A Study on the Effects of Wedge Filter in Peripheral Dose Distribution*

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The peripheral dose distributions of wedge fields of Co-60 γ-ray and 10MV x-ray were measured by the solid state detector controlled by means of semiautomatic water phentom system. The measurements were made on the principal plane parallel to the cross section of wedge filter (blade and ridge direction). For parallel motion of the detector to the beam axis the distance from the margin of radiation field at surface were 3, 5 and 10cm. For tranverse motion the depth of measurement were dm, 5, 10 and 15cm. The followings were drawn from the measurement.

1. The peripheral dose of the blade side of wedges was generally higher than that of the ridge side at symmetric point about beam axis.
2. In the superficial region phenomena of dose build-up appeared.
3. For Co-60 γ-ray field, the peripheral dose did not monotonously decrease with the distance from the field margin but increase in some range, consequently showing a peak dose.
4. The peripheral dose did not only depend on radiation quality and field size, but also on wedge angle and wedge direction.

Key Words: Wedge filter, Peripheral dose, Radiation quality

INTRODUCTION

The fact that in radiation treatment by megavolt x-ray and γ-rays secondary radiations come from treatment units and patients is a matter of common knowledge. The secondary radiations not only contribute to dose in the treatment field but also to peripheral dose.

Measurement of the peripheral dose have been the subject of many studies since 1970s. Keller, et al[1] reported that peripheral dose distribution at 10cm depth in water had the dependence on radiation quality. Mackie, et al,[2] Starkschall, et al[3] and Horton[4] reported that there was the existence of dose buildup outside the treatment field in the region corresponding to the buildup range of field. They advocated that the buildup outside the field was caused by electrons liberated from treatment unit. Kang, et al,[5] Bhatnagar,[6] Fraass, et al[7] and Kase, et al[8] did not only report the dependence of peripheral dose on field size and the existence of buildup phenomenon but also that the peripheral dose depended on field size, depth and design of collimating system. Kang, at al[5] and Kase, et al[8] reported the components of therapy unit and phantom to the peripheral dose.

All above ones are documentatioins for open fields. Scrimger, et al[8] reported that beam modifier influenced the peripheral dose. It is reasonable opinion that wedge filter, the most commonly used beam modifier, would also influence the peripheral dose distribution. The fact that the wedge filter is an absorber of primary and secondary radiations from therapy unit but at the same time functions as an another source of secondary radiation strongly implies above mention. It may be, however, almost impossible to estimate separately the two effects of a wedge on change of the peripheral dose in detail.

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It is only possible to measure the peripheral dose under such a situation that the two effects of a wedge filter coexist.

To estimate doses to tissues or organs outside the field even in a case of wedged field, the ratio of the peripheral dose relative to a reference dose is necessary. Authors measured the peripheral dose distribution relative to the maximum dose on beam axis at blade and ridge sides of wedge filters of ^{60}Co γ-ray and 10MV x-ray on their principal planes by means of solid state detector controlled by semiautomatic water phantom system.

MATERIALS AND MEASUREMENT

Radiations whose peripheral dose was measured were γ-ray from cobalt 60 teletherapy unit (Picker C-9) and 10MV x-ray from electron linear accelerator (Varian Clinac-18). Wedges of ^{60}Co unit were made of lead (Pb_{82}) and its wedge angles were 45° and 60°, nominal. The distance of source to wedge (SWD) and the distance of wedge to surface (WSD) of the ^{60}Co unit were respectively 50 and 30cm. The wedges were mounted on a lucite tray so that their slanting surface faced to the cobalt source. Maximum width of wedge field was 18cm at 80cm SSD.

Wedge filters of Clinac-18 were made of brass whose effective atomic number was approximately 29.4. Wedge angles of Clinac-18 were 15°, 30°, 45° and 60°, nominal. The distance of target to wedge (TWD) and WSD were respectively 52 and 48cm. The wedges were mounted under the lucite tray so that their slanting surface faced to water phantom. Maximum width of wedge field was 14cm at 100cm SSD.

