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Annual Effective Dose Equivalent and Excess Lifetime Cancer Risk from Measured Indoor Background Ionizing Radiation in Pharmacy, Radiotherapy/Oncology and Radiology Departments of Federal Teaching Hospital, Gombe, Gombe State, Nigeria

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Abstract: This study calculated the excess lifetime cancer risk and annual effective dose equivalent in the radiology, radiation, and pharmacy departments of the Federal Teaching Hospital, Gombe. The radiation levels were measured using a RADOS 200 survey meter. A handheld GPS was used to pinpoint several locations within each department, with the device held at a height of one meter. For the aforementioned departments, the average annual effective dose equivalent was calculated as 0.4325, 0.3787, and 0.4370 mSv/y, respectively. The average excess lifetime cancer risk values in the pharmacy, radiotherapy/oncology, and radiology departments were found to be $1.5 \times 10^{-3}, 1.3 \times 10^{-3}$, and 1.5×10^{-3}, respectively. In conclusion, the results obtained in this study show that the average annual effective dose equivalent for the sampled location complies with the 1 mSv/y maximum dose limit for the public, as recommended by the International Commission on Radiological Protection (ICRP) and the World Health Organization (WHO). However, the resulting average excess lifetime cancer risk is 1.4×10^{-3} which is higher than the limit of 0.29×10^{-3}.

Keywords: Ionizing radiation, Annual effective dose equivalent, Excess lifetime cancer risk, Rados survey meter, Radiation level.

1. Introduction

As radiation has always been a component of the environment, humans are constantly and unavoidably exposed to varied amounts of ionizing radiation in everyday life [1]. Daily activities expose us to radiation in a variety of forms and intensities, which can be both useful and detrimental. Negative impacts of radiation exposure include cancer, cataracts, gene mutations, bone and blood cell destruction, and the possibility of death [2].

Nuclear accidents, such as Chernobyl disaster, nuclear reactor operations, nuclear weapon testing, and some therapeutic and diagnostic X-ray devices are examples of human actions that have released radiation into the environment. Most of the radiation dose that humans receive comes from natural sources [3]. Radiation has several clinical uses that can be classified as either therapeutic or diagnostic, and in both cases, radioactive isotopes such as Tc-99, I-131, I-125, I-123, F-8, H-3, Ir-192, C-14, etc. are used [4]. Radiological techniques have resulted in the highest radiation exposure among all anthropogenic sources of ionizing radiation [5]. This suggests that the effect of ionizing

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radiation on the body's cells depends on the amount absorbed [6]. Therefore, it is necessary to measure ambient radiation in areas where it is used to ensure that radiation levels are within acceptable ranges [7]. A high amount of radiation leakage caused increased radiation exposure for patients, operators, and the general public [8]. Most radiological techniques utilize the X-ray-producing bremsstrahlung mechanism. According to estimates, X-rays account for approximately 14% of all radiation exposures worldwide from both natural and artificial sources [9]. The pharmacy department uses radioisotopes, such as different isotopes of iodine, therefore, which may contribute to ionizing radiation in the region.

The higher cancer risk could be linked to instances where radiation exposure dose restrictions are exceeded, which could help explain Basrah's high rate of cancer-related illnesses. When calculating excess lifetime cancer risk (ELCR), it is important to consider the high rates of cancer cases by measuring background radiation levels and estimating soil gamma dose rates [10]. There is a new hypothesis suggesting that despite the extremely low risk of induction, even tiny radiation doses from background radiation might contribute to cancer [11]. Ionizing radiation can cause cancer and heritable diseases even at low doses. These effects are known as stochastic effects because they are probabilistic and assume that any exposure can have an effect [12].

The primary goals of this study were to estimate the annual effective dose equivalent and excess lifetime cancer risk in the radiology, radiation, and pharmacy departments of the Federal Teaching Hospital in Gombe, Gombe State, Nigeria, and to compare these findings with global health hazard indices. In addition, the annual effective dose equivalent and excess lifetime cancer risk (ELCR) were evaluated for each department.

