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ASSESSMENT OF RADIATION DOSE RATE LEVELS AND RADIATION RISK AT THE COBALT -60 UNIT, KOMFO ANOKYE RADIOTHERAPY CENTER, GHANA.

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ABSTRACT

Purpose: A study was conducted to estimate the Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR) caused by the presence of an artificial cobalt-60 radioactive source producing ionizing radiation levels within the radiotherapy facility at Komfo Anokye Teaching Hospital (KATH) in Ghana. This study validated the safety of cobalt-60 radioactive sources, as well as the notion of calculating the Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR), which contributed to reducing occupational and public exposures inside the facility.

Methodology: The investigation was carried out with the use of a portable OD-01 Ionization Chamber Survey Meter. The absorbed dose rate (ADR) in air was changed between 5 m and 40 m, with measurements taken inside and around the cobalt 60 bunker, as well as at sixteen other sites within the radiation facility.

Findings: From 5 m to 40 m surrounding the Cobalt-60 source, the estimated Absorbed Dose Rate in air inside the cobalt-60 bunker ranged from 0.299 0.001 to 0.977 0.005 Sv/h, with an average of 0.498 0.005 Sv/h. The estimated Annual effective dose equivalent varied from 1.100 mSv/yr to 3.595 mSv/yr around the cobalt-60 source inside the Co-60 bunker. Radiation exposure levels ranged from 0.268 0.008 Sv/h to 0.678 0.005 Sv/h, with an average of 0.440 0.004 Sv/h observed around the fifteen sites chosen. Excess Lifetime Cancer has values ranging from 3.85 10-3 to 12.58 10-3 and 3.45 10-3 to 8.73 10-3. Risks were evaluated for the cobalt and the sixteen places inside the plant. The absorbed dose values at 5 m, 10 m, and 15 m inside the Co-60 bunker and the location Co-60 bunker as part of the facility exceeded the ICRP-recommended limit of 0.57. The AEDE and ELCR levels were within the ICRP's acceptable limits. The AEDE and ELCR statistics acquired indicate that the Cobalt-60 unit and its surroundings are radiation safe, although the likelihood of employees contracting cancer from the absorbed dose and background ionizing radiation is significant over a lifetime.

Recommendation: However, it is recommended that absorbed dose level monitoring and evaluation of the Radiation Therapy Technologist (RTT) and other workers surrounding the unit be monitored on a regular basis. It is also recommended that Occupational Staff, such as RTTs, spend as little time as possible in the bunker

Keywords: *Annual Effective Dose Equivalent, Excess Lifetime Cancer Risk, Cobalt-60 source, Absorbed Dose Rate (ADR), Background Ionizing Radiation (BIR)*

1.0. INTRODUCTION

The Komfo Anokye Teaching Hospital's Oncology Directorate (Komfo Anokye Radiotherapy Center) is a department of the Komfo Anokye Teaching Hospital in Ghana's Ashanti region. As a national center, it is a well-known radiation facility in Kumasi owing to its equipment's capacity to service nearby areas. The utilization of radiation in patient cancer treatment is critical in a radiotherapy facility, and the cobalt-60 radiotherapy equipment fulfills this goal. Long-term exposure to radiation in the cobalt-60 unit may result in health problems owing to occupational exposure. Individuals exposed to ionizing radiation may get cancer, according to research (Ezekiel, 2017).

A topic of importance is safety assessment, which guarantees that patients' medical exposure is correct and occupational exposure is maintained as low as practically practicable and below the applicable dosage limit in the radiation unit (Darrar, Mahmoud, EzzEl-Din, Khalaf, & Mostafa, 2019). According to Emeka (2003) in (Harb, 2016), radiation in hospitals comes from two primary sources: medical exposures and cosmic radiation, terrestrial radiation, and background radioactivity. This means that people in such places are constantly exposed to ionizing radiation, which cannot be prevented. Background ionizing radiation is produced by both natural and man-made sources. The natural sources of ionizing radiation include cosmic, terrestrial, and radioactivity from long-lived radionuclides in the earth crust and everywhere in the environment, which has been proved by (Bamidele 2013) to have some significant exposure on people.

Man-made sources of ionizing radiation are created intentionally for nuclear reactors and medical uses, and background ionizing radiation from these sources may have major impacts, particularly on humans within medium exposure, which can be stochastic or non-stochastic (Niu, 2011). In medicine, radioactive sources such as cobalt-60, iridium-192, caesium-137, strontium-90, and americium-241 are used for radiotherapy.

According to the UNSCEAR report on the sources and effects of ionizing radiation (UNSCEAR, 2008), the global estimated average dose of background ionizing radiation received by humans is about 0.274 Sv/hr, of which 80 percent comes from nature and the remaining 20 percent from exposure to man-made radiation sources. Cancer is one of the recognized negative consequences of ionizing radiation. It is well-known to be the main cause of mortality and a major public health issue (Akram et al., 2018). According to a study conducted by Ferlay (Ferlay et al., 2010) and Jemal (Jemal, Bray, & Ferlay, 1999), 20 million additional cancer cases are projected worldwide in 2020. According to the findings of this research, 19.3 million new cancer cases are expected in 2020, with female breast cancer being the most often diagnosed cancer and lung cancer being the leading cause of cancer mortality (Sung et al., 2021). Methods for resolving this public health issue have been identified via study.

According to (Ravichandran, 2009), 60 percent of patients need radiation, which is a primary modality of cancer treatment with either a palliative or curative purpose. When compared to linear accelerators, the Cobalt-60 is an easy-to-use teletherapy system with lower maintenance expenses and downtime. As Co-60 decays, gamma radiation is released, which is used to treat cancer in radiation treatment, and its scatter radiation may have long-term impacts on those who work near such devices. Some hospital employees in the secretarial department, nurses, and cleaners work near these radioactive sources and are therefore indirectly exposed to these radiations. Long-term exposure to such radiation may result in free radical generation, cancer, chromosomal alteration, and possible hereditary damage in the progeny of those who have been exposed to such radiation. Given that they are exposed to some radiation, there is a need for an evaluation of the radiation level and its impact owing to the biological effects on tissues. Ionization caused by the interaction of intense ionizing radiation with biological tissues results in the production of charged particles and free radicals, which causes DNA to be altered (Emelue, 2014).

The current research aims to examine and measure the background radiation absorbed dose rate in air in the Cobalt-60 bunker and a few other sites inside the oncology department. The observed radiation rate is then used to compute the annual effective dose equivalent (AEDE) received by study employees and visitors. The exposure's excess lifetime cancer risk (ELCR) is also calculated. The study's findings are compared to the standard suggested value in order to determine the radiological health impacts. Because there has been no radiological investigation of the region, the results will also serve as a radiation baseline data for the area.

2.0. METHODS

A portable OD-01 survey meter was used to quantify the Absorbed dose rate in Sv/h recorded around and inside the Cobalt-60 unit at Komfo Anokye Teaching Hospital's Oncology Directorate. The survey meter is a small gadget that includes a display and control unit, a probe, device support, 0.7 m of connecting cable, a USB connection, and software for measuring and analyzing data on a computer (PC). It detects photons with energy up to 15 MeV and beta radiation with energies ranging from 6 keV to 2 MeV. It also measures equivalent dose rate from 0 Sv/h to 2000 mSv/h and dosage from 0 Sv to 2000 Sv using an air-opened ionization chamber. STEP Sensortechnik und Elektronik Pockau GmbH, Siedlungsstraße 5-7, D-09509 Pockau, calibrated the meter in beta radiation fields according to ISO 6980 and photon radiation fields according to ISO 4037-1 (homogeneous radiation field). Ten (10) readings were taken in air at different positions in each location at different distances away from the radioactive source (Cobalt-60 teletherapy machine) within a time interval of 2 minutes when the beam was turned off, and the average value was considered to be the gamma dose rate at that distance. The portable OD-01 survey meter was also used to monitor background ionizing radiation (from the Cobalt-60 source) at sixteen (16) different places across the oncology department.

