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Impact of radiotherapy facility on indoor background radiation exposure at the University College Hospital, Ibadan

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Abstract

Background: The impact of high energy radiotherapy machine, used for cancer management at the University College Hospital, Ibadan, on indoor background radiation exposure of humans (staff, patients and their relatives) has been assessed.
Methods: Gamma radiation detectors were used to measure background radiation exposure rate at designated areas within the Department of Radiation Oncology over a period of three years (2014 – 2016).
Results: The mean indoor background radiation exposure rate (μR/hr) measured at these areas ranged from 0.139±0.053 to 0.157±0.061 while the corresponding mean absorbed dose rate (nGy/hr) ranged from 1.210±0.459 to 1.367±0.531. The effective dose, which is the radiation quantity defined by the International Commission on Radiation Protection (ICRP) to specify annual dose limit for both radiation workers (20 mSv averaged over 5 years) and the general public (1 mSv), was determined from the background radiation absorbed dose rate per annum and compared with the ICRP recommended radiation dose limit for general public. The mean annual effective dose (mSv) arising from background radiation obtained within the department of Radiation Oncology ranged from 0.019 to 0.021, which is about 2% of the recommended dose limit (1 mSv) for general public.
Conclusion: This result showed that the presence of high energy radiotherapy machine located in this department has no significant effect on the indoor background radiation exposure of people who work in or visit the department. Further study is aimed at measuring both indoor and outdoor background radiation exposure at other departments in the hospital and estimate their health impact on humans.

Keywords: *Indoor background radiation, Radiotherapy machine, Gamma rays, Cancer management, Exposure rate, Effective dose.*

Abstrait

Contexte : L'impact de l'appareil de radiothérapie à haute énergie, utilisé pour la gestion du cancer au Collège Hospitalier Universitaire d'Ibadan, sur l'exposition au rayonnement intérieur des êtres humains (personnel, patients et membres de leur famille) a été évalué.
Méthodes : Des détecteurs de rayonnement gamma ont été utilisés pour mesurer le taux d'exposition au rayonnement de fond dans des zones désignées du Département de radio-oncologie sur une période de trois ans (2014 - 2016).
Résultats : Le taux moyen d'exposition au rayonnement intérieur (μR / h) mesuré dans ces zones variait de 0,139 ± 0,053 à 0,157 ± 0,061, tandis que le débit de dose moyen absorbé correspondant (nGy / h) était compris entre 1,210 ± 0,459 et 1,367 ± 0,531. La dose efficace, qui correspond à la quantité de rayonnement définie par la Commission Internationale de Protection contre les Radiations (CIPR) afin de spécifier la limite de dose annuelle pour les travailleurs sous rayonnement (moyenne de 20 mSv sur 5 ans) et pour le grand public (1 mSv), a été déterminée à partir des résultats suivants : dose de base absorbée chaque année et comparée à la limite de dose de rayonnement recommandée par la CIPR pour le grand public. La dose efficace annuelle moyenne (mSv) résultant du rayonnement de fond obtenu au sein du département de radio-oncologie allait de 0,019 à 0,021, soit environ 2% de la limite de dose recommandée (1 mSv) pour le grand public.
Conclusion : Ce résultat a montré que la présence d'un appareil de radiothérapie à haute énergie situé dans ce département n'avait pas d'effet significatif sur l'exposition au rayonnement de fond à l'intérieur des personnes qui travaillent ou visitent le département. Une étude plus approfondie vise à mesurer l'exposition aux rayonnements de fond intérieurs et extérieurs dans d'autres départements de l'hôpital et à estimer leur impact sur la santé humaine.

