SD)
Male Hall (UI)	(101)	3.89 (0.00077)	7.40 (0.010)	6.07 (1.015)
Female Hall (UI)	(45)	1.95 (0.0004)	4.10 (0.0024)	3.27(0.8272)
UNIMED (NE)	(10)	0.059 (0.0000281)	0.96 (0.00026)	0.5719 (0.2248)
UNIMED (EX)	(10)	0.74 (0.000036)	1.22 (0.000051)	0.9977 (0.2418)
Teletherapy (UCH) (2)		--	--	0.65
BrachyArea(UCH)(4)		--	--	0.57

Table 7. Comparison of ELCR calculated in this study and other similar studies

Location	**Mean of ELCR (10^{-3})**	**Range of ELCR (10^{-3})**	**References**
UI Hall (male)	6.07 ± 0.015	3.89 – 7.40	This study
UI Hall (Female)	3.27 ± 0.8272	1.95 – 4.10	This study
UNIMEDTH (NE)	0.5719 ± 0.2248	0.059 – 0.96	This study
UNIMEDTH (EX)	0.9972 ± 0.2418	0.74 – 1.22	This study
UCH (Teletherapy)	0.65	--	This study
UCH (Brachytherapy)	0.57	--	This study
Pakistan (Jhelum Valley)	1.629	1.057 – 2.371	Rafique *et al.* (2014)
Pakistan (River)	2.84	1.23 – 5.66	Qureshi and Abdulwahab (2014)
Nigeria (South East) Quarry Site	1.115 ± 0.13 (within site) 0.847 ± 0.12 (around site)	0.910 – 1.365 0.665– 1.120	Ugbade and Echeweozo, 2017
Nigeria (Uyo) University Campus	2.26	1.55 – 3.18	Etuk *et al.* (2017)
Nigeria (South West)	0.143	--	Okeyode and Jibiri (2013)
Nigeria (South South)	0.152	--	Avwiri *et al* (2013)

NE: no exposure EX: exposure

A comparison of mean ELCRs calculated in this study with other earlier published articles indicates that the values obtained in male and female halls of UI are higher than those recorded at the two Teaching Hospitals and other studies as shown in Table 7.

The mean ELCR in the two halls are higher than the world average of 1.45 x 10^{-3} and the standard value of 0.29 x 10^{-3}(by factors not less than 1.97 units). The elevated ELCR is as a result of high dose rate recorded in the halls of residence. This might be attributed to the sources of building materials used, underlying rocks of the locations (Okeyode *et al.,* 2019), and perhaps other human (mining, use of radioactive compounds) activities in the neighborhood. Result of earlier study on activity concentration of topsoil (outdoor) of UI (Egunyinka *et al.*, 2009) shows that it falls within the acceptable value and does not pose any hazard. However, results of the present study indicate that the elevated dose rate could be as a result building materials used or perhaps certain recent radiological activities in the vicinity of the study location.The excess lifetime cancer risks calculated from the data of the two Teaching Hospitals (UCH and UNIMEDTH) are lower than the world average. However, this does not undermine the use of preventive measures to reduce the exposure of personnel and the public.

Conclusion: Dose rates of thirteen halls of residence in University of Ibadan, two units of Radiotherapy Department of University College Hospital and Radiology Department of University of Medical Sciences, Ondo were studied. The corresponding annual effective doses and excess lifetime cancer risks were determined. Results of the study show that the mean dose rate in the halls of residence, UCH and UNIMED are 0.2699 ± 0.0992 µSvh^{-1}, 0.121±0.036 µSvh^{-1} and 0.123 ± 0.00936 µSvh^{-1} respectively. The highest mean annual effective dose is found to be 1.22 mSv y^{-1}. The range of ELCRs calculated in this study is between 0.51 x 10^{-3} and 6.07 x 10^{-3}.

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