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Doppler Broadening Effects on Low-Energy Photon Dose Calculation: Spectral Analysis with and without Doppler Broadening

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Recent releases of MCNP5 and PENELOPE include the transport algorithm and momentum profiles that are necessary for accounting for Doppler broadening in Compton scattering processes. MCPLIB04 and PENDBASE (PENELOPE photon dataset) are based on the EPDL97 library with Compton momentum profiles, while MCPLIB03 and MCPLIB02 are based on the 1970's old library, with MCPLIB03 including the Compton momentum profiles. We varied the choice of the above photon databases using either version of MCNP5 or MCNP4 (no Doppler algorithm). We computed dose distributions for r = 0.2–10 cm from a point source in a 50 cm-diameter sphere of water. Nine discrete energies for primary photon sources were chosen in the range of 10–150 keV. Especially, we chose 50 keV photons for the spectral dose analysis because Compton scattering interactions dominate over photoelectric interactions, while their energy is low enough to produce noticeable Doppler broadening. A quantitative analysis on absorbed doses using calculated photon spectra and published mass energy-absorption coefficients was made. The results from both versions of MCNP with MCPLIB04 agreed with those of PENELOPE within statistical uncertainties (±1%) over the entire ranges of energies and radial distances investigated. The MCNP5 with either MCPLIB03 or MCPLIB02 yielded almost identical data within statistical uncertainties (±1%) over the entire ranges of energies and radial distances investigated. The spectral broadening of the first Compton scattered photons around the back-scattered peak was particularly noticeable, while the spectral analysis with both photon spectra of Doppler on and off produced the same amount of total dose. These imply that absorbed doses in water as an integrated quantity are not noticeably affected by the Doppler broadening.

Keywords : Doppler Broadening, MCNP and PENELOPE, Low-Energy Photon