CALCULATION OF EQUIVALENT DOSE FOR PHOTONS RESULTING FROM SKYSHINE PRODUTION ACCORDING TO NCRP Nº151

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ABSTRACT: Some radiation facilities are designed with little shielding in the ceiling above the accelerator. A problem may then arise as a result of the radiation scattered by the atmosphere to points at ground level outside the treatment room. Stray radiation of this type is referred to as skyshine, and the National Council on Radiation Protection and Measurements Report No. 151 (NCRP, 2005) gives methods for the calculation of the skyshine for accelerator facilities. McGinley (1993) has compared skyshine measurements made at an 18 MeV medical accelerator facility with values calculated using the techniques presented in the NCRP Report No.151. Measurements were made of the photon levels outside a treatment room housing a Varian 2100C equipment. The roof above the accelerator was designed for weather protection only and offered little shielding for the primary beam and scattered radiation. The distance from the treatment room floor to the roof was 4.27 m, and the primary walls were constructed of concrete 2.0 m thick. The secondary walls were made of concrete 0.99 m thick. The results for the photon skyshine dose rate, as a function of distance from the isocenter using Monte Carlo code, are compared with those in McGinley (1993) and measures obtained. The photon skyshine dose rates simulated for real clinic spectra transmitted through roof range from 4.7 to 14.6 $nSv.s^{-1}$ and differ from the values obtained using the empirical formula proposed by NCRP Nº 151.

KEYWORDS: Skyshine, Radiotherapy, Photons, Accelerator, Equivalent Dose.

CÁLCULO DA DOSE EQUIVALENTE PARA FÓTONS RESULTANTES DA PRODUÇÃO DE SKYSHINE DE ACORDO COM A NCRP Nº151

RESUMO: Algumas instalações de radiação são projetadas com pouca blindagem no teto acima do acelerador. Pode então surgir um problema como resultado da radiação espalhada pela atmosfera para pontos ao nível do solo fora da sala de tratamento. A radiação espúria deste tipo é referida como skyshine, e o documento nº 151 do Conselho Nacional de Proteção e Medições das Radiações (NCRP, 2005) fornece métodos para o cálculo do skyshine em instalações de aceleradores. McGinley (1993) comparou medições de skyshine feitas em uma instalação de acelerador médico de 18 MeV com valores calculados usando as técnicas apresentadas no documento NCRP No.151. Foram feitas medições dos níveis de fótons fora de uma sala de tratamento que abrigava um equipamento Varian 2100C. O teto acima do acelerador foi projetado apenas para proteção contra intempéries e oferecia pouca blindagem para o feixe primário e a radiação espalhada. A distância do piso da sala de tratamento até a cobertura foi de 4,27 m, e as paredes primárias foram construídas em concreto com 2,0 m de espessura. As paredes secundárias foram fabricadas em concreto com 0,99 m de espessura. Nossos resultados para a taxa de dose do skyshine de fóton em função da distância do isocentro usando o código de Monte Carlo são comparados com as medidas de McGinley (1993). As taxas de dose de fótons skyshine simuladas para espectros clínicos reais transmitidos através do telhado variam de 4,7 a 14,6 $nSv.s^{-1}$ e diferem dos valores obtidos pela fórmula empírica da NCRP Nº 151.

PALAVRAS-CHAVE: Skyshine, Radioterapia, Fótons, Acelerador, Dose Equivalente.

1 I INTRODUCTION

Short time after the discovery of ionizing radiations, in the end of the XIXth century, it became clear that such radiations to which human’s senses were completely blind could be characterized as double-edged swords, being able to heal illnesses but also to cause harm. Men took advantage of this paradox using the capacity of killing cells in radiotherapy.

Prodigious equipment technological developments allowed to overcome previous medical limits making radiation available for an increasing number of applications. Equipment’s able to deliver high energy beams became common in medical practices. Leaking radiations and other technical problems appeared, inclusive in hospital facilities. For example, in some radiotherapy facilities, where there is no occupancy on the top floor, the roof above the therapeutic accelerator is usually designed with little shielding.

The problem arises from the presence of scattered radiation into the atmosphere, known as skyshine. This scattered radiation can reach occupied areas on the ground floor outside the room, or any other adjacent buildings, and even interfere with medical equipment on the hospital premises. Clearly radioprotection must be a major concern.

National Council on Radiation Protection (NCRP) recommendation N°151 (NCRP, 2005) provides us with an empirical equation to calculate the equivalent dose for photons resulting from the production of skyshine. However, the results obtained by this formula are significantly different from those obtained through experimental measurements.

This work presents dose values calculated by the NCRP's formula and the values obtained experimentally. It also performs the calculation of the equivalent dose for photons resulting from the production of skyshine through simulation using the code, MCNPX (Monte Carlo Team, 2003). Hence, the purpose of this work was to compare simulated values and the results calculated using the empirical formula with experimental results found in the literature (McGinley, 1993).

2 I METHODOLOGY

In the present work, photon beams outside a radiotherapy room that houses a Varian 2100C accelerator, which produces an 18 MV X-ray beam, were studied. The roof above the accelerator was designed with the absence of concrete; the distance from the floor of the room to the roof (D1) was 4.27 m and from the floor to the source (D2) was 2.0 m. The secondary barriers (P4, P5, P6 and P7) were simulated with a thickness of 0.99 m of concrete (see Figure 1).

