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Effect of Field Size Dependence on Dose Rate on Co-60 Teletherapy Unit at BINOR

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Abstract: Background: Cancer, defined as the uncontrolled proliferation of malignant cells, is a serious hazard. Radiotherapy, which employs high-energy radiation, seeks to break cancer cell DNA. Due to the significant consequences involved, accuracy is of utmost importance. Before commencing radiation therapy, thorough quality assurance procedures are carried out. The Percentage Depth Dose (PDD) is employed to ensure accurate dose measurement. The research utilized Cobalt-60 Teletherapy, which produces gamma radiation at energy levels of 1.17 MeV and 1.33 MeV, to assess the various field widths observed in PDD. In this experiment, the percentage depth dose (PDD) was evaluated by using a Farmer chamber, water phantom, PC electrometer, ionization chamber, computer software and barometer. The chamber was used throughout a range of field sizes, which varied from $5x5cm^2$ to $20x20cm^2$.The TRS-398 approach was employed to assess the radiation dose. Comparable findings were observed when conducting comparisons with published PDD data for cobalt-60 beams. The accumulation dose

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zone was found to be located approximately 0.5 cm below the surface, coinciding with the maximum (Z_{max}) dose site. The absorbed amount of radiation resulted in a decrease in the percentage depth dose (PDD) below the given depth.

Subject Areas

Oncology

Keywords: Radiotherapy, Percentage Depth Dose ,Ionization Chamber, Electrometer, Barometer, Phantom, Isocenter

Introduction:

Co-60 Teletherapy treats cancer with gamma rays from the radioactive isotope Cobalt-60. In radiation treatment, high-energy photons destroy malignant cell DNA, slowing growth. Improvedtumor control.Co-60 penetrated gamma rays further making it better for treating deep-seated cancers [1]. Reduced skin dose Gamma rays spared healthy tissues at the surface, decreasing skin toxicity [2]. Optimizing Cancer Control radiation treatment eliminates cancer cells while sparing healthy tissue in Mega voltage (MeV) beam. To maximize tumor control, precise dose administration to malignant cell, while minimum dose to organ at risk [3]. Minimizing Side Effects Radiation can harm nearby healthy tissues, causing side effects. Precision dose administration reduces radiation exposure to healthy tissues, lowering adverse effects [4]. A treatment plan adherence in radiation therapy requires accurate dose delivery. Treatment effectiveness is maximized by matching doses to treatment plan. Accurate delivery reduces errors, sparing normal tissue [5]. Photons scatter when radiation beams travel through tissues or collimators. Larger treatment field sizes increase scatter dose, potentially increasing treatment dose [6]. To study the impact of field sizes (5x5 cm^2 to 20x20 cm^2) on dose rate in the Co-60 teletherapy machine installed at BINOR. A phantom is used to evaluate radiation dose rate at a certain depth. Consider stating measurements' reference depth [7].

Literature Review:

Understanding the numerous ways that radiation interacts with materials is essential for precise dose distribution in radiotherapy, especially when field size dependency is taken into account[8]. In Photoelectric absorption an electron is released whenever an atom absorbs gamma ray photon entirely. The interaction is strongest for low-energy photons and high Z materials like bone [9]. Compton Photons scatter here by transferring energy to electrons in atoms and deflecting them. This dispersed photon may still contribute to dose deposition, although with less energy [10].

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Produce Pairs only high-energy photons transform into a positron pair near an atom's nucleus. Positrons deposit energy in surrounding area [11]. Scatter radiation with larger field sizes, more photons can undergo Compton scattering in the collimator or patient, contributing to treatment field dose. Larger fields feature broader penumbras. Depending on their placement relative to the penumbra, more healthy tissues may get low-dose radiation [12]. The relationship between field sizes with PDD variation in Co-60 units has been the subject of several researches. When Calculating doses during treatment planning, these variables are essential. Research conducted by writers such as S.E. Johns, B.R. Paliwal, and P. Andreessen et al. Provide a report on the PDD data and measured output factors for various field sizes in Co-60 units. These can be used as a point of reference to compare with the measurements taken at center [13]. The term PDD, or percentage depth dose, describes how the dose deposition changes with depth in a phantom for a certain field size. Research on Co-60 PDD in different field sizes will show how field size impacts dose distribution, which is important to know how field size influences dose rate over the treatment region [14]. Variation in percentage depth dose with field size Co-60 this search phrase combines field size dependency with PDD. [15]. Co-60 units employ simple beam shaping, but sophisticated techniques to target tumors and limit healthy tissue exposure. Improved MLCs shape for tumor targeting and reduced healthy tissue exposure [16].