Mots clés : *Rayonnement ambiant intérieur, appareil de radiothérapie, rayons gamma, gestion du cancer, taux d'exposition, dose efficace.*

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Introduction

High energy ionizing radiation from megavoltage teletherapy machines are used for the management of cancer patients. This procedure, known as Radiotherapy, is one of the treatment modalities (Surgery, Radiotherapy, Chemotherapy, hormone therapy etc.) of cancer management [1]. Radiotherapy machine is one of the man-made (artificial) sources of ionizing radiation through which patients (medically exposed), radiation workers (occupationally exposed) and the general public can be exposed to ionizing radiation [2]. Radiotherapy machine emits beam of ionizing radiation such as x-rays, gamma rays and electrons, which are used for breaking cancer cells' DNA molecules and destroy their ability to grow or divide [3]. During the process of patients' treatment, some of these radiations (x or gamma rays) from the treatment machine get scattered in all directions. Consequently, the level of background radiation around (indoor and outdoor) the treatment facility can be increased if the treatment room or bunker is not well shielded with adequate thickness of concrete or materials of high density (such as Lead) to absorb these scattered radiations.

Naturally (background) occurring radiation is one of the sources of exposure of humanity to ionizing radiation. The sources of background radiation are both external (cosmic and terrestrial) and internal. Cosmic radiation includes charged particles from the sun, galaxies and stars. Terrestrial radiations are those from radioactive materials found in the soil, water and vegetation and they include Uranium, Thorium, Radium and their decay products [4]. Internal radiations on the other hand are radiation from isotopes inside the human body from birth. These include Potassium-40, Carbon-14 and Lead-210. The radiation doses from cosmic and terrestrial sources vary in different parts of the world due to differences in elevation, locations and effects of the earth's magnetic field.

This study was carried out to assess the impact of scattered radiation (gamma rays) from high energy radiotherapy machine on indoor background radiation exposure of humans (staff, patients and their relatives) at the Radiation Oncology Department, University College Hospital, Ibadan, Nigeria.

Materials and methods

This study was carried out at the Department of Radiation Oncology, University College Hospital, Ibadan, which is one of the eight and most functional radiotherapy centres in Nigeria. The Department has one external beam radiotherapy machine, Cobalt-60 unit (Bhabhatron-II, India) which continuously emits gamma-ray for treatment of about fifty patients, who are living with cancer, per day.

The walls of the treatment room (bunker) housing the Cobalt-60 unit are shielded with concrete of appropriate thickness and density while the remote-controlled door to the bunker is Lead lined. All these mechanisms are put in place to ensure adequate protection of people and the environment against scattered radiation arising from the bunker during patients' treatment.

The department of Radiation Oncology comprises of four major sections namely, clinical area, Brachytherapy suite, External beam treatment area and patients' lying-in wards. The clinical area includes the general waiting area, records unit, consulting rooms, Nurses' table/reception, toilets, departmental offices, seminar room and staff offices while the brachytherapy suite consists of all the facilities for high dose rate brachytherapy procedures. The external beam treatment area consists of waiting area for patients to be treated, dose planning room, engineering room, consulting rooms, chemotherapy room, simulator room, changing cubicle, Orderlies'corner, operators' table/ treatment console and the treatment room. The patients' lying-in ward is located on the first floor and it accommodates both male and female patients on admission.

The locations within the Department, where background radiation exposure was measured were namely, entrance to the department, reception, corridor, waiting area, Orderlies' corner, changing cubicle, treatment console/Operators' area and control area. These areas were monitored for measurement of natural indoor background radiation between July 2014 and September 2016 with calibrated digital gamma survey meters, Victoreen 672 and ThermoEberline FH 40 G. These Survey meters were calibrated once in a year at the Secondary Standard Laboratory located at the National Institute of Radiation Protection and Research, University of Ibadan, Ibadan under the Nigerian Nuclear Regulatory Authority (NNRA), Abuja. The Activity of Cobalt-60 radioactive source in the radiotherapy machine as at July 2014 and September 2016 was 224.5 TBq and 168.8 TBq respectively. This area monitoring was part of routine quality assurance procedures put in place in the department to ensure radiation protection of patients, personnel and the environment.

