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Original Article

Investigations on borate glasses within SBC-Bx system for gamma-ray shielding applications

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ABSTRACT

This paper examines gamma-ray shielding properties of SBC-Bx glass system with the chemical composition of $40SiO_2$–$10B_2O_3$–xBaO–(45-x)CaO– yZnO– zMgO (where x = 0, 10, 20, 30, and 35 mol% and y = z = 6 mol%). Mass attenuation coefficient (μ/ρ) which is an essential parameter to study gamma-ray shielding properties was obtained in the photon energy range of 0.015–15 MeV using PHITS Monte Carlo code for the proposed glasses. The obtained results were compared with those calculated by WinXCOM program. Both the values of PHITS code and WinXCOM program were observed in very good agreement. The μ/ρ values were then used to derive mean free path (MFP), electron density (N_{eff}), effective atomic number (Z_{eff}), and half value layer (HVL) for all the glasses involved. Additionally, G-P method was employed to estimate exposure buildup factor (EBF) for each glass in the energy range of 0.015–15 MeV up to penetration depths of 40 mfp. The results reveal that gamma-ray shielding effectiveness of the SBC-Bx glasses evolves with increasing BaO content in the glass sample. Such that SBC-B35 glass has superior shielding capacity against gamma-rays among the studied glasses. Gamma-ray shielding properties of SBC-B35 glass were compared with different conventional shielding materials, commercial glasses, and newly developed HMO glasse. Therefore, the investigated glasses have potential uses in gamma shielding applications.

1. Introduction

Progress and development technologies have brought many risk for humanity. For example, people may be exposed to low or high photon energies whether this is in X-ray rooms, nuclear power plants, or laboratories. These photons can travel fast and also can penetrate deeply through materials. An excessive exposure to such photons could cause many harmful effects such as genetic disorders, cataracts, cancer and possibly death [1]. This triggered many scientists to pay tremendous efforts for studying gamma-ray interaction properties with different types of shielding materials [2–4]. In this regard, different materials such as alloys, ceramics, concrete, rocks and polymers are utilized as shielding materials against gamma-ray radiation [5–13]. Although these materials are low cost and widely available, they also have many disadvantages such as they are not transparent to the visible light, cracks formation and water permeability [14–16]. On the contrary, glass materials are transparent to the light and can be used to design doors and windows in medical and nuclear establishments. Also, glasses have many unique mechanical and physical advantages such as hardness, excellent corrosion resistance, and ease of preparation by different methods [17–20].

Recently, many experimental, theoretical, and Monte Carlo Simulation (MCS) studies were carried out to study the gamma-ray shielding properties of different glass compositions [4,5,7,9,12–14,17,21–27]. The significant finding of these studies is that the heavy metal oxides (HMO) play an important role to evolve

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