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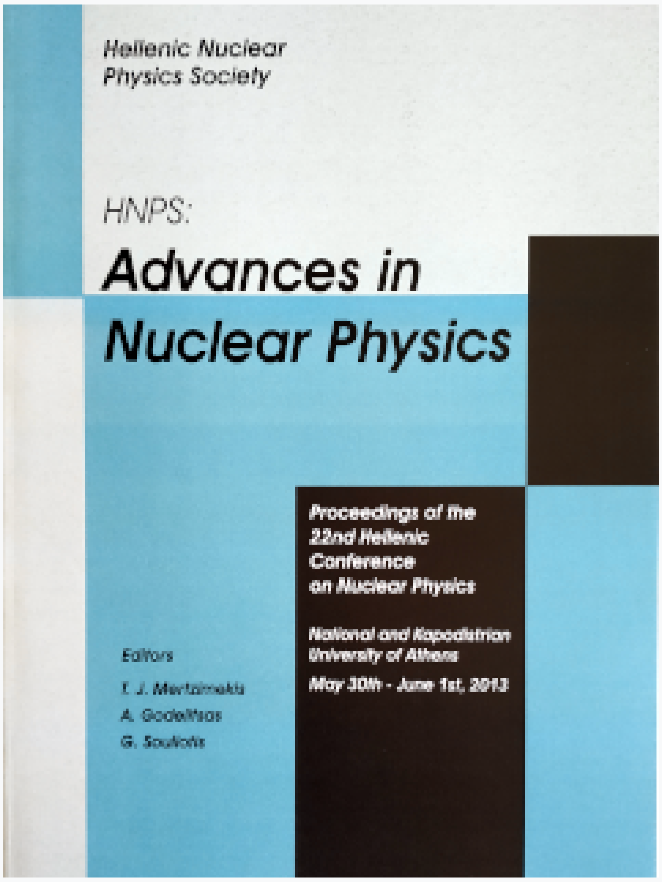

Neutrons along the labyrinth of high energy medical accelerators: Effect of wall materials

M. Fakinou, I. E. Stamatelatos, J. Kalef-Ezra

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Neutrons along the labyrinth of high energy medical accelerators: Effect of wall materials

M. Fakinou[a,b], I. E. Stamatelatos[1a], J. Kalef-Ezra[b]

[a]*Institute of Nuclear & Radiological Sciences, Technology, Energy and Safety, National Centre for Scientific Research "Demokritos", 15310 Agia Paraskevi, Greece*
[b]*Medical Physics Laboratory, School of Health Sciences, University of Ioannina, Greece*

Abstract

Neutron streaming along the labyrinth of a generic bunker of an 18 MV medical accelerator was evaluated. Monte Carlo simulations using MCNP code were performed to calculate neutron ambient dose equivalent along the labyrinth. The effect of plain, borated and barites concrete wall material, as well as borated concrete and plywood (Celotex), as neutron absorbing wall liners, was examined. The results of the study suggest that plywood can provide a cost effective material to attenuate neutron streaming along the labyrinth.

Keywords: Radiation Shielding, Medical Accelerator, Neutron streaming, Monte Carlo simulations

1. Introduction

Neutrons are produced in medical accelerators operating at energies above the threshold of photonuclear reactions (i.e. above 10 MV). The main sources of neutrons are the target, the flattening filter, the collimator and the accelerator head shielding materials. Treatment room shielding, optimized to attenuate the primary and secondary X-rays, is usually adequate to attenuate the neutrons, as well. However, neutrons streaming along the bunker labyrinth may result in a significant dose at the bunker door. The analytical approximation methods used for estimating photo-neutron doses at the door of accelerator bunkers have been shown to be inadequate to describe complex shielding configurations employing neutron attenuation techniques [1].

In this study, Monte Carlo code MCNP5 [2] was used to model a generic bunker of a medical linear accelerator operating at 18 MV. Neutron ambient dose equivalent was calculated along the entrance labyrinth. Dose calculations were performed for different bunker wall compositions. The effect of using different neutron absorbing material layers on the wall surface was studied. The significant advantage offered by the Monte Carlo simulation approach is the accurate modeling of the bunker geometry and material configuration.

2. Simulations

Simulations were performed in neutron transport mode. Cross sections were obtained from ENDF/B-VI.8 data file library. Figure 1 shows the modeled generic bunker geometry. The height of the treatment room was 4.5 m. Runs were performed for three wall material compositions: plain concrete ($\rho = 2.3g \cdot cm^{-3}$), borated concrete ($\rho = 2.3g \cdot cm^{-3}, 0.7\%$ in natural boron) and barites concrete ($\rho = 3.5g \cdot cm^{-3}$). Moreover, layers of borated concrete and plywood (Celotex^{TM}) ($\rho = 0.18g \cdot cm^{-3}$ and $\rho = 0.31g \cdot cm^{-3}$) were used as wall inner surface liners for the absorption of slow neutrons. A simple spherical neutron source was assumed at the position of the accelerator target (1 m above the isocenter). The neutron energy spectrum was taken from IAEA [3] and corresponded to neutrons emitted from a typical 18 MV linear accelerator with tungsten

[1]Corresponding author at: Institute of Nuclear & Radiological Sciences, Technology, Energy and Safety, National Centre for Scientific Research "Demokritos", 15310 Agia Paraskevi, Greece, tel: +30 210 6503718, fax: +30 210 6545496, e-mail:ion@ipta.demokritos.gr

target. Track length estimate tallies were used. The detectors were positioned 1 m above the floor surface level. Neutron fluence was multiplied by fluence to ambient dose equivalent conversion factors [4]. The results normalized per source neutron, were compared against the results obtained for plain concrete based on Portland cement, which is considered as the reference material for this study and is typically used for the construction of accelerator bunkers.