Data were obtained by means of solid state detector in water phantom controlled by a controller (Therados LSC-2). A reference probe was mounted under the wedge filter near the beam axis in radiation field and tightly fixed in the course of measurement for each combination of wedge and field size. Gain for the reference probe was set at 60 on the analog meter of LSC-2 control console. Gain for scanning probe was set so that when the probe was at the depth of maximum dose on beam axis the ratio of the signal of the scanning probe to that of the reference probe was 100 (0.5cm for ^{60}Co γ-ray and 2.5cm for 10MV x-ray). Peripheral dose was described in percentage dose relative to the maximum dose on the beam axis. Bias of both detectors was set to 0. Data were recorded by X-Y recorder connected to the controller (Fig. 1).

Peripheral dose on the principal plane at the blade and ridge sides of wedges was measured in water phantom. Motion of the scanning probe was confined in directions perpendicular or parallel to the axis of photon beams. The depths scanned in direction perpendicular to the beam axis were d_m, 5, 10 and 15cm. The distances from the field margin scanned in direction parellel to the axis were 3, 5 and 10cm.

RESULTS

Fig. 2 shows the peripheral dose profiles in the blade and ridge sides of 60° wedges at 3, 5 and 10cm from the margin of 10 × 10cm field versus depth for ^{60}Co and 10MV photons. It appears that in the near region from the field the qualitative character of the two photons is the same but in the far region the character of peripheral dose profile of ^{60}Co has distinguishable difference from that of 10MV x-ray. (1) The dose of ^{60}Co γ-ray in the near region

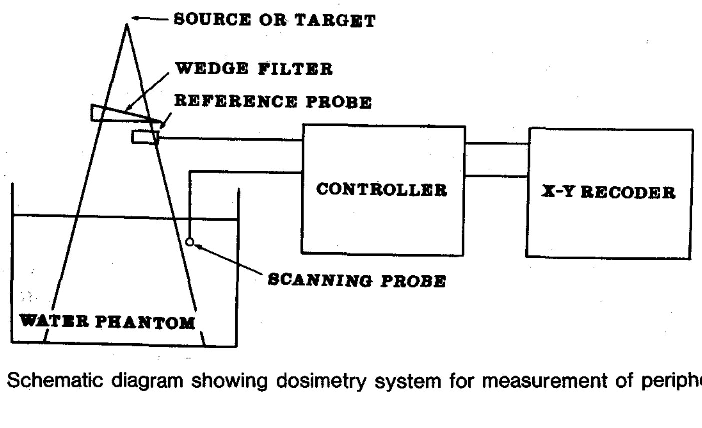
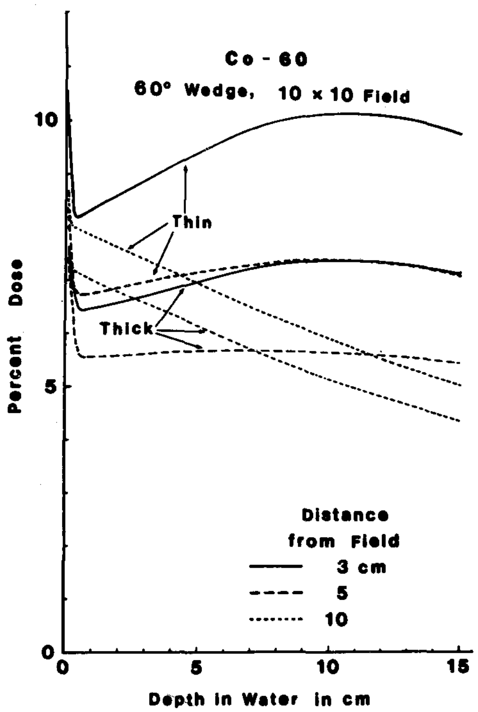


Fig. 1. Schematic diagram showing dosimetry system for measurement of peripheral dose.



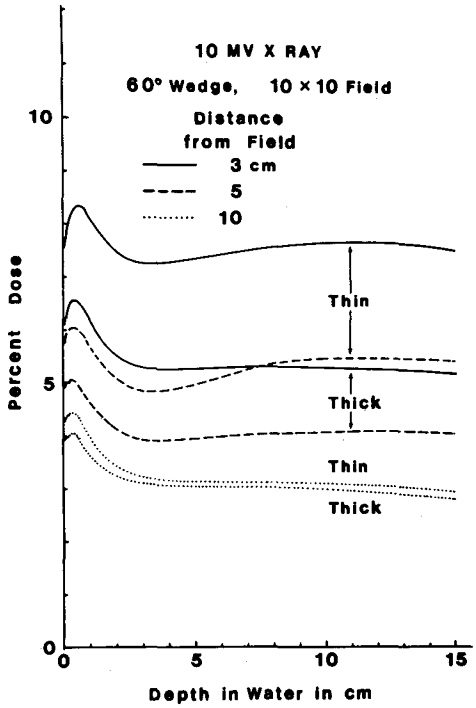


Fig. 2. Comparison of peripheral doses on both side of 60° wedge versus depth in water for 10 × 10cm field. (a) Co ray and (b) 10MV x-ray.

