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Incorporation of Sri Lanka's natural minerals, zircon and apatite, in radiation shielding

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With the rapid increase in the application of ionizing radiation, radiation protection has become a predominant factor in ensuring the safety of humans and the environment. Blocking high-energy photon radiation has proven to be much more challenging due to its excessive penetrating power. Lead-based materials are commonly used for shielding due to their high efficiency in attenuating gamma rays and X-rays. However, the cumulative toxicity of lead to the ecosystem, the weight and the stiffness have made it unpopular when portable shielding application is considered. This study aims to investigate the possibilities of using naturally available minerals in Sri Lanka to develop multifunctional shielding devices for various radiation protection applications. In this preliminary work, zircon and appetite were utilized as the primary attenuating materials due to their elemental compositions. Using silicone rubber and epoxy as binding materials 0.5 cm thick composite layers of zircon and apatite were prepared separately. The selection of binders and the weight ratio of the filler to the binder were chosen to fulfil the requirement of flexibility, low-weight and processability. The capability of radiation shielding of each sample was tested for 662 keV gamma radiation emitted from Cs-137 isotope. Radiation was detected by a NaI (Tl) scintillation detector and analysed by a multi-channel analyser. The linear attenuation coefficient of the binders, single layers of zircon and apatite, and the effective linear attenuation coefficient of two-layer systems with possible orders of layer-arrangement were calculated. The linear attenuation coefficient of epoxy was considerably higher than that of silicone rubber. Among the fillers used, zircon showed more attenuation than apatite due to the higher effective atomic number. In addition, the higher electron density of zircon leads to a higher Compton scattering rate compared to apatite. The linear attenuation coefficients of pure zircon and apatite are calculated to be 0.092 and 0.059 cm^{-1}, respectively, for 662 keV photons. It was observed that in the two-layer composite system effective attenuation coefficient depends on the order of the material layer. Out of the two-layer structures studied, apatite-zircon combination with epoxy as the binding material showed better shielding with 18.1% blocking rate where the apatite layer was placed towards the source. The effective linear attenuation coefficient of this composite system is calculated to be 0.087 cm^{-1} with an effective half-value layer thickness of 7.9 cm.

Keywords: Apatite, Attenuation, Gamma radiation, Radiation shielding, Zircon,

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