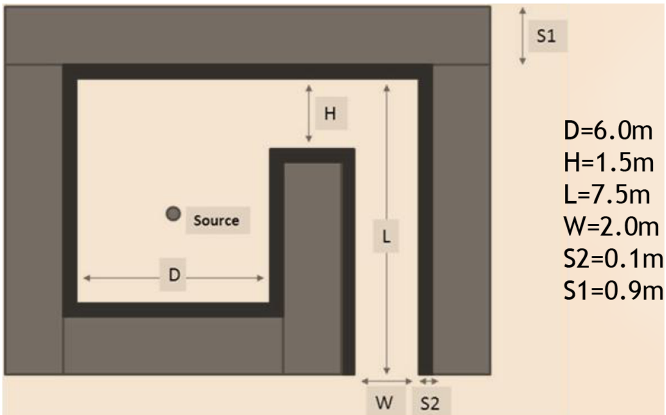

Figure 1: Generic treatment room

3. Results and Discussion

Figure 2 shows the MCNP calculated neutron ambient dose equivalent, $H^*(10)$, along the accelerator labyrinth for different wall materials. From this figure it can be observed that for the bunker configuration studied the use of barites and borated concrete of identical width resulted in a reduction of the neutron ambient dose equivalent at the bunker door. In particular, barites and boron doped concrete were more effective in attenuating streaming neutrons than plain concrete at the door by a factor of 1.5and 1.3, respectively. However, it has to be stressed that this result depends on the treatment room dimensions and the labyrinth geometric cross-section area as well.

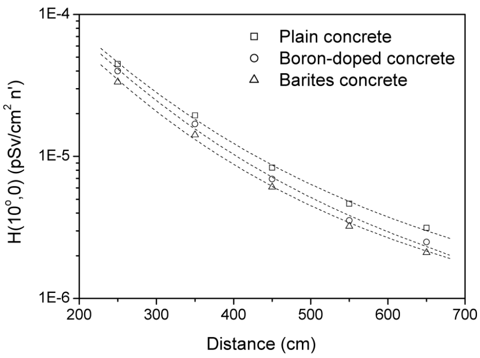

Figure 2: Neutron ambient dose equivalent along the bunker labyrinth for different concrete types. Normalization per source neutron. Statistical uncertainty $< 5\%$.

Figure 3 shows the MCNP calculated neutron ambient dose equivalent, $H^*(10)$, along the accelerator labyrinth for different wall surface liner materials. It is evident that the use of neutron absorbing materials as wall inner surface liners can significantly reduce the neutron dose at the door. In particular, a 10 cm thick liner of boron-doped concrete on a 90 cm plain concrete wall achieved a neutron dose reduction by a factor of 1.3, which is comparable with the result obtained by the boron-doped concrete wall of 100 cm

thickness shown in Figure 2. The alternative use of a 10 cm thick liner of type 1 ($\rho = 0.31g \cdot cm^{-3}$) and type 2 ($\rho = 0.18g \cdot cm^{-3}$) Celotex^{TM} resulted in a much higher reduction factor, 3.0 and 2.5, respectively, at reduced cost.

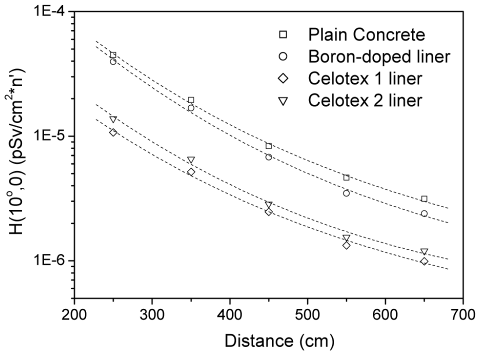

Figure 3: Neutron ambient dose equivalent along the bunker labyrinth for different wall liner materials.Normalization per source neutron. Statistical uncertainty $< 5\%$.

4. Conclusions

Neutron ambient dose equivalent was calculated along the labyrinth of a generic bunker of a typical 18 MV linear accelerator. The effect of plain, borated and barites concrete wall material and borated concrete and plywood (Celotex^{TM}) as wall liners was examined. The results of the study are in agreement with the findings of [1] and suggest that plywood wall lining may provide a cost effective solution to neutron streaming along the labyrinth in expense to a photon dose increase to the surrounding spaces. Further work is required to optimize the thickness and density of the plywood.

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