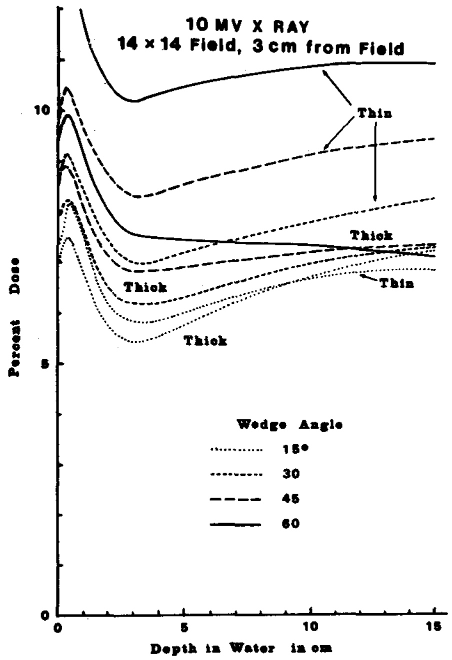


Fig. 3. Comparison of peripheral doses of 10MV x-ray for 4 different wedges and for both sides of the wedges.

and 10MV x-ray is high near the surface and drops to a minimum at d_{max}. (2) The dose increases again as the depth increases. (3) The peripheral dose tends to become constant with depth as distance from the field margin for 10MV x-ray increases. (4) At far distance 10cm or so from the field margin for ^{60}Co γ-ray, the peripheral dose is rather higher than that at short distance and decreases monotonously as depth increases. The first and fourth points are considerable results.

Fig. 3 shows a comparison of the peipheral doses of 4 wedges with different wedge angles at 3cm distance from field margin versus depth for 10MV x-ray 14 × 14cm field. In both blade and ridge sides of wedges, the peripheral dose increases with wedge angle but the variation of the peripheral dose is larger in the blade side than in ridge side. At 3cm depth where dose is roughly minimum, the peripheral doses of 15° and 60° wedges are respectively 5.9% and 10.6% in the blade side, on the other hand 5.5% and 7.6% on the ridge side.

In Fig. 4 the peripheral doses of different field sizes on the blade side of 60° wedge of 10MV x-ray are compared. It appears that the peripheral dose increases as the field size increases.

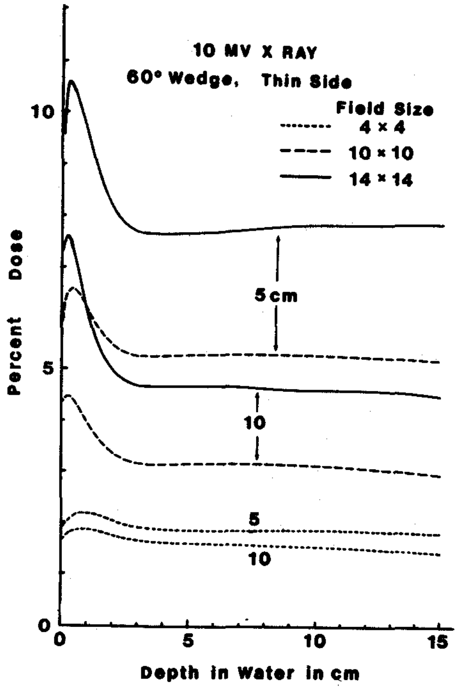
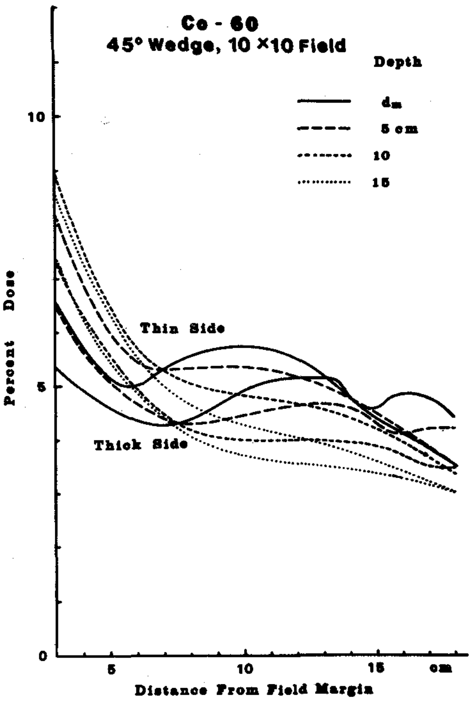


