Verification of the ESR-dose calibration curve for the Alanine/ESR dosimeter based on the Monte Carlo Method

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The environmental qualification for ionizing radiations inside nuclear power plants (NPPs) with the alanine/ESR dosimeter is required by International Atomic Energy Agency (IAEA). The alanine dosimeter measures the absorbed dose by evaluating ESR signal that represents the amount of free radicals produced inside the alanine pellet during irradiations. The ESR signal is converted to the alanine dose by using ESR/alanine dose calibration curve, which is linear function between the ESR signal obtained by the alanine dosimeter and the air kerma or dose-to-water measured by the ion chamber. The aim of this study was to verify the calibration curve of the alanine/ESR dosimeter based on the Geant4 Monte Carlo (MC) simulations. Previous to validate the calibration curve, the effect of the beam irradiation conditions on alanine/ESR dosimetry were evaluated in terms of the beam type, beam direction, and pellet reference point to define source-pellet distance. ^{137}Cs, ^{60}Co devices and 6 MV linear accelerator (linac) were modeled to produce photon beams with different energies. The alanine dosimeter was modeled as a cylider with radious of 2.00 mm and height of 2.45 mm, which consisted of the pure alanine ($C_3H_7NO_2$) with the density of 1.42 g/cm^3. The dosimeter was placed at 100 cm from the radiation source. Total of 2.5×10^8 photons were generated in each simulation. The beam directions were decided as vertical and horizontal to the dosimteter. To verify the ESR/dose calibration curve, the air kerma and dose-to-water were calculated for the same volume of the alanine pellet at the same position. The air kerma was defined as the total kinetic energy of the secondary electrons inside the air volume. The dose-to-water was calculated at 5 cm depth in the water phantom that measured 40x40x40 cm^3. The photon beams proved their availabilities on the simulations by showing the beam characteristics with difference less than 2% from the measurements. The alanine dose was decreased up to 10% with the beam along the vertical direction according to the beam energy: that was, 1.2% for ^{137}Cs, 5.6% for ^{60}Co, and 10.1% for 6MV linac. Meanwhile, the alanine dose was insignificantly affected by the reference points within the difference less than 2%. For verification of the ESR/alanine dose calibration curves, Figure 1 represents that the air kerma was notably different from the alanine dose as the photon energy is lower. Especially, the alanine dose was doubled to the air kerma with the 6MV linac. However, the dose-to-water was almost identical to the alanine dose (Figure 2).
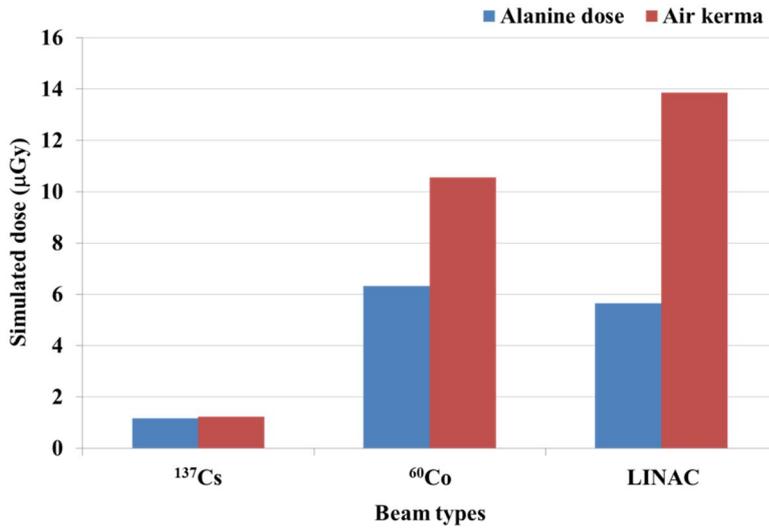
Figure. 1. Comparison of the alanine dose and air kerma with different beam energies
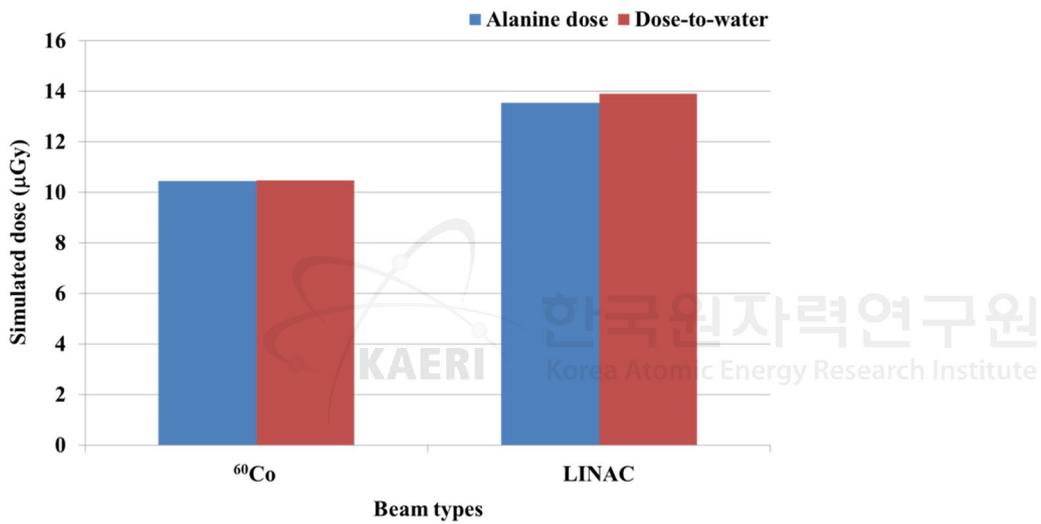

Figure. 2. Comparison of the alanine dose and dose-to-water with different beam energies