The survey meters were used to measure background radiation exposure (in air) rate in μR/hr

Table 1: Exposure Rates measured at various locations at the Department of Radiation Oncology

Location	Exposure Rates (μR/hr)							
	2014		2015		2016			
	VT	TE	VT	TE	VT	TE	Mean	SD
Entrance	0.141	0.163	0.146	0.118	0.092	0.249	0.152	0.054
Reception	0.130	0.161	0.218	0.117	0.079	0.238	0.157	0.061
Corridor	0.134	0.158	0.144	0.109	0.079	0.236	0.143	0.053
Waiting Area	0.128	0.157	0.142	0.114	0.080	0.230	0.142	0.051
Orderlies' Area	0.125	0.157	0.135	0.109	0.077	0.232	0.139	0.053
Changing Cubicle	0.125	0.153	0.136	0.105	0.141	0.237	0.149	0.046
Operators' Area	0.123	0.154	0.138	0.108	0.078	0.244	0.141	0.057
Control Area	0.127	0.155	0.145	0.100	0.141	0.240	0.151	0.047

Table 2: Absorbed Dose Rates measured at various locations at the Department of Radiation Oncology LocationAbsorbed Dose Rates (nGy/hr)

Location	Absorbed dose rates (nGy/hr							
	2014		2015		2016			
	VT	TE	VT	TE	VT	TE	Mean	SD
Entrance	1.228	1.420	1.266	1.029	0.804	2.167	1.319	0.467
Reception	1.128	1.397	1.892	1.022	0.689	2.072	1.367	0.531
Corridor	1.162	1.377	1.254	0.950	0.687	2.057	1.248	0.465
Waiting Area	1.114	1.362	1.238	0.990	0.692	1.998	1.232	0.440
Orderlies' Area	1.091	1.363	1.173	0.948	0.666	2.017	1.210	0.459
Changing Cubicle	1.086	1.327	1.180	0.912	1.222	2.066	1.299	0.401
Operators' Area	1.073	1.337	1.197	0.939	0.680	2.123	1.225	0.494
Control Area	1.109	1.346	1.259	0.866	1.225	2.087	1.315	0.413

and a conversion factor of 8.7 nGy/μR was used to convert it to absorbed dose rate in nGy/hr. In order to convert the absorbed dose in air to its equivalence in human body, a conversion factor of 0.7 Sv/Gy was used [5]. Also, to estimate the average number of hours people, especially the personnel, spend indoors within the department of radiation oncology, an occupancy indoor factor of 0.75 was used [6]. The effective dose per annum received by an individual at each of the areas monitored was then evaluated from the measured exposure rate and the correction factors mentioned above. All data was analyzed using the Microsoft excel software version 2016 and the results were presented in tables and clustered column charts.

The equations used for determination of various radiation quantities considered in this study are as shown below:

$$\text{Absorbed dose rate } \frac{nGy}{hr} = \text{Exposure dose rate } \frac{\mu R}{hr} \times 8.7 \frac{nGy}{\mu R} \quad (1)$$

$$\text{Effective dose mSv/yr} = \text{Absorbed dose rate } \frac{nGy}{hr} \times 8760 \frac{hr}{yr} \times 0.75 \frac{Sv}{Gy} \times 0.75 \quad (2)$$

Results

The mean value and standard deviation (SD) of exposure rates measured with Victoreen (VT) and ThermoEberline (TE) survey meters at selected areas of the department within a period of three-year (2014 – 2016) are presented in Table 1. These values, which ranged from 0.139±0.053 to 0.157±0.061μR/hr, are the background radiation exposure rate in air measured at various locations within the Department of Radiation oncology. Similarly, the absorbed dose rate derived from the measured background exposure rates are presented in Table 2. These ranged from 1.210±0.459 to 1.367±0.531 nGy/hr. The annual effective doses evaluated from the absorbed dose rates and corrected for number of hour per year, the indoor occupancy factor and absorbed dose rate in air to tissue conversion factor are presented in Table 3. These values ranged from 0.019±0.032 to 0.021±0.035 mSv/yr. Figures 1 and 2 are clustered column charts showing the average annual effective doses measured at different locations using VT and TE detectors respectively while the clustered column chart in figure 3 compares the mean average annual