Fig. 4. Comparison of peripheral doses of 10MV x-ray for different field sizes at different distances from field margin.

Fig. 5 shows the variation of the peripheral dose of 45° and 60° wedges at 4 depths and both sides of wedges versus distance from field margin for ^{60}Co γ-ray beam. The significant phenomenon is that as the distance from the field margin increases the peripheral doses at d_m and 5cm depth do not monotonously decrease so that there are minimum and a peak of dose, and although there is no peak at more deep level there is a range that the peripheral dose slowly varies. For the most part, there is a minimum of the peripheral dose at 5 to 7cm distance from field margin and peak at 9 to 11cm distance on the blade side and at 12 to 14cm distance on the ridge side. On the ridge side of ^{60}Co wedges there is a secondary minimum and a secondary peak. The positions of the secondary minimum and peak move outward as the depth increases. Peripheral dose for ^{60}Co is also larger for larger wedge angle (60°C) than for smaller wedge angle (45°) as well as 10MV x-ray. Peripheral dose on the blade side is higher than that on ridge side at relatively short distance, but at long distance the situation is reversed.



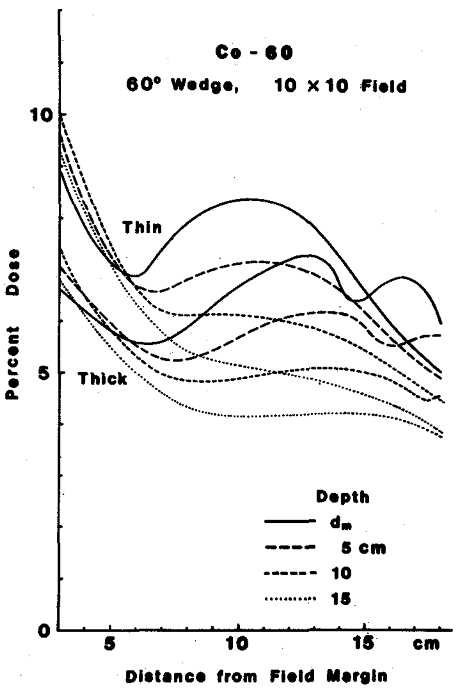


Fig. 5. Comparison of peripheral doses for both sides of wedges at 4 different depths for 10 × 10cm² field of ^{60}Co beam. (a) 45° wedge and (b) 60° wedge.

Peripheral doses for different field sizes and two wedges (45 and 60) of ^{60}Co versus the distance from field margin at 4 different depths are compared in Fig. 6. Peripheral doses have one minimum and one peak for such relatively small field size as 4 × 4cm and 10 × 10cm, but have a region of relatively slow variation for such relatively large field as 16 × 16cm. The position of a minimum dose is at 5 to 6cm distance from field margin for the blade side of wedge irrespective from both wedge angle and field size. The position of a peak dose is almost irrespective to field size but becomes more distant with the increase of depth and wedge angle. At more far distance than 6cm the peripheral dose decreases except for 16 × 16cm / 45° wedged field as the depth increases. The peripheral dose for 60° wedge is higher than that for 45° wedge and especially on peak region more serious.

DISCUSSION

For 10MV x-ray, the qualitative characteristic of the peripheral dose of wedged fields is very similar to open field.[5-8] For ^{60}Co γ-ray that is similar except for region longer than 5 to 6cm from the field margin. Near the surface the peripheral dose decreases as depth increases. It is regarded that for wedged field the dose near the surface has the large contribution by electrons emitted from other than phantom as well as open field.[3-8] However, it is reasonable to estimate that the electrons come from wedge rather than treatment unit. The reason is that the wedge filter is too thick for electrons recoiled from therapy unit in interaction process to penetrate it. As compared with open field the contribution of electrons to the dose near surface was reduced for wedged field. In 10MV 10 × 10cm field, the maximum contribution of electrons was 2.5%[5] for open field while 1.3% for 60° wedged field.