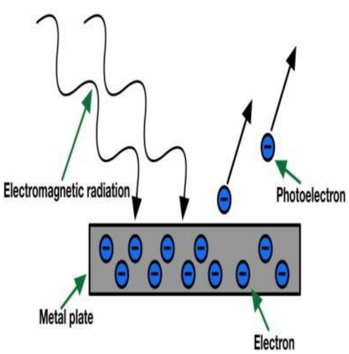

Figure 1.1 Photoelectric Effect

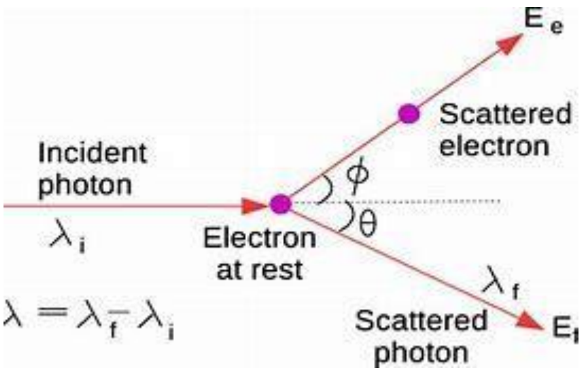

Figure 1.2 Compton Effect

Materials and Method:

This cutting-edge cancer treatment center required data for proper radiation therapy, so researchers used the Cobalt-60 teletherapy system to study the effect of field size on dose rates. A water phantom, ionization Chamber PTW 0.6 cc (Model 30013), 1-D Scanner Assembly, PC electrometer, Computer software (Sun Nuclear), barometer and thermometer were used in data

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Collection. For calculating the dose of radiation in a one-minute exposure of the beam, the charge (nC) collected by the ion chamber was measured for three times to get the average charge M

$$D_m \text{ (Measured Dose rate in water) } = M\frac{(nc)}{(min)} \times N_{D,w} \times \frac{(GY)}{(nC)} \times K_{T,P} \quad (1)$$

Where **M** is charge reading measured by electrometer in nano-columb (nC), $N_{D,w}$ is the chamber calibration factor provided by SSDL for standard measurements and **KTP** is the temperature pressure correction factor calculated by

$$KTP = \frac{273.2+T}{273.2+22} \times \frac{101.33}{P} \quad (2)$$

Theoretical dose was calculated using exponential decay formula:

$$\dot{D} = \dot{D}\,(SSDL)\; e^{(-\lambda t)} \quad (3)$$

The percentage difference between calculated and measured was Obtained using relation

$$\text{Percentage Difference} = 100 \times \left(\frac{D_{cal} - D_m}{D_{cal}}\right) \quad (4)$$

The dosimetry values are recorded and maintained .Co- 60 Teletherapy Gantry & collimator were set to 0 degrees, field sizes of 5x5 cm² to 20x20cm² at an SSD of 80 cm in water Phantom

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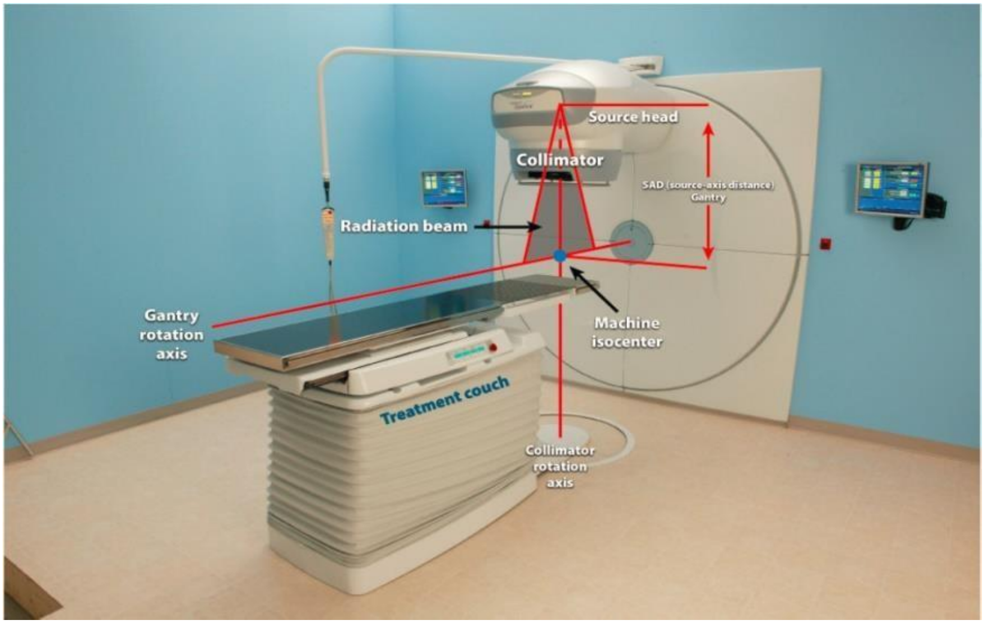