The Nuclear Medicine bunker, Simulator room area, Administration area, Conference room area, Linac maze, Linac control console room, Chemotherapy room area, Nurses office area, Dosimetry room area, SPECT CT room area, SPECT/CT control Area, Records area, Patients waiting area, Radiotherapists area, OPD area, and the Cobalt -60 bunker room were the locations chosen within the facility. The layout of the oncology department is seen in Figure 1. Gamma radiation levels were measured inside and outside the rooms, as well as in the surrounding regions, at a height of one meter above ground level in open air. To cover the whole region, ten (10) to sixteen (16) measurements were obtained at various positions in each site at 2 minute intervals, and the mean value was the average Absorbed Dose Rate for the location. The average absorbed dose rates (ADR) were used to compute the Annual Effective Dose Equivalent (AEDE) received by employees and tourists in millisieverts per year. The AEDE was calculated as follows: AEDE (mSv/yr) = 4600(h/y) (T) X 0.8(OF) x 0.001(CF) X ADR (Sv/h) (1)

Where T is total time in hours per year (4600), OF denotes occupancy factor, CF denotes dosage conversion factor, and ADR denotes absorbed dose rate. An outdoor occupancy factor of 0.8

(UNSCEAR, 2008) was employed for this study. The excess lifetime cancer risk (ELCR) was determined using the equation based on the AEDE values:

$$ELCR = AEDE\ (mSv/yr) \times DL\ (70\ years) \times RF\ (0.05) \qquad (2)$$

Where AEDE is the annual effective dose equivalent, DL is the duration of life and RF is the risk factor or fatal cancer risk per Sievert. For stochastic effects from low dose background radiation, ICRP 103 suggested the value of 0.05 for the public exposure (ICRP 2007)

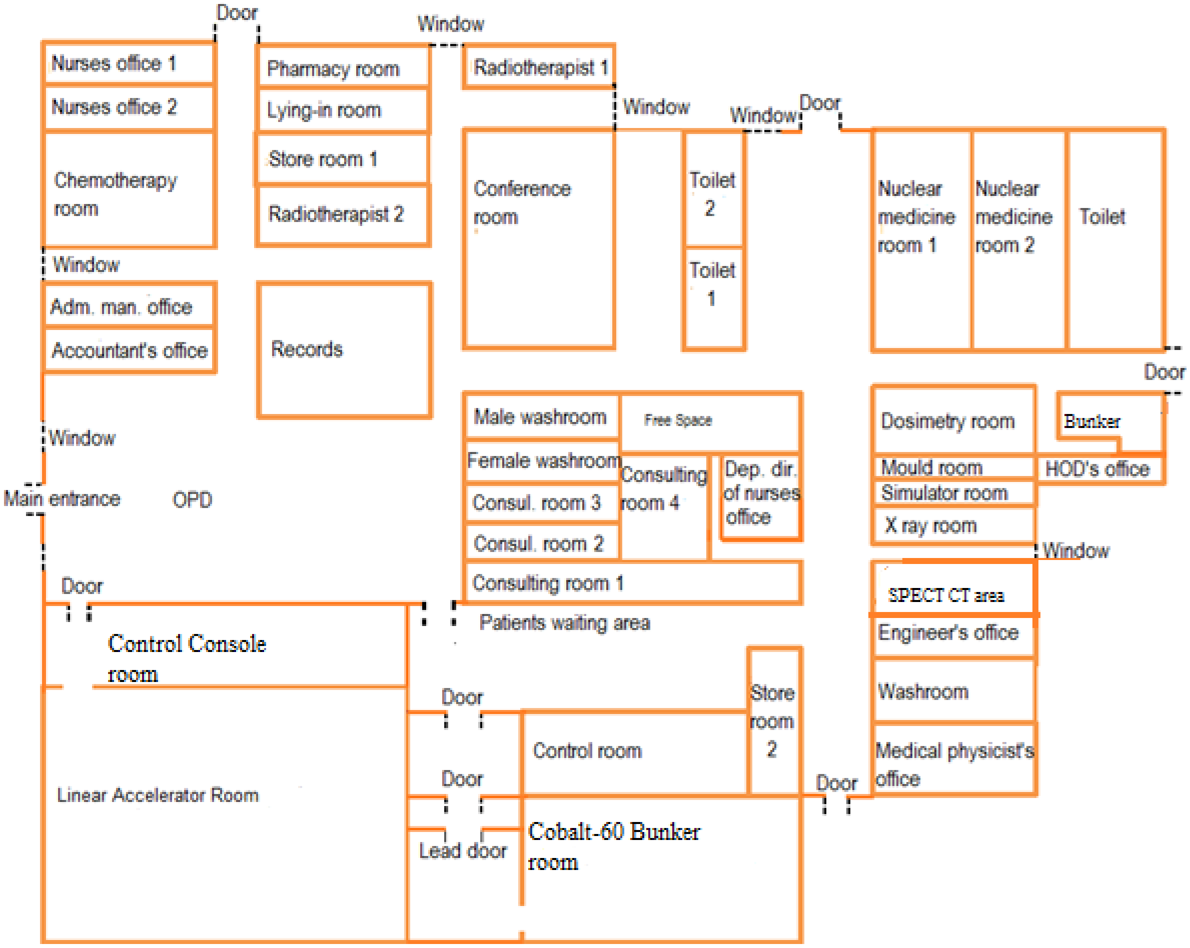

Figure 1: Layout of the KATH Oncology Department.

3.0. RESULTS AND DISCUSSION

The results of the measured Absorbed Dose Rate, Background Ionizing Radiation, the calculated Annual Effective Dose Equivalent and Excess Lifetime Cancer Risk are presented in Tables 1 and 2 which is graphically represented in figures 2,3,4,5,6 and 7 within the Cobalt-60 unit at different distances and at selected locations within the oncology directorate.

Table 1: The Absorbed Dose Rate (ADR), Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR) at different distances from the Cobalt-60 teletherapy machine within the Bunker

Distance from the source (m)	5 m	10 m	15 m	20 m	25 m	30 m	35 m	40 m
No. of readings taken	10	10	10	10	10	10	10	10
Exposure dose rate in air (µSv/h) (Range)	0.971-0.982	0.593-0.628	0.648-0.659	0.405-0.417	0.368-0.372	0.341-0.345	0.312-0.321	0.296-0.301
Exposure dose rate (µSv/h) (Mean)	0.977± 0.005	0.612± 0.014	0.655± 0.005	0.410± 0.009	0.370± 0.002	0.343± 0.006	0.317± 0.004	0.299± 0.001
Annual Effective Dose Equivalent (mSv/yr)	3.595	2.252	2.410	1.509	1.362	1.262	1.167	1.100
Excess Lifetime Cancer Risk ($x10^{-3}$)	12.58	7.88	8.44	5.28	5.28	4.42	4.08	3.85

Table 1 shows the absorbed dose rate readings, the annual effective dose equivalent estimated and their corresponding excess lifetime cancer risk at different distances from the radioactive source. It was observed that the absorbed dose rate ranged was 0.299±0.001 µSv/h to 0.977±0.005 µSv/h with an average of 0.498±0.005 µSv/h at varied distances from the radioactive source when the beam was OFF and therefore measuring background radiation.