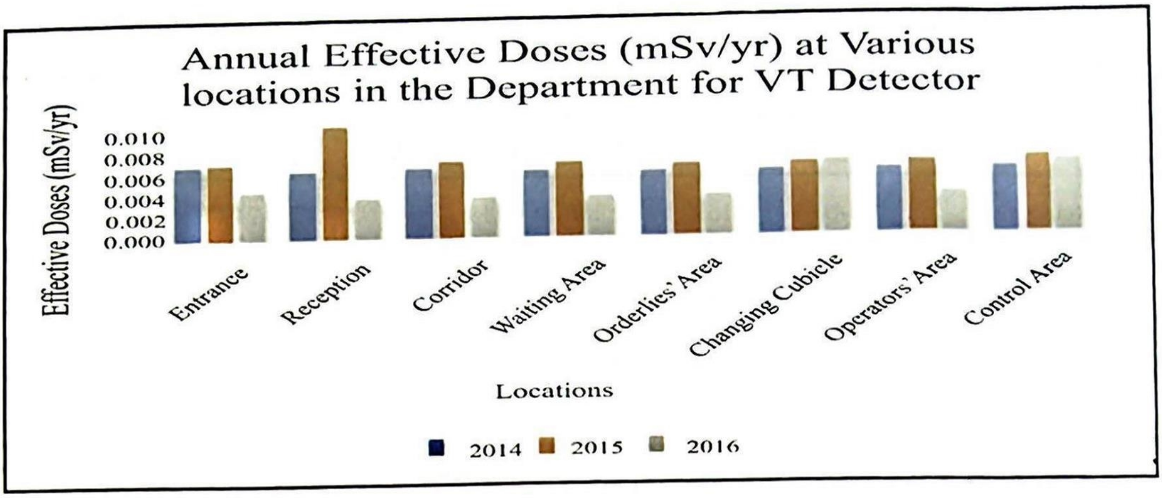

Fig 1: Annual effective dose measured with victoreen detector

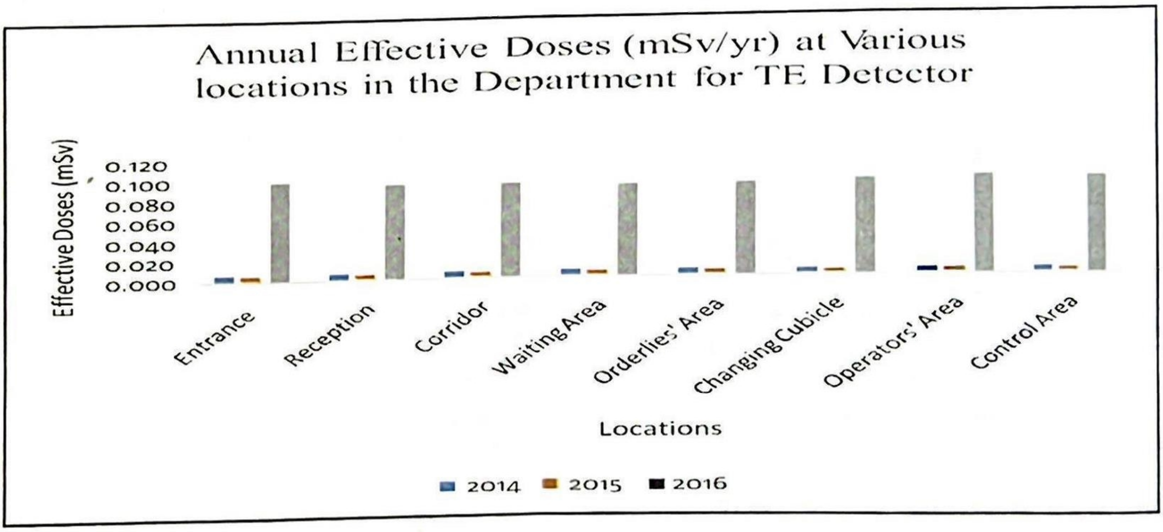

Fig 2: Annual effective dose measured with thermoeberline detecto

Table 3: Annual effective dose measured at various locations at the Department of Radiation Oncology