The Figure 1.3 shows the Cobalt-60 Mechine and its Parts

Results and Discussion:

The research was conducted at Bannu Institute of Nuclear Medicine Oncology & Radiotherapy (BINOR, Bannu), to ensure accurate radiation dose delivery for treatment of cancer patients, the beam output is an essential quality assurance procedure. The mathematical expression for PDD is:

$$Percentage\ Depth\ Dose(PDD) = \frac{Dd}{Dmax}\ X\ 100\ \% \quad (5)$$

The percentage depth dose (PDD) is critical since it is the primary determinant in calculating patient dose .the percentage depth dose is dependent on beam quality, field size, and SSD. The SSD was set at an 80 cm distance. The percentage depth dose varied by filed size. The study estimated PDD for varied field sizes. The field sizes were 5x5, 10x10, 15x15, 16x16, 17x17, 18x18, 19x19 and 20x20 cm^2; with increments of 2.0 cm and dose normalize at Zmax i.e 0.5 cm depth. The investigation followed the IAEA TRS-398 guidelines, and the results were compared to previously published data.

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Percentage Depth Dose Profile for Field Size of 5x5 cm^2:

The percent depth dose profile for 5x5 cm^2 was measured from 0.5 cm to 30 cm with 2.0 cm depth increments, as shown in **Table 1.4** PDD was calculated for different depths using nC measures of collected charges. The PDD was normalized to dose at 0.5 cm depth, i.e maximum dose Z_{max}.

Table 1.4Percentage Depth Dose Profile for 5×5cm^2 Field Size:

Depth(cm)	C1(nC)	C2(nC)	C3(nC)	Cavg(nC)	Dose(mGy)	PDD
0.5	24.63	24.63	24.64	24.633	1408.6	100
2	22.49	22.48	22.49	22.486	1285.0	91.0
4	19.76	19.76	19.75	19.756	1129.7	80.2
6	17.14	17.14	17.13	17.136	979.95	69.4
8	14.63	14.62	14.63	14.626	836.41	59.2
10	12.49	12.49	12.48	12.486	714.04	50.5
12	10.64	10.63	10.64	10.636	608.25	43.0
14	9.07	9.07	9.06	9.0666	518.47	36.6
16	7.76	7.76	7.75	7.7566	443.56	31.3
18	6.68	6.67	6.68	6.6766	381.80	27.0
20	5.69	5.69	5.68	5.6866	325.18	23.0
22	4.88	4.88	4.87	4.8766	278.0	19.6
24	4.16	4.16	4.15	4.1566	237.69	16.7
26	3.55	3.54	3.55	3.5466	202.81	14.2
28	3.03	3.03	3.02	3.0266	173.07	12.0
30	2.61	2.61	2.6	2.6066	149.06	10.4

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Figure 1.4 plots Table 1.1 data for 5x5 cm^2 depths from 0.5 cm to 30 cm