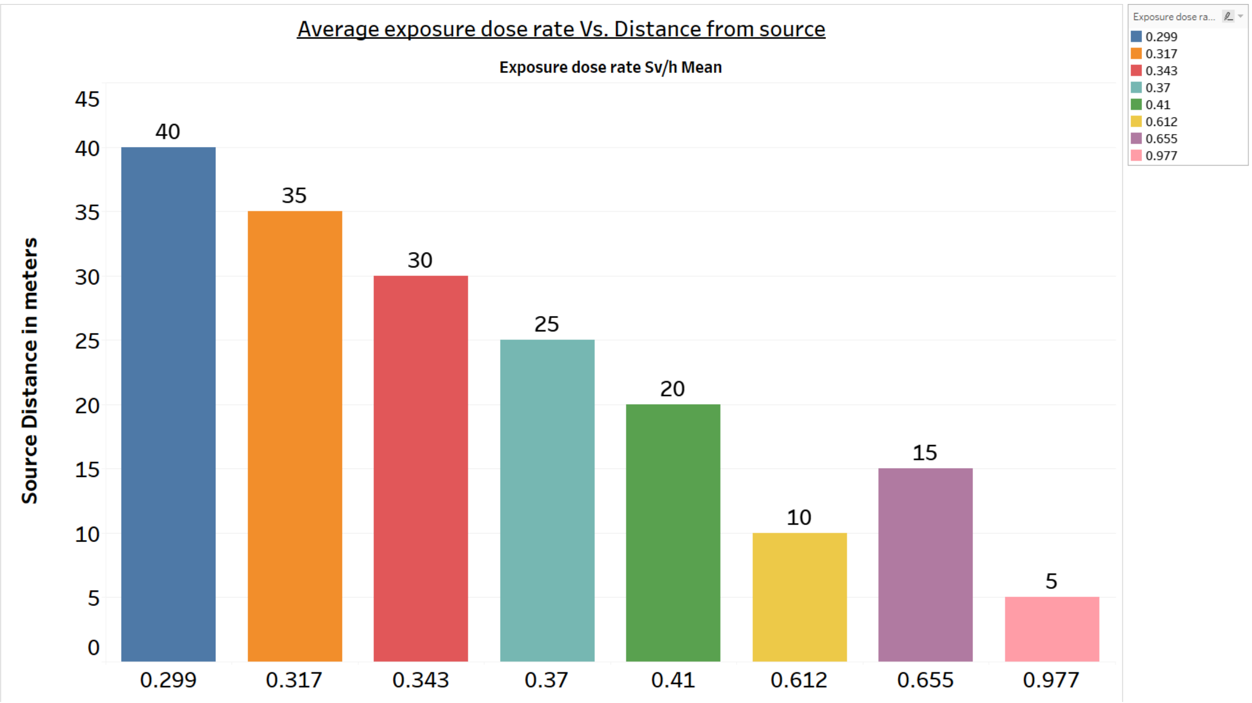

Figure 2. Exposure dose rate with respect to varying distance from cobalt source.

As shown in figure 2, the greatest absorbed dose rate range was 0.9970.005 Sv/h at a distance of 5 m, while the lowest absorbed dose rate range was 0.2990.001 Sv/h at a distance of 40 m. Figure 2 shows that the intensity of the radiation dropped as the measuring distance rose. This confirms the inverse square rule pertaining to radiation measurement with regard to distance. A larger absorbed dosage was recorded at a distance of 15 m from the radioactive source than at a distance of 10 m from the source. The dose rate at various distances from the radioactive source showed very low levels of background ionizing radiation, with the exception of several distances (5 m, 10 m, and 15 m) that showed significant levels of background radiation over the ICRP maximum permitted limit, as shown in figure 3.

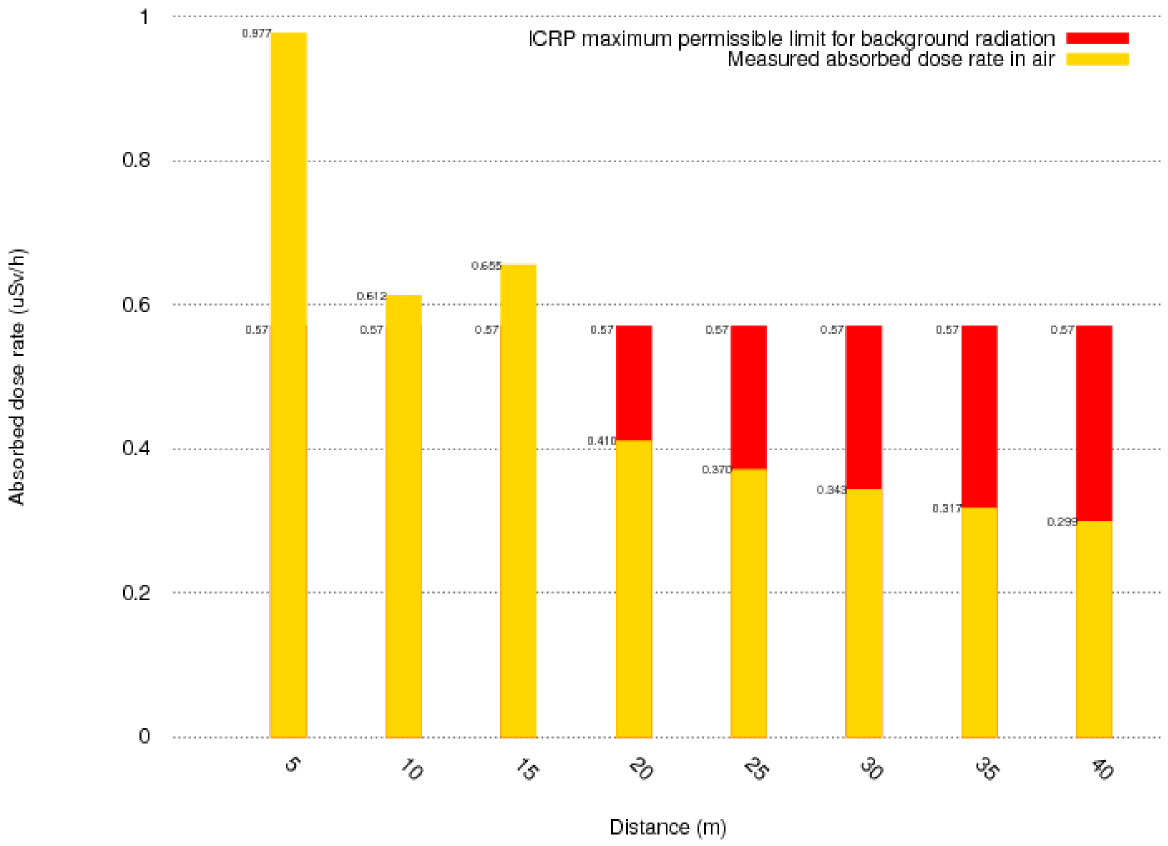

Figure 3. Absorbed dose rate comparison to ICRP permissible standard.

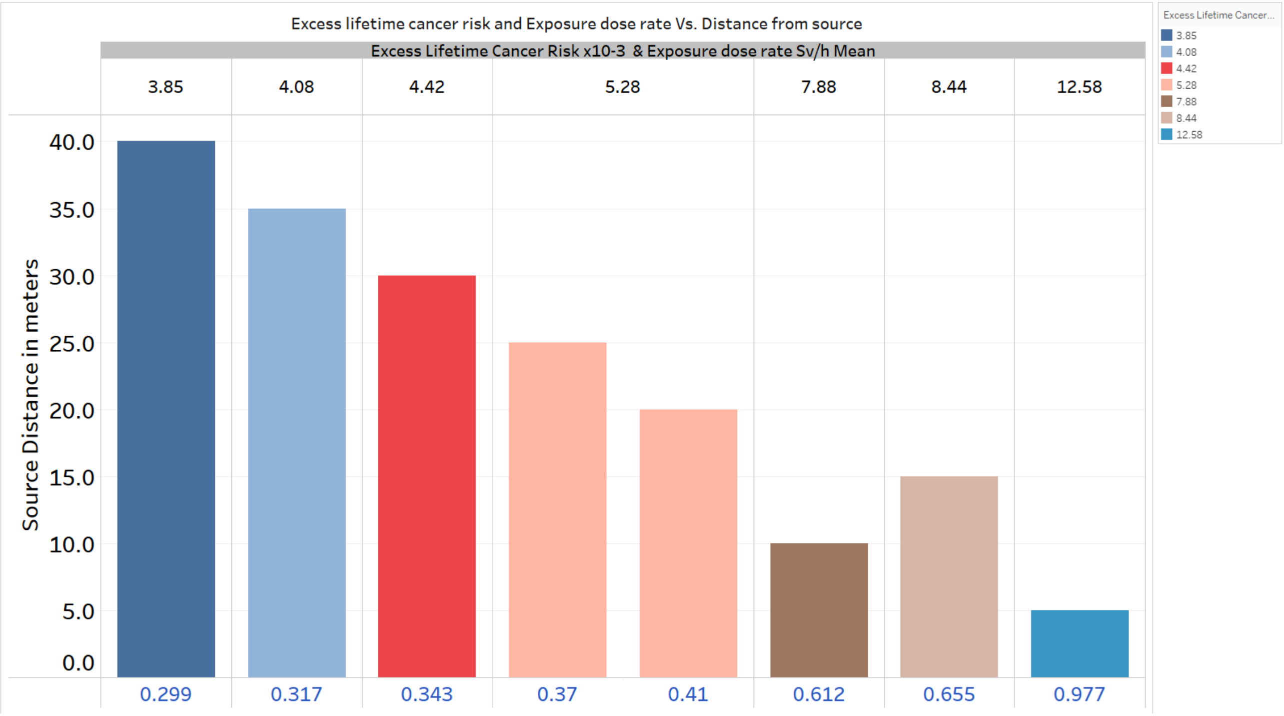

Figure 4. Excess lifetime cancer risk varying distances from cobalt source.

