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Radio-protective properties of some sunblock agents against ionizing radiation

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ABSTRACT

When the human exposure to nuclear radiation such as gamma ray, neutrons or charged particles (protons and alpha) it may cause the menacing consequences of skin organ. The devastating effects of nuclear radiation pose a need radioprotective for protecting the skin organ and to avoid the deadly related to these radiations. The sunblock agents samples: Padimate O (SB1), Homosalate (SB2), Dioxybenzone (SB3) Sulisobenzone (SB4), titanium dioxide (SB5) and zinc oxide (SB6) have been studied in terms of mass attenuation coefficient, effective atomic number, buildup factors, fast neutron removal cross section and proton, alpha and electron mass stopping power. The results showed that the ZnO sunblock agent (SB6) has better shielding properties followed by TiO_2 sunblock agent (SB5). This study could be very useful to develop novel pharmacological compounds used in radioprotection, medical diagnostics, and radiation therapy.

1. Introduction

In today's world, the mischievous effects of radiation are customary. Due to the speedy technological progress, day-by-day the level of radiation has been increased, therefore there is a required to protect the human against such mischievous effects of nuclear radiation. Radiations exist in our world from the origin of the Universe. The human exposure to 5% of the radiation comes from outer space (cosmic rays). Exposure to nuclear radiation causes threatening consequences of skin organ. Destructive impacts of nuclear radiation pose a need for radioprotective for protecting the skin organ and to avoid the deadly related to these radiations. In the worldwide twenty-two million people are cancer patients and about 27% die of the disease. When the nuclear radiation interacts with healthy cells, it may be a reason to generate free radicals from cytoplasmic water, which induce harm to the DNA content of the nucleus. This DNA harms may lead to cause cancer in healthy cells. It means that the nuclear radiations are closely related to cancer. Thus, it is required to create such pharmacological efficient radioprotective that can present the protection of human skin against the destructive and damaging outcome of nuclear radiation (Painuli and Kumar, 2016).

The incidence of skin cancers (melanoma and nonmelanoma) has been increased in many countries recently and many of these cases are attributed to long exposure of skin to intense sunlight. Many public health authorities are initiating primary prevention programs recommending the regular use of sunscreens that absorb ultraviolet radiation. The chemical agents such as Padimate O, Homosalate, Oxybenzone, Dioxybenzone and Sulisobenzone and the natural materials such as titanium dioxide and zinc oxide are absorbers whereby radiation enter the skin (Marks et al., 1993).

To examine the effectiveness of sunblock materials as radioprotective agents, in this present study, an endeavor was made to study the interaction of nuclear radiation with some sunblock agents samples. The mass attenuation coefficient (μ_m), half value layer (HVL), mean free path (MFP) and effective atomic number (Z_{eff}) have been calculated in the photon energy range of 1 keV–100 GeV for six sunblock agents: Padimate O (SB1), Homosalate (SB2), Dioxybenzone (SB3), Sulisobenzone (SB4), Titanium dioxide (SB4) and Zinc oxide (SB6). Furthermore, the exposure buildup factor (EBF) and energy absorption buildup factor (EABF) have been calculated using the G-P fitting method for the selected compounds in the energy range 0.015–15 MeV up to penetration depths 40 mfp. Also, fast neutron removal cross sections (Σ_R) in addition to projected range and stopping power for proton have been calculated in the energy range of 10 keV-1GeV.

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Table 1
Chemical composition, weight fraction % and density of sunblock agents.

code	Sample	Formula	Fraction by Weight	Density (g/cm^3)
SB1	Padimate O	$C_{17}H_{27}NO_2$	H (0.098103), C (0.736056), N (0.050492), O (0.11535)	0.99
SB2	Homosalate	$C_{14}H_{12}O_3$	H (0.052992), C (0.736718), O (0.21029)	1.04
SB3	Dioxybenzone	$C_{14}H_{12}O_4$	H (0.049521), C (0.688459), O (0.26202)	1.38
SB4	Sulisobenzone	$C_{14}H_{12}O_6S$	H (0.039231), C (0.545403), O (0.311362), S (0.104005)	1.449
SB5	Titanium dioxide	TiO_2	O (0.400592), Ti (0.599408)	4.23
SB6	Zinc oxide	ZnO	O (0.196578), Zn (0.803422)	5.61

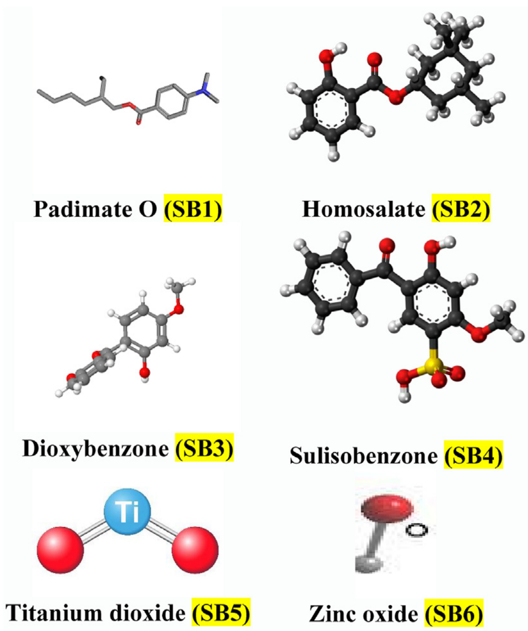

Fig. 1. The molecular structure of sunblock agents.