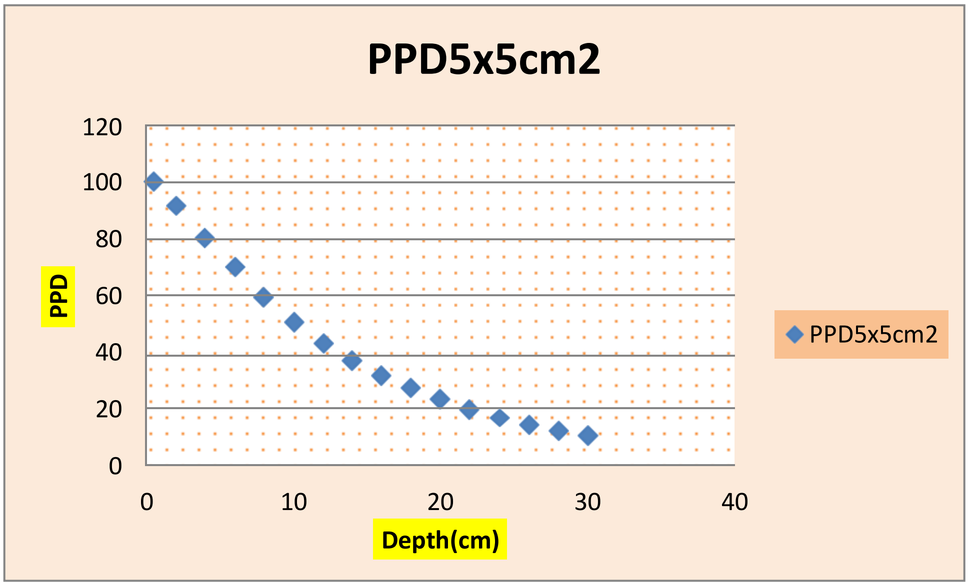

Figure 1.4 percentage Depth Dose Profile for Size of 5×5cm^2

Figure 1.4 illustrates that scattered radiation from the air and material surface causes the highest percentage depth dose at Zmax. Initial dose buildup is shown by PDD increasing from 0 cm to 0.5 cm. PDD decreases after 2.0 cm due to Linear Energy Transfer, radiation beam attenuation, and inverse square law

Percentage Depth Dose Profile for a 20x20 cm^2 Field Size:

Table 1.5 shows the percentage depth dose profile for 20x20 cm^2 from 0.5 cm to 30 cm with a 2.0cm depth increment. PDD was estimated for different depths using nC measures of collected charges. The PDD was normalized to dose at 0.5 cm, Cobalt-60's maximum dose point Zmax.

Table 1.5 Percentage Depth Dose Profile for 20×20cm^2

Depth(cm)	**C1(nC)**	**C2(nC)**	**C3(nC)**	**Cavg(nC)**	**Dose(mGy)**	**PDD**
0.5	100	27.67	27.66	27.00	1582.20	100
2	94.0	26.01	26	26.00	1487.00	94
4	85.2	23.57	23.56	23.00	1347.00	85.0
6	76.4	21.14	21.13	21.00	1208.8	76.2
8	68.0	18.81	18.8	18.00	1075.6	68.0

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10	60.2	16.66	16.65	16.00	952.69	60.0
12	53.2	14.72	14.71	14.00	841.75	53.0
14	47.0	13	12	13.00	743.39	47.0
16	41.5	11.48	11.48	11.00	655.90	41.3
18	36.7	10.15	10.14	10.00	580.42	36.5
20	32.6	9.02	9.01	9.00	515.80	32.3
22	28.8	7.97	7.96	7.00	455.7	28.6
24	25.4	7.03	7.02	7.00	402.00	25.2
26	22.5	6.23	6.22	6.00	356.25	22.3
28	19.9	5.51	5.5	5.00	315.00	19.7
30	17.5	4.84	4.84	4.00	276.20	17.3

Figure 1.5 Plots Table 1.4 data for 20×20cm^2 depths from 0.5 to 30

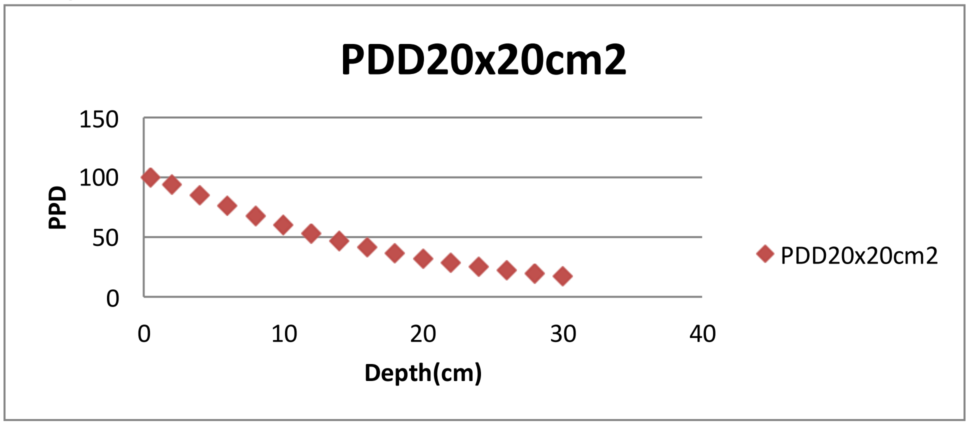

Figure 1.5 Percentage Depth Dose profile for 20x20 cm^2 Field.