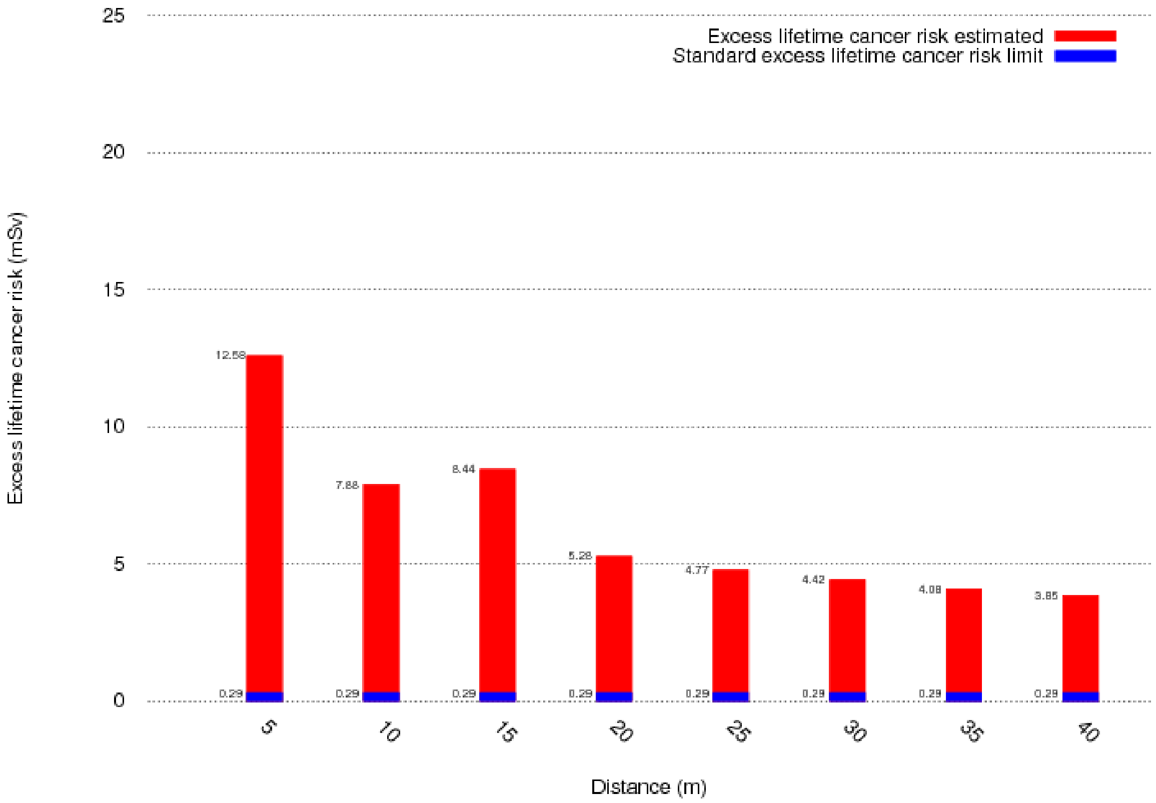

Figure 5. Excess lifetime comparison with standard limit.

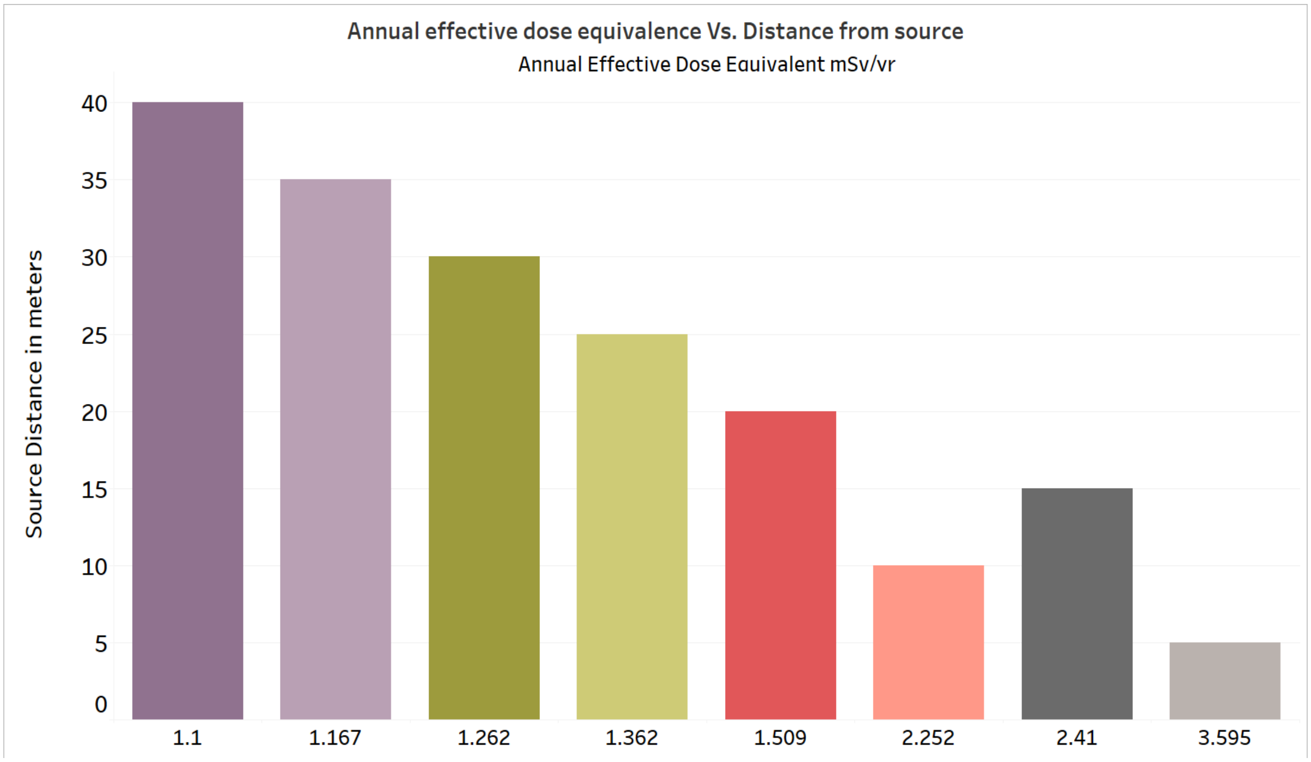

Figure 6. Annual Effective dose Equivalence varying distances from cobalt source.