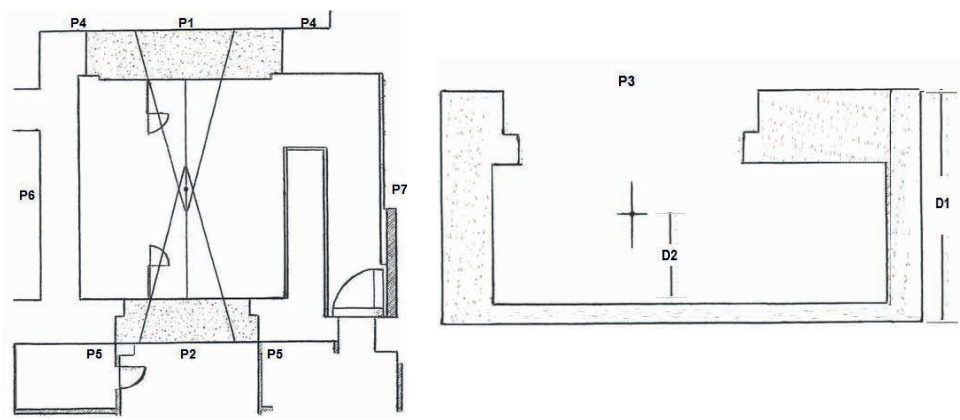

Figure 1: On the left: drawing of the bunker and identification of the points related to the primary barriers P1 and P2 and the secondary barriers P4, P5, P6 and P7. On the right: vertical section of the installation and identification of the adopted dimensions and without the upper barrier P3 (NCRP, 2005), following Rodrigues & Poli (2012).

To calculate the dose rate (nSv.s^{-1}) at the isocenter of the room, the F5 record (Spot detector or Spot flow) was used for the photon beam and normalized by the conversion coefficients of ICRP (1996, 2010). To perform this simulation, the MCNP code, version X (Monte Carlo Team, 2003), based on the Monte Carlo method was used. MCNP is a general-purpose code that simulates the transport of particles such as neutrons, electrons, photons, individually or together (coupled). The so-called Monte Carlo method is the name given to the mechanism responsible for generating random values, used in the stochastic processes of simulation models. The method can be used to simulate the transport of photons through media such as: air, equivalent tissue, and concrete (a commonly shielding used in radiotherapy treatment facilities), to obtain the transmitted spectra of photon fluence on the surface of a mathematical simulator of the human body (phantom). The equation below calculates the dose rate values obtained through the empirical formula, provided by NCRP No. 151 (NCRP, 2005)

$$D = 0{,}249\text{x}10^{6}\ B_{XS}\ (D_iO\ \Omega^{1.3}) / (d_i d_s)^2 \qquad (1)$$

D: equivalent dose rate due to photons

ds: distance (m) from the isocenter to the measured point of D

di: distance (m) from the x-ray target to a point 2 m above the ceiling

D_iO: dose rate at 1 m from the x-ray target

Ω: solid angle of X-ray beam

B_{XS}: transmission rate at ceiling

3 I RESULTS AND DISCUSSION

The experimentally measured values increase as they move away from the isocenter, reaching a maximum value at 13.6 m and then decreasing again. For the values calculated by the empirical equation of NCRP Nº151 (NCRP, 2005), the values calculated for the dose rate due to photons continuously decrease with increasing distance from the isocenter. The values calculated by the Monte Carlo method are in good agreement with the values measured experimentally, about 10%; on the other hand, the values calculated by empirical equation differ about 40% from the values obtained in this work.

The measured results for skyshine due to photons are lower than the values calculated using the NCRP Nº151 method for points near the wall barrier. At a distance of 10.6 m from the isocenter, the measured levels are greater than the values calculated by NCRP Nº151 (see Fig. 2). This work suggests corrections to the empirical equation recommended by NCRP Nº 151.

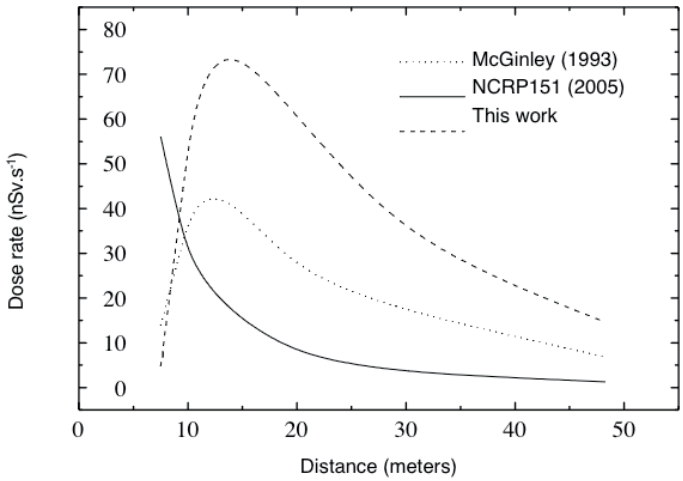

Figure 2: Equivalent dose rate due to photons at a distance ds from the target.

4 I CONCLUSIONS

When comparing the results, it was possible to observe a large discrepancy between the values obtained through the empirical equation and the other values, both experimental and simulated. Thus, it was possible to observe that the dose rate for photons obtained by the empirical formula is not only in disagreement with the experimental measurements, but also with the values obtained by the MCNP code. Therefore, this work concludes that the empirical equation recommended by NCRP 151 is unreliable and suggests corrections in this equation.

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