As shown in **Figure 1.5** the maximum percentage depth dose (0.5cm) is caused by radiation scattered from the air and material surface .PPD is increased from 0 to 0.5 cm as the first dose increment. The red line graph indicates that as the depth increases, the PDD decreases. This means that the dose of radiation absorbed by the tissue reduces as the radiation penetrates deeper. This information is crucial in radiation therapy to ensure the correct dosage is administered at various depths within the body.

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Combining Cobalt-60 PPD:

Figure 1.6 shows that absorb radiation induce the buildup region, resulting in 100% PDD at

0.5 cm depth for different field widths. PDDs expand from 0 to 0.5 cm depth for all field sizes operate as accumulation regions. Maximum dose is 0.5cm build up point, according to Karma vs. dose. Secondary electrons from photon beams deposit all their energy at the end of their range. The secondary electron range for Co-60 beam opening is 0.5cm at the dose setup. Larger field sizes increase dose due to scatter dose. The surface dose of 30x30 cm^2 is higher than other field sizes because of scattering contribution. Plot shows PDD slowly decreasing after building region for all field sizes. Linear Energy Transfer (LET), inverse square law, and radiation beam attenuation lower PDD. Photon beam power is slowly decreasing, diminishing lower electron energy.

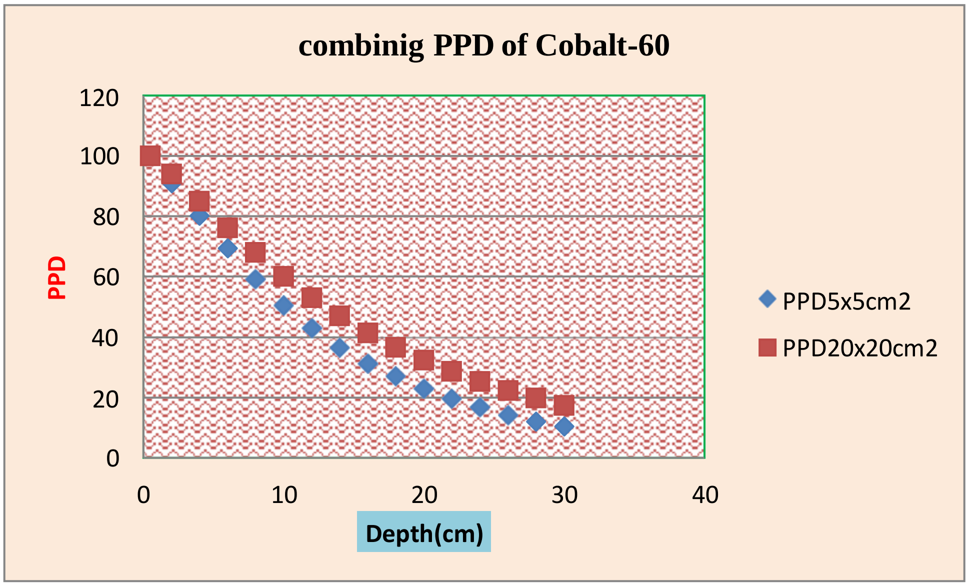

Figure 1.6 Combine PPD of Cobalt-60

Conclusion:

When the treatment field size is increased in radiation therapy, the scatter dosage likewise increases. The main source of this scattered dosage is mostly from collimator scatter and phantom scatter. Regrettably, the contribution from scatter has a direct impact on the actual dose that is administered. On the other hand, when the size of the field is reduced, the peripheral dose

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(PPD) drops in comparison to higher field sizes. This phenomenon arises due to the increased influence of scatter radiation at a consistent depth in smaller fields.

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List of Abbreviations

IAEA: International Atomic Energy Agency

BINOR: Bannu Intitute of Nuclear Medicine, Oncology and Radiotherpy