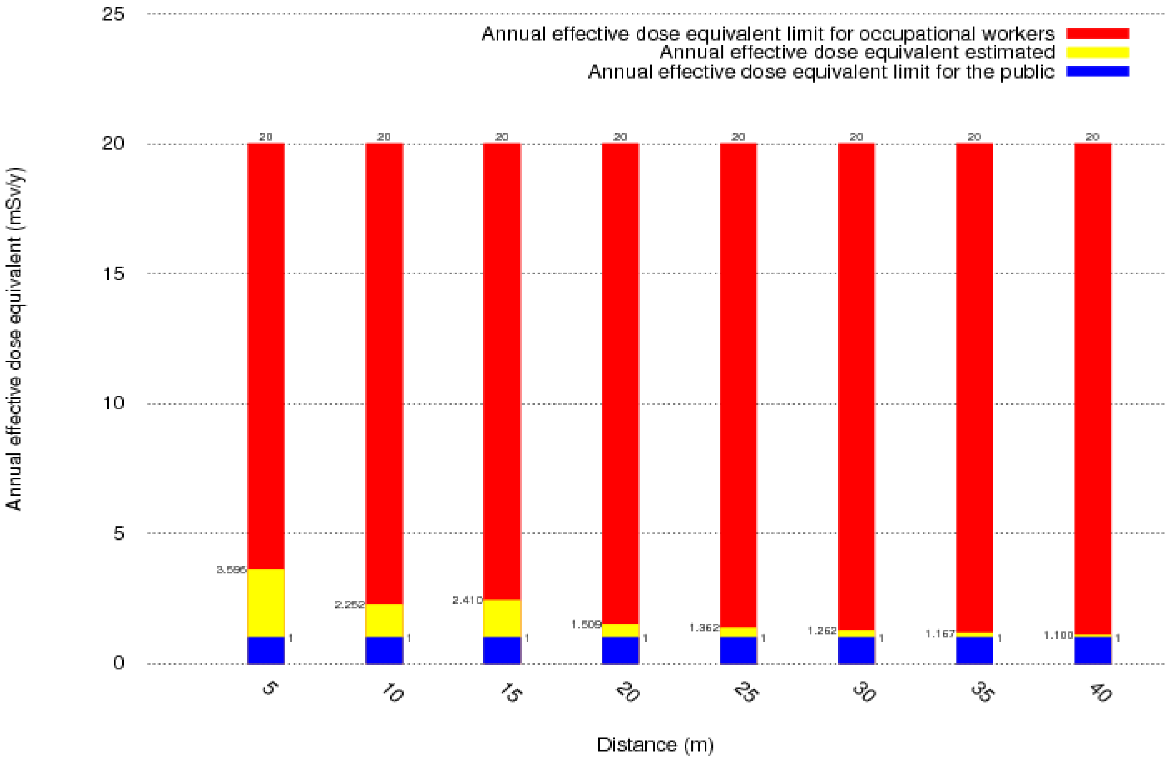

Figure 7. AEDE comparison with ICRP permissible limit.

The other values observed were under the ICRP's maximum allowed limit of 0.57 Sv/h (Streffer, 2007). When the beam was turned on for treatment, the elevated dose rates measured at these distances were ascribed to dispersed radiation from the radioactive source. Annual effective dose equivalents varied between 1.100 and 3.595 mSv/yr. As indicated in figure 6, the greatest AEDE assessed was 3.595 mSv/yr at a distance of 5 m and the lowest AEDE was 1.100 mSv/yr at a distance of 40 m. As shown in figure 7, the yearly effective dose equivalent values were over the safe limit of 1 mSv/yr for public exposure but below the allowed limit of 20 mSv/yr for occupational exposure (Streffer, 2007). Equation 2 was used to compute the additional lifetime cancer risk values. Figure 4 shows that the greatest extra lifetime cancer risk for occupational and public exposure was found to be 12.58x10-3 at a distance of 5 m, while the lowest excess lifetime cancer risk was determined to be 3.85x10-3 at a distance of 40 m. As indicated in figure 5, the increased lifetime cancer risks predicted were more than the usual acceptable level of 0.29 mSv/yr (Taskin et al., 2009).

Table 2. The absorbed dose rate, annual effective dose equivalent and excess lifetime cancer risk at selected locations within the radiotherapy facility

Location	Absorbed dose rate in air (µSv/hr)		Annual effective dose equivalent (mSv/yr)	Excess lifetime cancer risk (x10^{-3})
	Range	Mean		
Simulator room area	0.430-0.477	0.466±0.001	1.715	6.00
Administration area	0.309-0.320	0.313±0.007	1.152	4.03
Conference room area	0.452-0.481	0.469±0.003	1.726	6.04
Linac maze	0.508-0.524	0.515±0.002	1.895	6.63
Control console room	0.558-0.571	0.564±0.002	2.076	7.27
Chemotherapy room area	0.313-0.322	0.317±0.003	1.167	4.08
cobalt bunker room	0.650-0.698	0.678±0.005	2.495	8.73
Nurses office area	0.254-0.283	0.268±0.008	0.986	3.45
Dosimetry room area	0.447-0.482	0.463±0.001	1.704	5.96
Nuclear medicine room area	0.457-0.475	0.467±0.002	1.719	6.02
SPECT CT room	0.492-0.521	0.512±0.004	1.884	6.59
SPECT-CT Console Area	0.457-0.473	0.467±0.005	1.719	6.02
Records area	0.265-0.297	0.281±0.001	1.034	3.62
Patients waiting area	0.491-0.521	0.509±0.003	1.873	6.56
Radiotherapist area	0.288-0.318	0.302±0.006	1.111	3.89
OPD	0.433-0.471	0.455±0.003	1.674	5.86
Minimum		0.268±0.008	0.986	3.45
Maximum		0.678±0.005	2.495	8.73
Average		0.440±0.004	1.621	5.67

Table 2 shows the results, and figure 8 depicts the absorbed dose rates in air, which ranged from 0.2680.008 Sv/h to 0.6780.005 Sv/h with a mean value of 0.4400.004 Sv/h. Figure 9 shows that the total mean absorbed dose value was under the ICRP maximum allowed limit of 0.57 Sv/h (Streffer, 2007). As indicated in Figure 8, the greatest absorbed dose rate is 0.6780.005 Sv/h, while the lowest absorbed dose rate is 0.2680.008 Sv/h in the nurse's office area. At majority of the chosen sites, the dispersed radiation levels in the radiotherapy facility were relatively lower and below the ICRP allowed range. The highest and lowest dispersed radiation levels measured in the radioactive room and nurse's office area, respectively, show that occupational exposure to the Cobalt-60 source is more likely than public exposure. The average absorbed dose rate was used to calculate the annual effective dose equivalent (AEDE) for individuals exposed in the workplace and those exposed in the community in the study region. Due to work shifts and overtime, UNSCEAR typically utilizes 4600 hours per year rather than 8760 hours per year (UNSCEAR, 1993). The predicted annual effective dose equivalent values varied from 0.986 mSv/yr to 2.495 mSv/yr, with an average of 1.62 mSv/yr. The mean AEDE value was discovered to be approximately 1.6 times higher than the annual effective dose equivalent limit of 1 mSv/yr for public exposure (Streffer, 2007) and approximately 20 times lower than the annual effective dose equivalent limit of 20 mSv/yr for occupational exposure (Streffer, 2007). (Streffer, 2007). As indicated in figure 10, the mean value from the radioactive source room had the greatest AEDE, while the nurse's office had the lowest AEDE when compared to the ICRP limit in figure 11.

According to a research conducted by Temaugee, Daniel, Oladejo, & Daniel (2014), cancer types may tend to increase following exposure to ionizing radiation and may be recognized using epidemiological measures. Cancer progression is a random outcome caused by ionizing radiation exposure. The Excess lifetime cancer risk is the likelihood of a person acquiring cancer after being exposed to radiation over a lifetime (ELCR). Figure 12 shows the estimated values of the increased lifetime cancer risk for dispersed ionizing radiation doses ranging from 3.45x10-3 to 8.73x10-3, with an average value of 5.67x10-3.

