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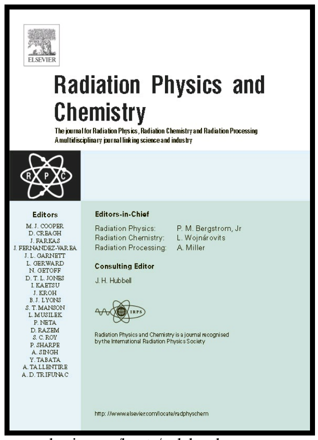

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Computation of the mass attenuation coefficient of polymeric materials at specific gamma photon energies

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Abstract:
The gamma ray mass attenuation coefficients of some synthetic polymeric materials, namely polyethylene (PE), polystyrene (PS), polycarbonate (PC), polyvinyl alcohol (PVA), polyvinyl chloride (PVC), Polyethylene terephthalate (PET), Polyvinyl pyrrolidone (PVP), Polytetrafluoroethylene (PTFE), Polypropylene (PP) and Polymethyl methacrylate (PMMA) are calculated using second order polynomial equation and logarithmic interpolation formula at selected gamma photon energies, in the energy range starting from 14.4 keV up to 1332 keV. It is important to note that second order polynomial equation fits very well with NIST data, for all the polymeric materials considered here, for photon energies ranging from 300 keV up to 2000 keV. Third order polynomial fitting is best suited for lower gamma photon energies (from 10 keV up to 200 keV).

Keywords:
Mass attenuation coefficient, Radiation shielding, polymeric materials, second order polynomial equation, Logarithmic interpolation formula.

1. Introduction

An exposure to a high dose of ionizing radiation is dangerous to man and causes severe health disorders (Thomas et al., 2016). In order to protect personnel from such radiation, shielding is absolutely required while using radiation sources in nuclear reactors, nuclear medicine facilities, nuclear research laboratories, radiation processing units, x-ray generating units and particle accelerators. Several materials like steel (Bashter et al., 1997), concrete (Yilmaz et al., 2011), polymers (Mann et al., 2015; Sayyed, 2016), composites (Hosseini et al., 2015), lead (Erdem et al., 2010), glasses (Singh et al., 2005; Kaur et al., 2016), resins (Elmahroug et al., 2014) and alloys (Kobayashi et al., 1997) have been used as shielding materials.

The use of high atomic number (Z) materials like lead and mercury has several disadvantages. They produce adverse effects on human health as well as the environment (Medhat et al., 2015). The materials used for radiation shielding applications must satisfy some characteristic properties, so that they can be effectively used for a long period of time. At the present time, materials which are more stable, economical, transparent, light-weight, and at the same time effective in radiation shielding are preferred (Nambiar et al., 2012). Polymers are materials which satisfy many of these required properties. Polymers are widely preferred for shielding as well as dosimetric purpose because of their unique properties like low density, low cost, less toxicity, high flexibility and ease of processibility (Bahadur et al., 2002). The study of mass attenuation coefficients of low-Z materials like polymers find applications in radiation dosimetry (Brown et al., 2008) and aids in the selection of good radiation shielding materials for use as tissue equivalent materials (Singh et al., 2014) and radiation masks (Sharp et al., 2005). In addition, many polymers have high hydrogen content, which makes them effective for shielding against neutrons, say, in a nuclear reactor (Malkapur et al., 2015). Thus, polymers are considered as better shielding materials against exposure of personnel to gamma radiation.

Polymers have some disadvantages when they are used as shielding materials to stop the ionizing radiations which are coming out from the nuclear power stations, nuclear installations and industrial gamma irradiators. The effect of radiation on polymers has to be factored in, before considering polymeric materials for radiation shielding applications. Radiation degradation during processing helps to modify the properties of many polymers, in order increase the commercial value (Cleland et al., 2003). The mode of degradation of polymers under irradiation may differ. They may undergo cross-linking or chain scission depending upon the chemical structure of the polymers and the radiation dose rate. Irradiation of polymeric materials with ionizing radiation like gamma rays has some advantages. It helps in the development of engineering materials, since polymeric materials develop modified properties such as thermal, mechanical and chemical resistance. Also, the size of the polymeric molecules is reduced due to scission and the molecular weight is increased due to cross-linking. It should be noted that recycling of polymer waste causes adverse effects on the environment (Burillo et al., 2002).

Most of the radioactive sources (gamma sources) available in radiation laboratories have gamma photon energy in the range starting from 14 keV up to 1332 keV. List of such sources given in the table (1). Also, gamma sources (of higher activity) are utilized for many applications, for example in agriculture (Manuel et al, 1985) and nuclear medicine (Granero et al, 2007). Hence, in order to know the effectiveness of a shielding material, it is