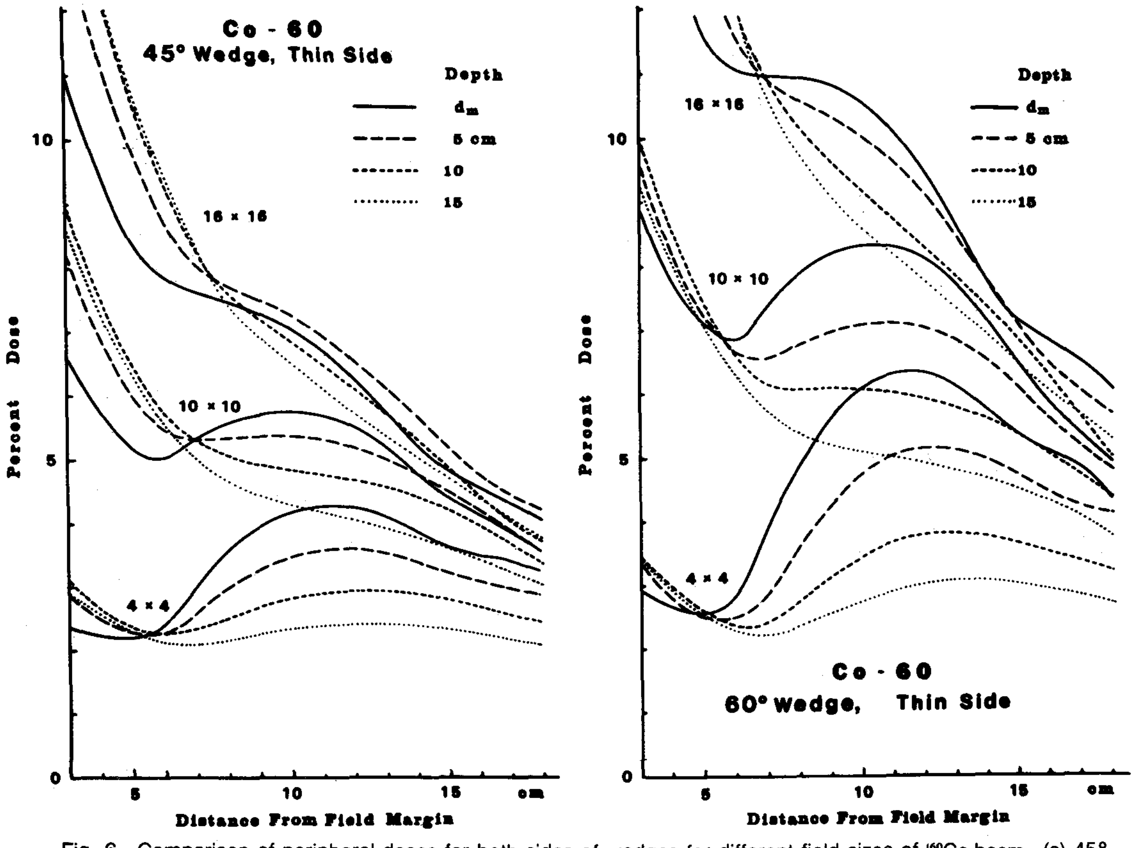


Fig. 6. Comparison of peripheral doses for both sides of wedges for different field sizes of ^{60}Co beam. (a) 45° wedge and (b) 60° wedge.

For wedged field, the peripheral dose distribution is not symmetric but higher on the blade side than on the ridge side. That is similar to the pattern of dose distribution inside the wedged field.

Peripheral dose increases with the increases of wedge angle. That could not be interpreted as the substantial increase of the peripheral dose filter that decreases with the wedge angle.

Peripheral dose of wedged fields increases as field size increases. That phenomenon is similar to open fields and could be explained as increase of the volume of the source of secondary radiation.