2. Methodology

A radiation survey meter (RADOS 200) was used to detect and measure the radiation equivalent dose, with measurements expressed in microsieverts per hour (μSv/h). The meter was first calibrated to detect and measure the equivalent dose in μSv/h at the Center for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria, which is listed by the International Atomic Energy Agency as having a 0.1 calibration factor [13]. The handheld radiation monitor measures the alpha, beta, gamma, and X-ray radiation.

2.1 Taking Readings with the Survey Meter (Dose Rate Measurement)

First, the survey's zero error was examined and noted, together with the instrument's calibration factor. At each strategic point within the study area, the meter was placed at a height of 1 m from ground level to avoid any form of contamination and interference from the ground surface [14]. Readings were then taken three times at each location within each department, and in each case, the average values were calculated.

2.2 Calculation of Annual Effective Dose Equivalent (AEDE) in $\mathrm{mSv/y}$

Because the department only operates from 8 am to 4 pm, it was presumed that people were present at the research site at all times. The annual effective dose equivalent (AEDE) was calculated using the following equation:

$$E = X \times 8760 \times 0.8 \times CC \quad (1)$$

where X is the indoor reading in μSv/h, 8760 is the annual conversion factor from hours to years, and 0.8 is the indoor occupancy factor as provided in Ref. [9]. The conversion coefficient (CC) is given as 0.7, which is the conversion coefficient for adults, as reported by UNSCEAR, to convert the absorbed dose in air to the effective dose.

2.3 Calculation of the Standard Deviation of the Mean

The standard deviation of the mean at each sampling point was calculated using the following formula:

$$S.D = \sqrt{\frac{1}{N}\sum_{i=0}^{N}(x_i - \mu)^2} \quad (2)$$

where N is the number of readings, x_i is the individual survey meter reading, and μ is the calculated mean from the survey meter readings.

2.4 Calculation of the Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risk (ELCR) was estimated using the following equation:

$$ELCR = E \times \mathrm{DL} \times \mathrm{RF} \quad (3)$$

where E is the annual effective dose equivalent, DL is the average duration of life (approximately 70 years), and RF is the risk factor or fatal cancer risk measured per sievert (Sv^{-1}). For stochastic effects from low-dose background radiation, Ref. [5] suggested a value of 0.05 for public exposure.

3. Results

For each of the sampled departments (pharmacy, radiotherapy/oncology, and radiology), the standard deviation to the mean, annual effective dose equivalent (AEDE), and excess lifetime cancer risk (ELCR), as well as their corresponding locations as determined by a Global Positioning System (GPS), are presented in Tables 1, 2 and 3, respectively. The average ELCR value ranged from 1.3×10^{-3} to 1.5×10^{-3}, and the cumulative AEDE values across each department ranged from 0.3787 mSv/y to 0.4393 mSv/y, all of which are determined to be below the recommended value of 1 mSv/y.

TABLE 1. Estimations of annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) in the pharmacy department.

Location		GPS Reading	Survey meter Reading (µSv/h)			Mean (µSv/h)	S.D (10^{-2})	AEDE (mSv/y)	ECLR (10^{-3})
Code	Name		1st	2nd	3rd				
P1	HOD's Office	Lat.10º17'52"N Lon.11º8'18"E	0.06	0.07	0.08	0.0700	0.82	0.3884	1.4
P2	Toilet	Lat.10º17'58"N Lon.11º8'17"E	0.04	0.04	0.03	0.0367	0.47	0.1782	0.6
P3	Cloak Area	Lat.10º18'0"N Lon.11º8'16"E	0.04	0.06	0.07	0.0567	1.25	0.2753	1.0
P4	Semi-packaging Area	Lat.10º17'55"N Lon.11º8'17"E	0.10	0.12	0.09	0.1033	1.25	0.5015	1.8
P5	Aseptic Room	Lat.10º17'59"N Lon.11º8'25"E	0.15	0.13	0.16	0.1467	1.25	0.7123	2.5
P6	NHIS Pharmacy	Lat.10º17'51"N Lon.11º8'17"E	0.14	0.12	0.07	0.1100	2.94	0.5341	1.9
P7	A & E/ GOPD	Lat.10º17'52"N Lon.11º8'17"E	0.11	0.09	0.10	0.1000	0.82	0.4855	1.7

TABLE 2. Estimations of annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) in the radiotherapy/oncology department.