Location	Annual Effective Dose (mSv/yr)							
	2014		2015		2016			
	VT	TE	VT	TE	VT	TE	Mean	SD
Entrance	0.006	0.007	0.006	0.005	0.004	0.100	0.021	0.035
Reception	0.005	0.006	0.009	0.005	0.003	0.095	0.021	0.034
Corridor	0.005	0.006	0.006	0.004	0.003	0.095	0.020	0.033
Waiting Area	0.005	0.006	0.006	0.005	0.003	0.092	0.019	0.032
Orderlies' Area	0.005	0.006	0.005	0.004	0.003	0.093	0.020	0.033
Changing Cubicle	0.005	0.006	0.005	0.004	0.006	0.095	0.020	0.034
Operators' Area	0.005	0.006	0.006	0.004	0.003	0.098	0.020	0.035
Control Area	0.005	0.006	0.006	0.004	0.006	0.096	0.020	0.034

effective doses obtained in this study with the International Commission on Radiation Protection (ICRP) recommended dose limit of 1 mSv per annum for the general public [7].

Discussion

Radiation Oncology Department is usually misconceived as a place, where anyone who works in or visits the Department will always be exposed

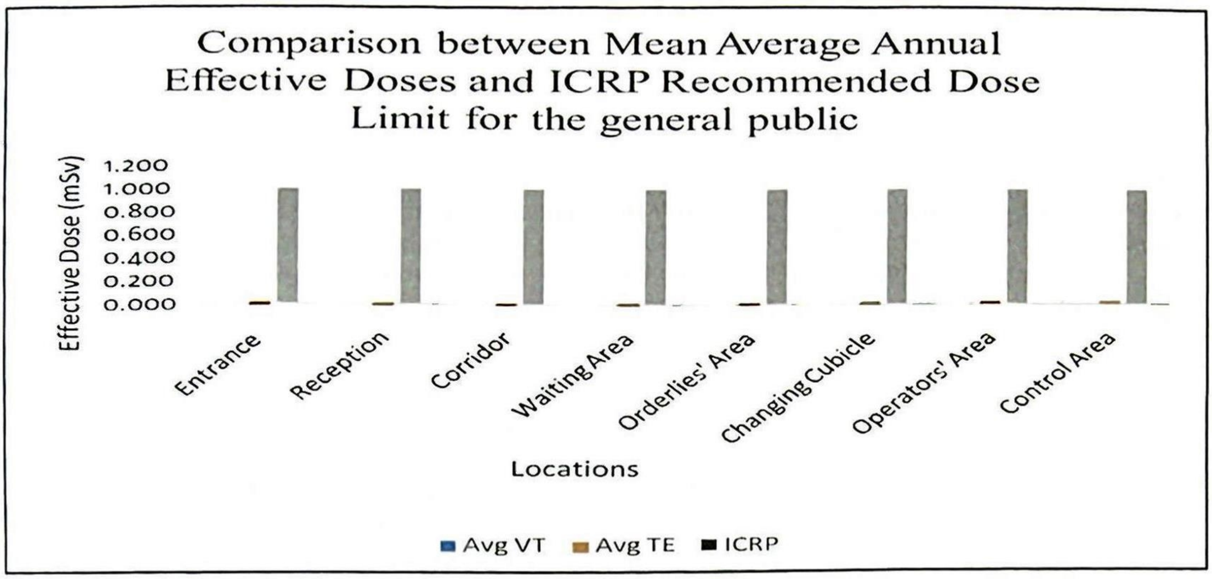

Fig 3: Comparison between mean average Annual effective doses and ICRP Recommended dose limit for the general public

to excessive level of ionizing radiation from high energy radiation treatment machine capable of inducing cancer and prevent procreation. This myth is usually believed by some health workers (Nurses, Health attendants, Hospital maids, Orderlies, etc.), who do not have adequate knowledge about radiation protection of radiotherapy facility during their routine duty posting to the Department or when they accompany referred patients to Radiotherapy clinic.