Fig. 2, Fig. 5 and Fig. 6 show that in some depth the peripheral dose for ^{60}Co does not monotonously decrease but has one minimum and one peak on the blade side of wedge, and two minimum and two peaks on the ridge side. The secondary minimum on the ridge side came into being because of the existence of a pull of wedge holder. The existence of peak outside the ^{60}Co field is an extremely significant phenomenon and entirely beyond expectation. The question is why peripheral dose increases with increase of the distance from field margin and there is a peak dose outside the ^{60}Co field. Radiation quality, wedge material, WSD and design of collimator system of cobalt unit could be considered as the cause.

CONCLUSION

The peripheral dose of wedged field was measured by water phantom system with solid state detector. The variations of the peripheral dose due to radiation quality, wedge angle, wedge side and field size were examined in some region outside radiation field. For 10MV x-ray, peripheral dose near surface decreases as depth increases. That has a minimum at d_m and next increases with the increase of depth for large field but has nearly constant dose in spite of increase of depth for small field. As distance from field margin increases, the peripheral dose decreases. For ^{60}Co γ-ray, however, the peripheral dose in some depth range does not monotonously decrease for increase of the distance from the margin, and has minimum and peak dose consequently. The peripheral dose of wedged field is higher for lower quality than for higher quality. The peripheral dose of wedged field for both ^{60}Co and 10MV photons is higher for larger field than for smaller field, higher for larger wedge angle than for smaller angle and higher for the blade side of wedge filter than for the ridge side. To shield critical organs or normal tissue outside the ^{60}Co wedged field is desirable for radiation protection.

REFERENCES

1. Keller B, Mathewson C, Rubin P: Scattered radiation dosage as a function of x-ray energy. Radiology 111:447-449, 1974.
2. Mackie TR, Scrimger JW: Contamination of a 15-MV photon beam by electrons and scattered photons. Radiology 144:403-409, 1982
3. Starkschall G, St George GJ, Zellmer DL: Surface dose for megavoltage photon beams outside the treatment field (Abstract). Med Phys 9:632, 1982.
4. Horton JL: Dose in the buildup region outside the primary beam. Med Phys 11:331-334, 1984.
5. Kang WS, Huh SJ, Ha SW: A study on does distribution outside ^{60}Co γray and 10MV x-ray fields. J Korean Soc Ther Radiol 2:271-280, 1984.
6. Bhatnagar JP: Secondary radiation from supervoltage accelerators — Its implication in patient protection. Br J Radiol 50-450, 1977.
7. Fraass BA, van de Geijin J: Peripheral dose from megavolt beams. Med Phys 10:809-818, 1983.
8. Kase KR, Svensson GK, Wolbarst AB, et al: Measurements of dose from secondary radiation outside treatment field. Int J Rad Oncol Biol Phys 9:1177-1183, 1983.
9. Scrimger J, Kolitsi Z: Scattered radiation from beam modifiers used with megavoltage therapy units. Radiology 130:233-236, 1979.

국문초록=

Wedge Filter가 주변선량분포에 주는 영향에 관한 연구

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Wedge filter를 사용할 때 ^{60}Co γ선과 10 MV X-선의 주변선량분포를 반자동식 물팬톰장치에 의해 제어되는 고체 방사선검출기로 측정하였다. wedge filter의 날과 등의 방향을 잇는 주단면상에서 주변선량을 측정하였다. 방사선의 투과력과 wedge 각, wedge에 대한 방향, 조사면의 변화에 대하여 주변선량의 변화를 고찰하였다. 선축에 수직인 방향의 측정은 깊이 dm, 5 cm, 10 cm, 15 cm에서 선축과 평행인 방향에서는 조사면 경계에서 3 cm, 5 cm, 10 cm 떨어진 위치에서 측정이 이루어졌다. 측정으로부터 wedge가 사용되는 조사면에 대한 주변선량분포가 아래와 같음을 볼 수 있었다.

1. wedge filter의 날의 방향의 주변선량이 등의 방향의 주변선량보다 높았다.
2. 표면근처에서는 깊이가 깊어짐에 따라 선량이 감소하였다.
3. ^{60}Co γ선의 경우 어떤 깊이에서는 조사면의 경계로부터 거리가 멀어짐에 따라 주변선량이 단조감소하지 않고 다시 증가하는 영역이 있었다.
4. wedge를 사용하는 경우 주변선량은 방사선의 투과력이나 조사면의 크기 뿐만 아니라 wedge의 각과 방향에도 영향을 받는다.