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79-2 Positional Optimization of Dosimeters for Improved Neutron Albedo Dosimetry

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Abstract:

In this work, we discuss advancements in neutron albedo dosimetry. While personal dosimetry for X, gamma, and beta radiation is straightforward, challenges arise in mixed-field environments involving neutrons and gamma rays, such as nuclear plants, accelerators, and space flights [1]. Neutrons exhibit a wide energy spectrum, ranging from thermal neutrons (~0.025 eV) to fast neutrons exceeding hundreds of MeV [2]. A key aspect of neutron dosimetry is determining the 'dose equivalent', which accounts for the neutron's 'quality factor', dependent on its energy [3]. Neutrons, high linear energy transfer (LET) particles, ionize more densely than electrons. Biological effectiveness, indicated by the quality factor (wR), is 2.5 to 20 times higher for neutrons than photons, complicating mixed-field dosimetry [3]. Neutrons interact with atomic nuclei through several processes, with cross-sections varying with neutron energy and resonances in specific energy ranges [4]. Materials such as ^6Li and ^{10}B have notable (n,a) cross-sections for thermal neutrons [4]. Since the 1970s, various neutron dosimeters have been developed [1]. However, personal neutron dosimetry faces challenges due to strong gamma fields, wide-ranging neutron energies, and the difficulty of detecting fast neutrons, which pose higher harm per unit of energy deposited than thermal neutrons [1]. Effective detection mechanisms must differentiate against low-LET radiations and may incorporate materials susceptible to neutrons, such as ^6Li or ^{10}B , with high cross-sections [2]. Thermal neutrons are commonly detected using (n,a) reactions. Albedo dosimetry is widely used for personal neutron dosimetry [5]. An albedo dosimeter measures thermal neutron fluence emitted from the body after exposure to thermal and intermediate neutrons, moderated and scattered by the body [5]. Detection of reflected thermal neutrons (albedo) uses pairs of thermoluminescent dosimeters (TLDs), ^6LiF (highly sensitive to thermal neutrons) and ^7LiF (insensitive to neutrons but sensitive to photons) [5,6]. Accurate calibration provides reasonable estimates of fast neutron doses. Effective albedo dosimeters require removing incident thermal neutrons from the radiation field, often achieved by neutron-capturing materials over TLDs [5,6]. Dosimeters are typically worn over the chest; however, lung tissue's lower density makes it more permeable to neutrons, yielding fewer albedo neutrons for detection. A critical challenge in albedo dosimetry is detecting very fast neutrons, which penetrate deeply and may not reflect back to the detector, potentially underestimating measured doses. This study aims to enhance neutron albedo dosimetry by evaluating measurement protocols. We investigated pairs of TLDs sensitive and insensitive to thermal neutrons across different energies and fluxes in a standard chest phantom, adjusting for dosimeter placement effects. We combined dosimeters for neutron transmission and reflection, assessing response variations to energy changes and neutron fluxes. Our presentation will highlight the differences in TLD responses and their implications for accurate neutron dose assessment. The authors acknowledge the Brazilian agencies CNPq (grants 305142/2021-6, 307621/2023-5) and FAPESP (grant 2018/05982-0) for partial financial support.

Keywords:

Neutron dosimetry, Albedo dosimetry, Position Optimization