Therefore, this study was conducted partly to correct this myth and also to estimate the impact of ionizing radiation (gamma rays) from high energy radiation therapy machine on the indoor background radiation within the Department and compare the results with the International recommended dose limit for the general public, people who are not radiation workers in a radiation generating facilities.

It can be seen from Table 1 that the lowest mean background exposure rate value (0.139 ± 0.053 ìR/hr) was obtained at the place, where Orderlies are normally found during working hours while the highest mean background exposure rate value (0.157 ± 0.061 ìR/hr) was obtained at the reception, where the patients and visitors (non-members of staff) to the Department are normally received. This is followed by 0.152 ± 0.054 ìR/hr obtained at the entrance to the Department. Although, the place where the Orderlies are located is about 5 m away from the treatment room/bunker yet a minimal background radiation exposure was found there as compared to the background radiation exposure measured at the reception, which is about 20 m away from the treatment room. Therefore, the relatively high background radiation exposure measured at the reception cannot be associated with the radiation emanating from the treatment machine according to the inverse square principle [8]. Apart from radiation from primordial radionuclides in the soil, there is also radiation from the atmosphere (cosmic rays), which tends to raise the level of background radiation in any location close to the outdoor area compared to the areas located indoor. The relatively high background radiation measured at the reception might have been influenced by the cosmic rays due to its closeness to the outdoor. The world is naturally radioactive and approximately 82% of human-absorbed radiation doses which are out of control, arise from natural sources such as cosmic, terrestrial and exposure from intake radiation sources [9].

A similar study (but not in radiotherapy facility), carried out in Keffi Nigeria reported that the indoor background radiation exposure (effective dose) to humans obtained from various houses (residential, churches, etc.) ranged from 0.21 to 0.28 mSv per annum [10]. Also, another study conducted to determine indoor background radiation exposure to humans from soil samples collected from various districts of India reported an indoor background annual effective dose of 0.38 mSv [11]. These values, though within the ICRP recommended dose limit for the general public, are higher than the values obtained in this study.

Jwanbot *et al* [12], Okoye *et al* [13] and Abubakar *et al* [14] conducted similar study in radiology department of hospital in Jos, Port Harcourt and Asaba, Nigeria respectively. The mean indoor radiation level obtained and reported were 2.44 mSv/yr, 0.57 mSv/yr, 0.79 mSv/yr respectively. While the values obtained in Port Harcourt and Asaba were within the acceptable radiation dose limit for the general public, that of Jos was higher, even higher than what is obtained in Radiotherapy department (this study).

It is important to note that Thermo Eberline detector recorded relatively higher values in the year 2016 compared to values in the previous years as shown in fig. 2. This may be due to random nature of radioactivity, the state of its counting device at the time of measurement, power fluctuation and other technical factors. This is why it is advisable in radiation survey measurements to use more than one type of radiation detector (ionization chamber, proportional counter, Geiger counter, etc.) and taking several readings at a given location during measurements.

The ICRP recommends a dose (effective dose) limit of 1 mSv per annum for general public, people who are not radiation workers in a radiation facility. In this study, the annual effective dose obtained from background radiation at strategic locations, where people, other than radiation workers, are likely to be found ranged from 0.019±0.032 mSv to 0.021±0.034 mSv. This value is about 2% of the ICRP recommended dose limit for general public, meaning that the radiation exposure to any visitor to the department of radiation oncology is within the acceptable dose limit.

Conclusion

This study has assessed the impact of a high energy Radiotherapy machine (Telecobalt unit) on indoor background radiation level within a radiation oncology Department in Ibadan. Background indoor radiation doses measured across areas in proximity to the Telecobalt machine and those at distant points were found to be comparable. The annual effective doses resulting f· .n background radiation measurements at all locations were also related and much significantly lower than the recommended dose limit of 1mSv published by the ICRP for general public. This attests to the fact that the telecobalt unit was adequately shielded to ensure radiation safety in the facility when the Cobalt-60 source is both in use and out of use.

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