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Calculation of Equivalent Dose for Photons Resulting from Skyshine Prodution According to NCRP151

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1. Introduction

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 skyshine for accelerator facilities. The calculations were done using the MCNPX Monte Carlo code. The values obtained were compared with data derived from the literature. McGinley (2005) has compared skyshine measurements made at an 18 MeV medical accelerator facility with values calculated using the techniques presented in NCRP Report No.151. Measurements were made of the photon levels outside a treatment room housing a Varian 2100C. 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 fabricated of concrete 0.99 m thick. The results for the photon skyshine rate dose as a function of distance from the isocenter using Monte Carlo code, are compared with those in NCRP publication 151 and measured obtained. The photon skyshine dose rates simutated for real clinic spectra transmitted through roof range from 4.7 to 14.6 $nSv.s^{-1}$.

Key words: Skyshine, Radiotherapy, Photons, Accelerator, Equivalent Dose.

1. Introduction

Some Radiotherapy facilities, where there is no occupancy on the top floor, are designed with little shielding on the roof above the therapeutic accelerator. The problem arises from the presence of scattered radiation in 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. NCRP n°151[1] 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. The work presents dose values calculated by the formula and the values obtained experimentally and performs the calculation of the equivalent dose for photons resulting from the production of skyshine through simulation. Hence, the purpose of this work was to perform the calculation of these values by the code, MCNPX [2] and compare them with the results calculated using the empirical formula and the experimental results found in the literature. 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.

2. Methodology

In the present work, photon beams outside a radiotherapy room that houses a Varian 2100 C accelerator, which produces an 18 MV X-ray beam, were studied. The roof above the accelerator was designed with the absence of concrete and the distance from the floor of the room to the roof was 4.27 m and from the floor to the source was 2.0 m. The secondary barriers were simulated with a thickness of 0.99 m of concrete. 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 [3,4]. To perform this simulation, the MCNP code, version X [2], based on the Monte Carlo method was used. MCNP is a general purpose code that simulates the transport of particles such as neutrons, electron, 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 (shielding commonly 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 presents the dose rate values obtained through the empirical formula, provided by NCRP No. 51,

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

D: equivalent dose rate due to photons

d_s: distance (m) from the isocenter to the measurement point of D

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

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

Ω: solid angle of X-ray beam

BXS: transmision rate at ceiling

3. 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 51[1], 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 equations 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 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. This work suggests corrections to the empirical equation recommended by NCRP 51. See Fig. 1.

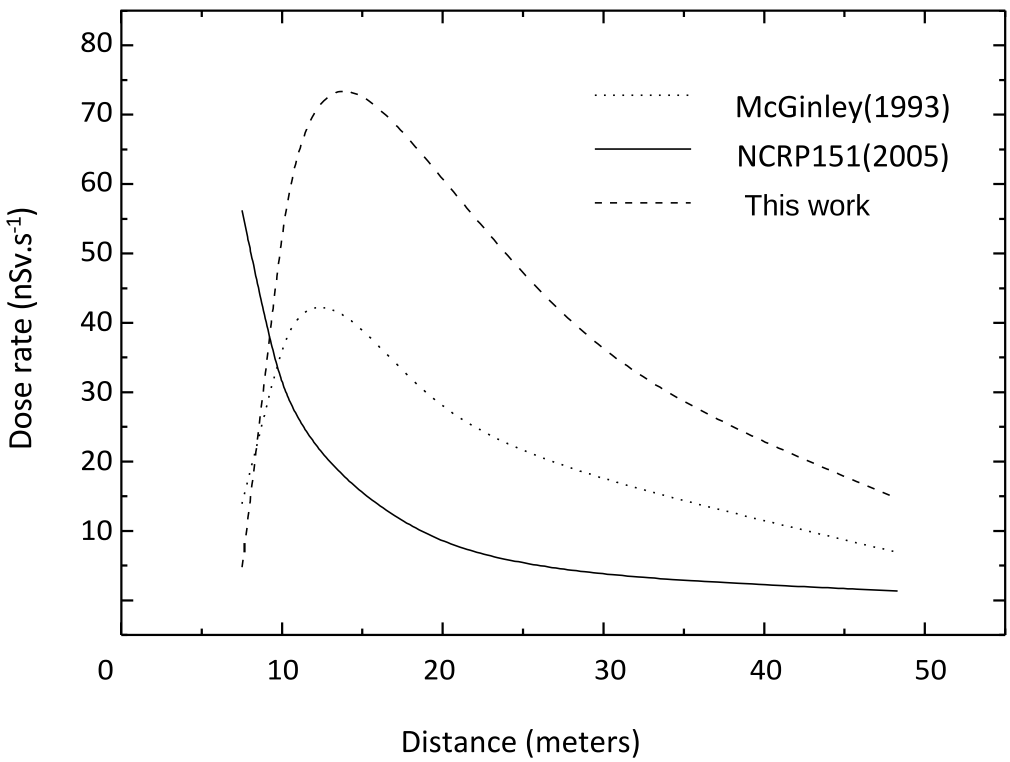

Figure 1: Equivalent dose rate due to photons at a distance d_s from the target.

4. 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. Therefore, this work concludes that the empirical equation recommended by NCRP 51 is unreliable and suggests corrections in this equation.

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