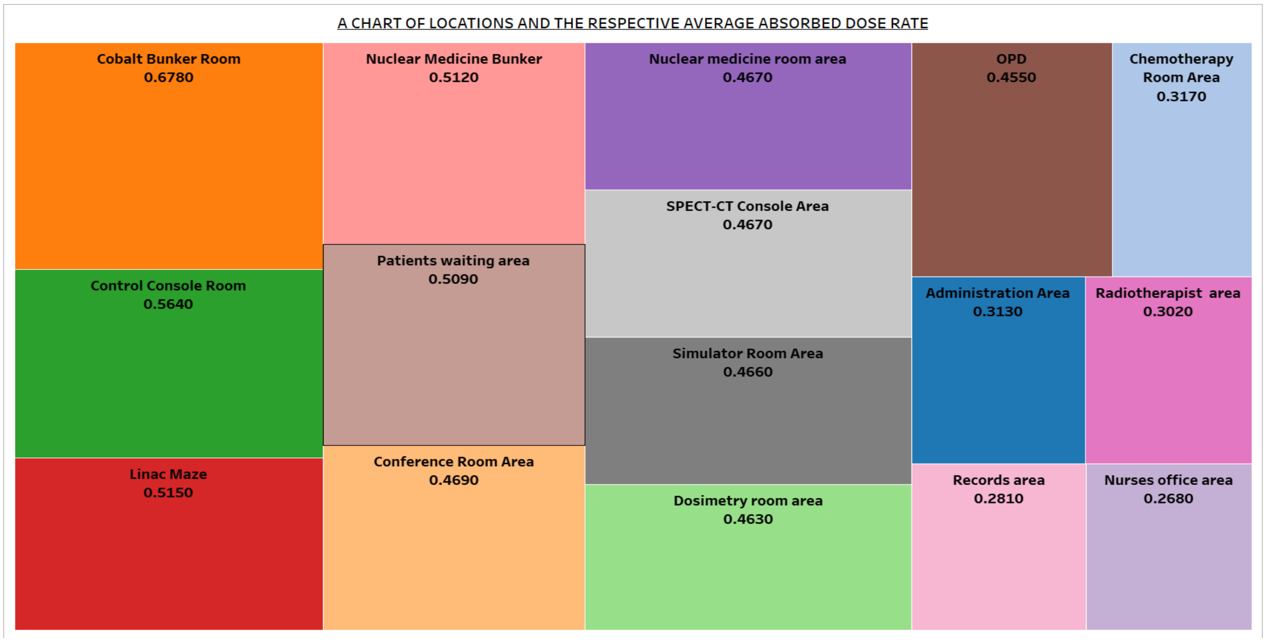

Figure 8. Average absorbed dose rate of the sixteen locations within the facility

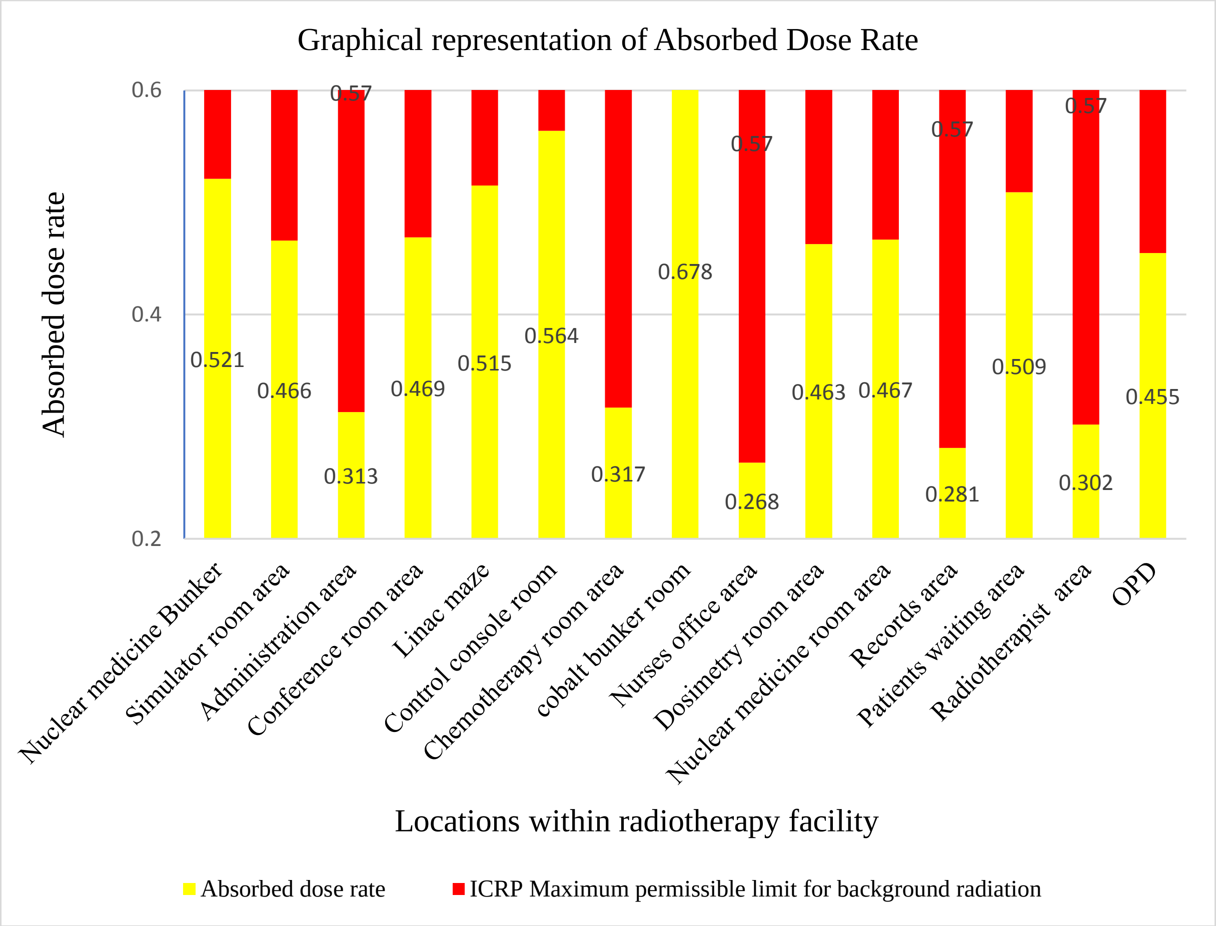

Figure 9. The distribution of absorbed dose rate with ICRP permissible limit at selected locations within the radiotherapy facility.

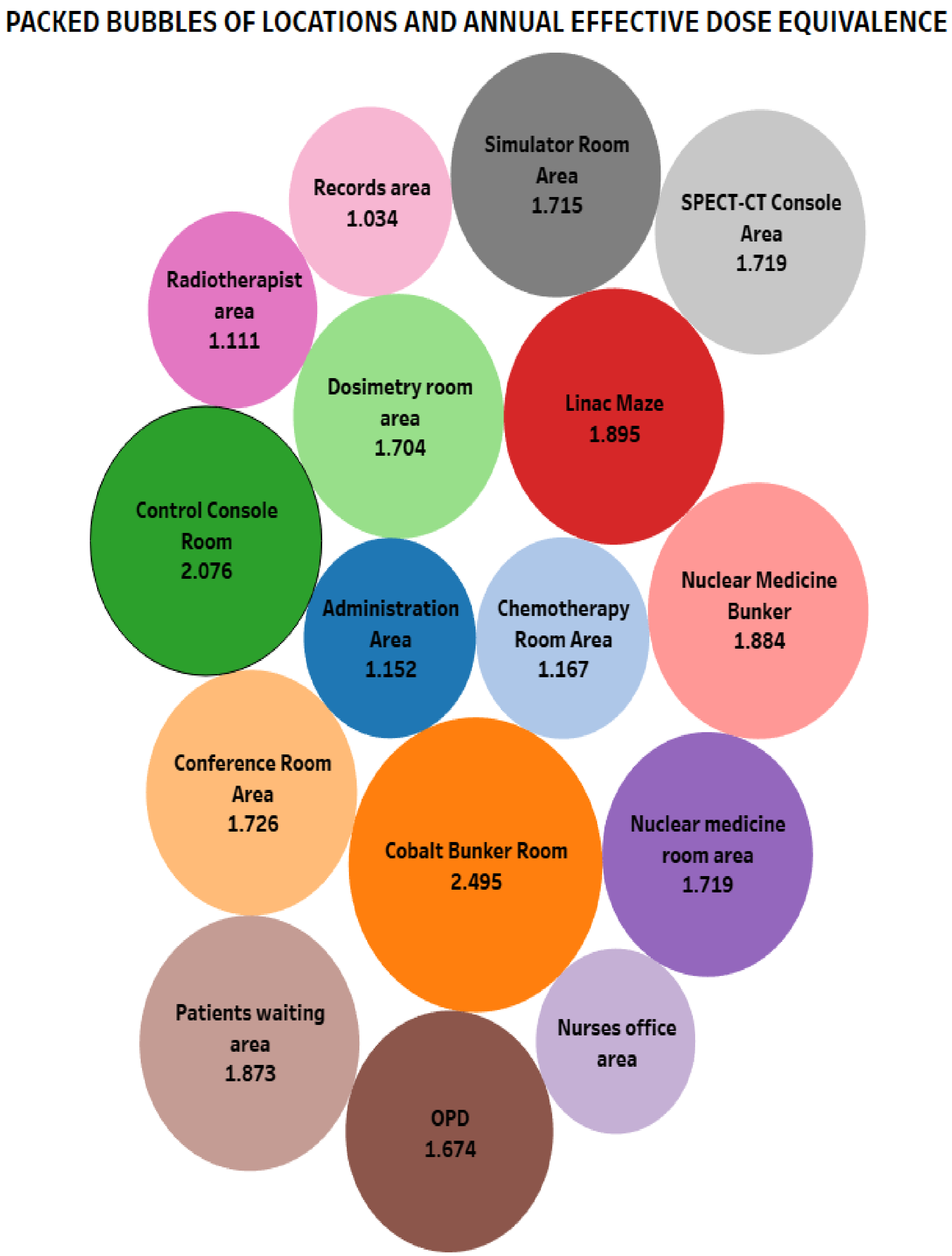

Figure 10. Annual Effective dose equivalent at locations within the facility.