Location		GPS Reading	Survey meter Reading (µSv/h)			Mean (µSv/h)	S.D (10^{-2})	AEDE (mSv/y)	ECLR (10^{-3})
Code	Name		1st	2nd	3rd				
R1	Control Room	Lat.10º17'53"N Lon.11º8'19"E	0.03	0.06	0.11	0.0667	3.30	0.3238	1.1
R2	Toilet	Lat.10º17'52"N Lon.11º8'22"E	0.08	0.10	0.09	0.0900	0.82	0.4370	1.5
R3	Resident Room	Lat.10º17'50"N Lon.11º8'19"E	0.07	0.09	0.10	0.0867	1.25	0.4209	1.5
R4	Medical Physicist Office	Lat.10º17'51"N Lon.11º8'19"E	0.06	0.07	0.09	0.0733	1.25	0.3559	1.2
R5	Reception	Lat.10º17'53"N Lon.11º8'19"E	0.05	0.07	0.10	0.0733	2.05	0.3559	1.2

TABLE 3. Estimations of annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) in the radiology department

Location		GPS Reading	Survey meter Reading (μSv/h)			Mean (μSv/h)	S.D (10^{-2})	AEDE (mSv/y)	ECLR (10^{-3})
Code	Name		1st	2nd	3rd				
R1	Radiographers' Room	Lat.10°17'52"N Lon.11°8'17"E	0.10	0.15	0.13	0.1267	2.05	0.6152	2.2
R2	Processing Room	Lat.10°17'35"N Lon.11°8'33"E	0.13	0.12	0.09	0.1133	1.70	0.5501	1.9
R3	X-ray Room	Lat.10°17'47"N Lon.11°8'33"E	0.04	0.05	0.07	0.0533	1.25	0.2588	0.9
R4	Patients' Waiting Room	Lat.10°17'47"N Lon.11°8'20"E	0.06	0.07	0.06	0.0633	0.47	0.3073	1.1
R5	Dark Room	Lat.10°17'35"N Lon.11°8'34"E	0.11	0.07	0.10	0.0933	1.70	0.4530	1.6

TABLE 4. Cumulative mean dose rate, annual effective dose equivalent, and excess lifetime cancer risk in the three sampled departments.

Department	Cumulative Mean Dose Rate (μSv/h)	Average AEDE (mSv/y)	ELCR (10^{-3})
Pharmacy	0.0891	0.4325	1.5
Radiotherapy/Oncology	0.0780	0.3787	1.3
Radiology	0.0900	0.4370	1.5

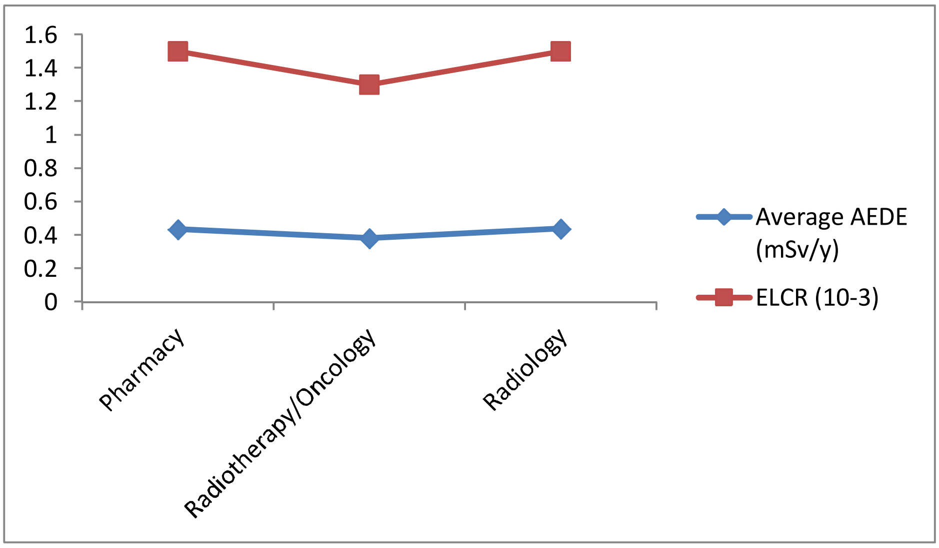

FIG. 1. Plot showing the average AEDE and ELCR for all departments in the study area.