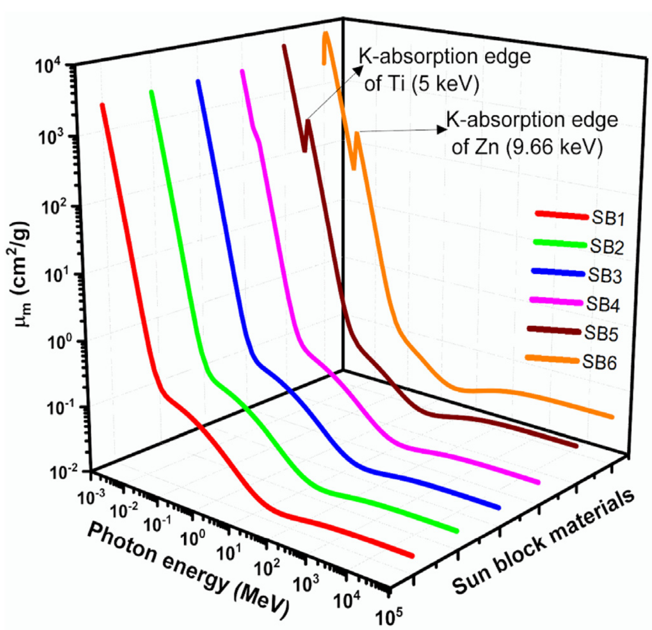

Fig. 2. Variation of total mass attenuation coefficients versus photon energy (1 keV-100 GeV) for sunblock agents.

2. Materials and methods

The mass attenuation coefficient, half value layer, mean free path and buildup factors are the most important parameters for characterization of the penetration and diffusion of gamma-rays in any material. The fast neutron removal cross section is very useful parameter to study the fast neutron interaction with certain material. On the other hand, the mass stopping power and projected range are important parameters that estimate the charged particles such as protons protection properties. Calculation procedures and formulae used in the evaluation of different protection parameters were given in detail elsewhere (Issa et al., 2017a, 2017b; Issa and Mostafa, 2017; Kurudirek, 2014, 2013; 2011; Kurudirek and Çelik, 2012; Kurudirek and Onaran, 2015; Lakshminarayana et al., 2017a, 2017b; Manohara et al., 2009; Mostafa et al., 2017).

3. Results and discussion

3.1. Mass attenuation coefficients

The sample code, chemical composition, weight by the fraction and densities of the investigating Padimate O (SB1), Homosalate (SB2), Dioxybenzone (SB3), Sulisobenzone (SB4), Titanium dioxide (SB5) and Zinc oxide (SB6) are listed in Table 1 and them molecular structure are shown in Fig. 1. Fig. 2 shows that the variation of μ_m values with photon energy and composition of investigating sunblock agents. It is clear that, the values of μ_m for all samples decrease with increasing photon energy and depend on the composition of the sunblock agents. The μ_m values increase quickly up to photon energy < 0.02 MeV. This behavior may be attributed to the photoelectric absorption cross sections which are conversely relative the energy ($E^{3.5}$) of photon (Issa, 2016). At 0.02 < E < 20 MeV MeV the values of μ_m decrease slowly with the photon energy increasing. This may be attributed to the process of Compton scattering was the predominant mechanism. Because the process of Compton scattering is conversely relative the energy (E^{-1}) of photons. Due to the processes pair production begin ruling, the μ_m values decrease very slowly with the photon energy greater than 20 MeV. Because the cross section of the pair production process depends on the atomic number (Z^2) (Han et al., 2009). As shown in Fig. 2 the ZnO sunblock agent (SB6) has the highest values of μ_m followed by TiO_2 sunblock agent (SB5).

3.2. Half-value layer (HVL) and mean free path (MFP)

It is important to express the attenuation of photons in terms of another quantity named as half value layer (HVL). The HVL is an indication of the equivalence of the sunblock agents thickness that decreases the intensity of the photon to half. The HVL physically indicates that the penetration of the photon increases with the increase of the energy of this photon. Moreover, mean free path (MFP) is another important quantity to investigate the attenuation of photon and measures its probability of interaction. MFP represents the average-distance between consecutive interactions of photons with material (sunblock agents of this work). It is worth mentioning that both HVL and MFP are used to estimate the effectiveness of a protection of the present sunblock agents. The HVL and MFP for the present samples in the photon energy range1 keV–100 GeV are given in Fig. 3 and Fig. 4 respectively. Up to photon energy 8 keV and 50 keV the HVL values are the photon