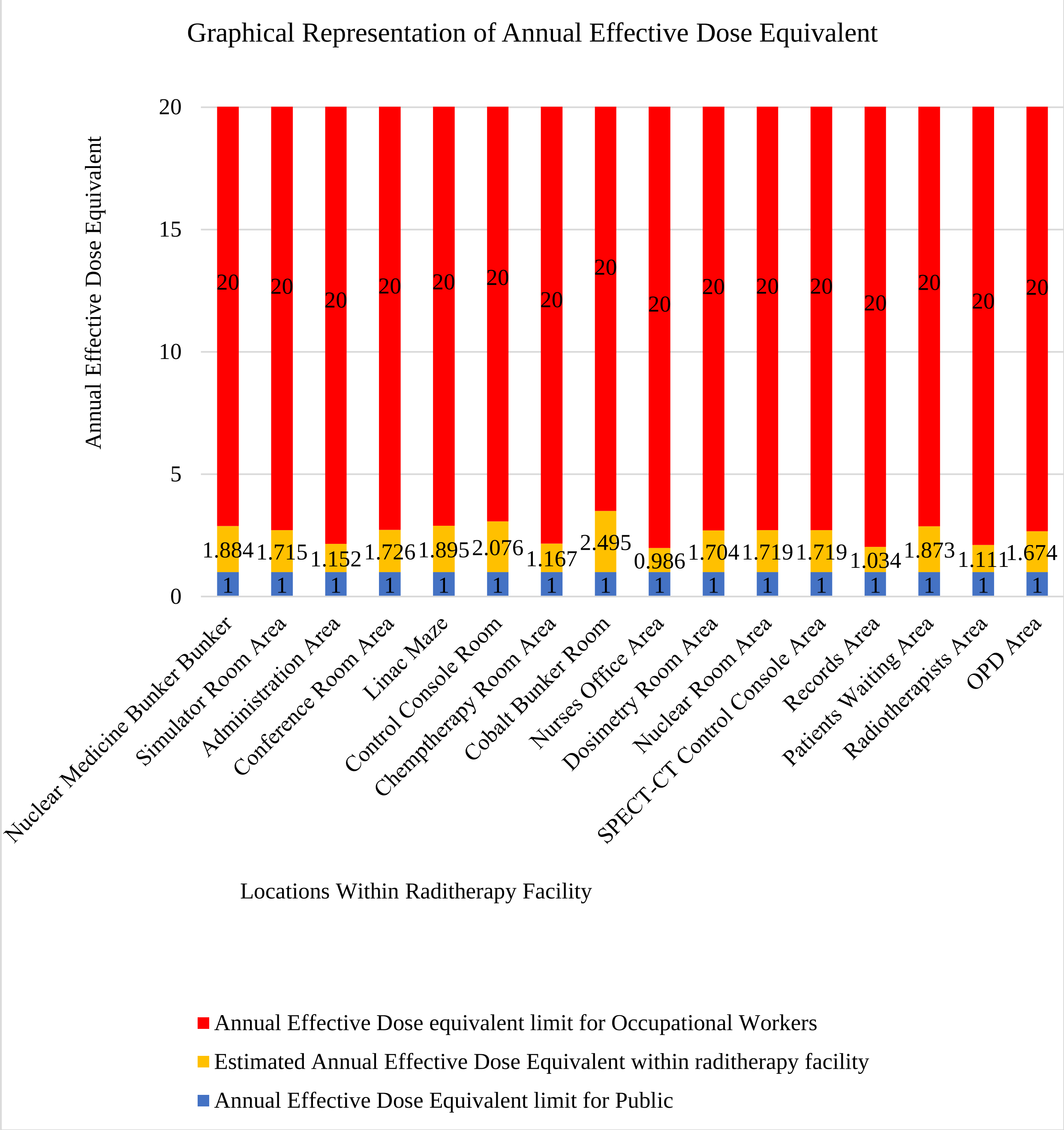

Figure 11. The annual effective dose equivalent distribution with ICRP permissible limit at selected locations within the radiotherapy facility.

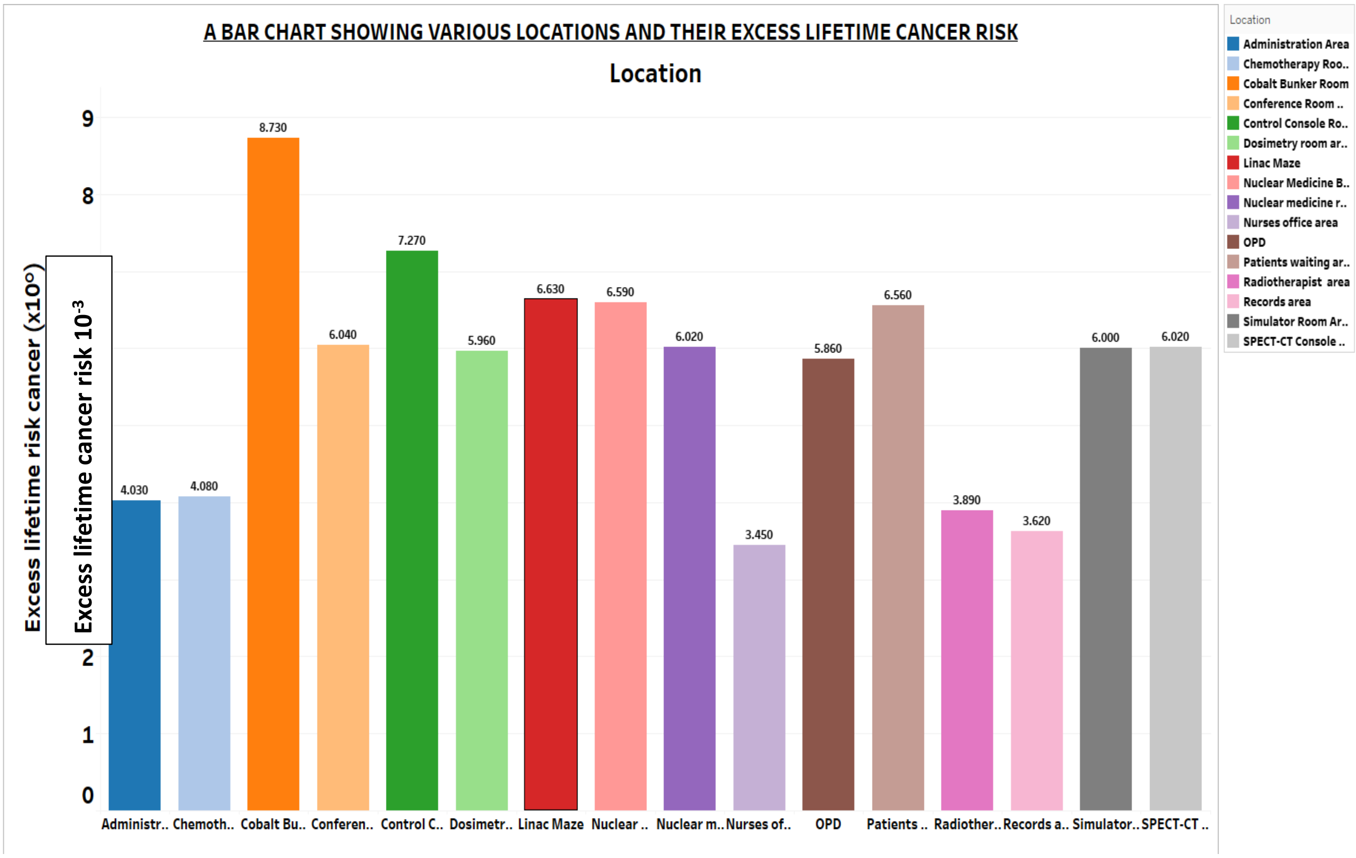

Figure 12. Excess lifetime cancer risk for the selected locations.