3.1 Discussion

For all of the examined locations in the pharmacy department, the AEDE values ranged from 0.1782 mSv/y to 0.7123 mSv/y, as shown in Table 1. All these values fall within the advised limit of 1 mSv/y. The estimated ELCR ranged from $0.6 \times 10^{-3} to\ 2.5 \times 10^{-3}$ for all of the sampled locations. The AEDE values for the radiotherapy/oncology department for all of the sampled areas ranged from 0.3238 mSv/y to 0.4370 mSv/y, as shown in Table 2. All these values fall below the recommended threshold of 1 mSv/y, with ELCR values ranging between 1.1×10^{-3} and 1.5×10^{-3}. The low dosage rate in the control room may be attributed to an appropriate shielding barrier, particularly against the brachytherapy room. Overall, the low AEDE value in the radiotherapy/oncology department can be attributed to the fact that, at the time of this report, the brachytherapy room was not in use because of the lack of a radiation source

(Iridium-192) required for treatment. Nonetheless, a significant amount of AEDE was still detected, which may be related to the fact that the radiology department was nearby and active.

According to Table 3, all of the sampled locations in the radiology department had AEDE values ranging from 0.2588 mSv/y to 0.6125 mSv/y. Each fell within the suggested upper limit of 1 mSv/y. The ELCR values varied from $0.9 \times 10^{-3} to\ 2.2 \times 10^{-3}$.

The average AEDE value for the pharmacy department across all examined locations was 0.4325 mSv/y (Table 4), with a mean ELCR value of 1.5×10^{-3}. The average AEDE value for the radiotherapy/oncology department for the entire study area was 0.3787 mSv/y, which was lower than the values for the other two departments. Moreover, the average ELCR score was 1.3×10^{-3}. Although the average AEDE value in the radiology department, which is equivalent to 0.4370 mSv/y, is much greater than that in the other tested departments, it is nevertheless higher. The average ELCR value was of 1.5×10^{-3}.

Ibrahim *et al*. estimated a mean AEDE of 0.32±0.04 mSvy^{-1} and 0.24±0.03 mSvy^{-1} within and around the Okpoto quarry site, respectively [15]. These values are attributed to elevated concentrations of natural radionuclides such as ^{238}U, ^{232}Th, and ^{40}K and their decay products, which are widespread in the soil and rocks of the Earth's crust.

Muhammad *et al*. reported that the mean excess lifetime cancer risk (ELCR) factor for outdoor exposure is 0.3×10^{-3}, which is below the world's outdoor average of 0.29×10^{-3} [16]. Our calculated mean ELCR value for indoor is 0.06×10^{-3}. This is lower than the world average of 1.16×10^{-3} for indoor. The total estimated mean ELCR value for both indoor and outdoor stands at 0.36×10^{-3}. This is 24.8% lower than the world's total ELCR average of 1.45×10^{-3}.

Olanrewaju *et al*. determined that all health risk factors were within safe limits across all tested levels [17]. The findings demonstrated that there was no difference in background radiation levels between the research locations and blacksmithing workshops. The calculated excess lifetime cancer risk showed minimal effective dosages to adult organs, suggesting a low likelihood of cancer development among inhabitants who reside in these communities throughout their lives.

Whereas Qureshi *et al*. reported an average total of 0.37×10^{-3} for outdoor and 2.84×10^{-3} for indoor, with a total of 3.21×10^{-3}. for northern Pakistan [18].

Hamideen conducted a study measuring the activity concentration of natural gamma-emitting radionuclides (^{40}K, ^{226}Ra, and ^{232}Th) in at least forty samples of local Portland and Pozzolanic cement types using gamma spectrometric techniques [19]. The range of the mean specific activity (minimum and maximum values) due to all three radionuclides was found. Various radiological hazard parameters were assessed, including the representative level index, the external hazard index, the internal hazard index, the radium equivalent index, and the absorbed dose rate. Some of the measured radiological hazard parameters were compared with similar data from different countries.