The estimated mean value for the ELCR was approximately twenty times higher than the standard value of 0.29×10^{-3} for natural ionizing radiations (Taskin et al., 2009) as shown in figure 13.

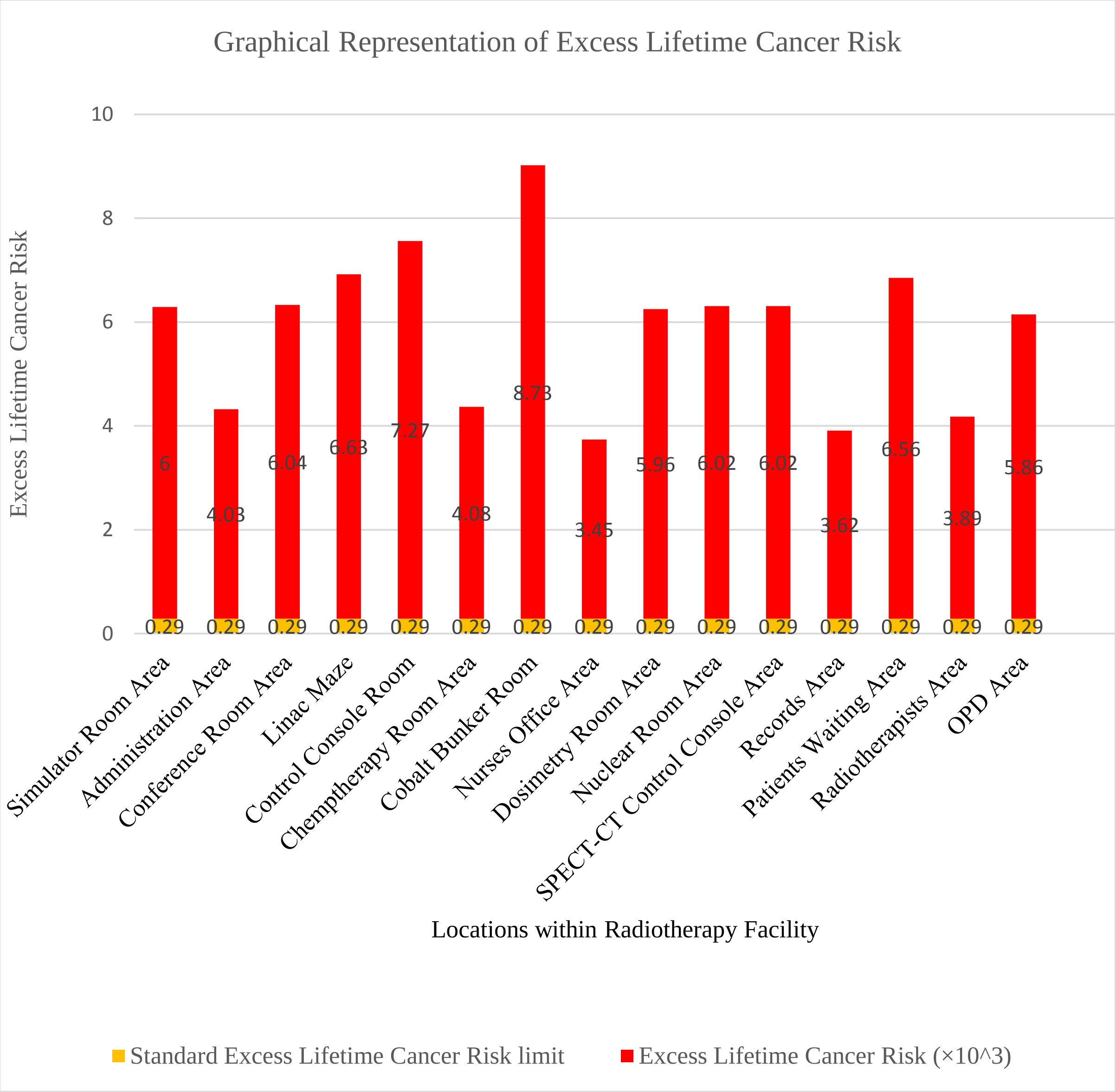

Figure 13. The excess lifetime cancer risk distribution with ICRP permissible limit at selected locations within the radiotherapy facility.

This ELCR value indicates that residents of the study area who will spend their entire lives in the city are unlikely to develop cancer. The BIR exposure model of the annual effective dose to organs estimates the amount of radiation intake by a person that enters and accumulates in various body organs and tissues. In comparison to prior studies, our data reveal an increase in radiation exposure level, absorbed dose rate, and yearly effective dose equivalent rate in the study region, particularly near the cobalt -60 unit. These values, however, may not pose an urgent health concern to the personnel or general residents. Nonetheless, there is a possibility of potential, long-term health concerns for workers getting occupational exposure for lengthy periods of time (more than eight hours per day over a 30-year period) at the Komfo Anokye Teaching Hospital's oncology department.

4.0. CONCLUSION

This research was designed to evaluate the yearly effective dose and extra lifetime cancer risk owing to absorbed dose rate levels and background ionizing radiation inside and around the cobalt-60 Unit in the Komfo Anokye Teaching Hospital's Oncology department. Radiation safety monitoring and evaluation have become major concerns because ionizing radiation is carcinogenic at large doses, and it is critical to identify dose levels in order to manage and analyze the health consequences. The measured gamma dose values (from Absorbed Dose Rate and Background Ionizing Radiation), yearly effective dose equivalents, and extra lifetime cancer risks were calculated in the research. The mean AEDE estimated for the cobalt-60 unit was found to be approximately 1.6 times higher than the permissible Annual Dose Equivalent limit of 1 mSv/yr for public exposure (Streffer, 2007) and approximately 20 times lower than the annual dose equivalent limit of 20 mSv/yr for occupational workers (Streffer, 2007). Excess lifetime cancer risks were also found to be 20 times more than the typical standard value of 0.29×10^{-3} for natural ionizing radiations (Taskin et al., 2009). This is related to the concentration of the cobalt source and the time spent near the source. Because of diffused radiation from the radioactive source and increased natural background radiation in the facility, the computed excess lifetime cancer risk values were raised.

Both dispersed radiation and natural background radiation should be investigated, and employees and residents of the site should be made aware of the high cancer risk so that precautionary measures may be implemented to reduce it. The excess lifetime cancer risks were high and exceeded the natural background limit, but in terms of occupational exposure, it implies that the Oncology directorate is radiation safe for any immediate radiological health effects due to absorbed dose from BIR, but the probability of stochastic effects over a lifetime in the quarry environment is very high. It was also discovered that radiation doses were inversely proportional to the distances between the machine and the observation point. However, there was no discernible difference in radiation levels when the teletherapy unit was rotated at different gantry angles. The background radiation levels in the oncology facility were higher when compared to other research works at the teaching Sohag hospital in Egypt (Harb, 2016), some hospitals in Jos (Jwanbot, Izam, Nyam, & Agada, 2012), and the kwali general hospital in Abuja (James, Moses, Vandi, & Ikoh, 2015); however, they were not extreme enough to pose a significant radiation hazard to occupational workers in the short term but It is stated that occupational employees such as oncologists, medical physicists, technicians, nurses, and maintenance workers are at risk of occupational exposure consequences when exposed to radiation for an extended length of time, highlighting the need of radiation monitoring and protection.

Recommendation

It is recommended that occupational workers should not keep as close to the source as possible, that minimal time be observed by occupational workers, and that the Medical Physicist access periodic ADR monitoring and evaluation of radioactivity concentration of the cobalt source.

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