Al-Khaza'leh investigated eleven types of seeds consumed by Jordanian people to determine the concentration levels of ^{226}Ra, ^{228}Ra, and ^{40}K radionuclides [20]. The calculated concentration ranged from 0.214 ± 0.017 to 7.583 ± 0.592 Bq/kg_{dry}, 10.629 ± 0.914 Bq/kg_{dry}, and 92.0 ± 7.61 to 576 ± 46.22 Bq/kg_{dry} for ^{226}Ra, ^{228}Ra, and ^{40}K, respectively. The total annual effective dose resulting from ingestion of these seeds was estimated at 35.17 *µSv/year*, with cancer risk ranging between 1.58×10^{-6} for fennel and 23.53×10^{-6} for beans. However, the average cancer risk value was 7.74×10^{-6}, which is less than the world average cancer risk value of *3mSv/year*.

Ahmad *et al*. determined the natural and artificial radioactivity levels in surface soil samples collected from various sites in the Tafila governorate in Jordan, using gamma-ray spectrometry [21]. The average concentrations of ^{238}U, ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs were 23.6 ± 3.1, 23.3 ± 0.7, 16.7 ± 1.0, 234.1 ± 9.85, and 5.4 ± 0.3 Bq kg^{-1}, respectively. The activity ratio between ^{238}U and ^{226}Ra for all samples was close to unity. The average values of radium equivalent activity, gamma-absorbed dose rate in air, annual effective dose equivalent, external hazard index, internal hazard index, and excess lifetime cancer risk were 65.2 Bq kg^{-1}, 30.6 nGy h^{-1}, 37.6 µSv y^{-1}, 0.18, 0.24, and 1.39 10^{-4}, respectively. These values do not exceed the permissible limits. Therefore, the studied area does not pose any significant radiation hazard to the public. Furthermore, the activity concentration of ^{137}Cs radionuclide was found to be within recommended safe levels.

Ogunremi and Adewoyin stated that radionuclide concentrations in imported food products depend on the geological and mineralogical characteristics of the soil from which the products are derived, a major cause of concern in radiation monitoring [22]. The analysis of three naturally occurring radionuclides - ^{226}Ra, ^{232}Th, and ^{40}K - in fourteen selected imported food samples was carried out in this research using a sodium iodide detector. Reasonable quantities of each sample were packed in cylindrical containers and kept for a month to attain secular equilibrium. The activity concentrations of the analyzed samples ranged from 48.76 ± 5.03 to 85.45 ± 3.20, from 10.10 ± 1.70 to 21.10 ± 2.20, and from 8.06 ±1.4 to 10.54 ± 3.64 Bq/kg, with average values of 65.32 ± 4.14, 11.23 ± 2.18, and 9.68 ± 2.08 for ^{40}K, ^{226}Ra and ^{232}Th, respectively. For ^{232}Th, ten samples were below detention limit BDL. The mean effective dose was estimated to be 4.17 μSv/y. The result of the radiation dose was less than the average value of 1mSv/y for the general public, making the foodstuff analyzed radiologically safe for consumption.

4. Conclusions

The annual effective dose equivalent and excess lifetime cancer risk (ELCR) due to radiation levels were estimated and determined for the pharmacy, radiotherapy/oncology, and radiology departments of the Federal Teaching Hospital in Gombe. The results indicated that ALARA procedures were consistently followed in the sampled departments, as all values of the annual effective dose equivalent were within the 1 mSv/y reference limit. The average excess lifetime cancer risk was found to be 1.4×10^{-3} which is slightly higher than the acceptable limit of 0.29×10^{-3}. Although all annual effective dose equivalent (AEDE) values were within the reference limit, this study still recommends continual periodic area monitoring to ensure that radiation levels remain within the recommended limit. In addition, special attention should be given to the radiation levels in the pharmacy department, particularly in the aseptic room (compounding unit), as it could pose significant health risks to the public and workers in the near future. However, because this research was carried out when some machines were not in operation, a follow-up study is recommended when all machines are in full operation.

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