Calibration and mathematical modelling of the SIS α-particle irradiator system, developed for radiobiological applications

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The aim of this study was to calibrate and test the SIS α-particle irradiator (Stuk Irradiator System). The irradiator consisted of the 1.1 GBq ²³⁸Pu source (RITVERC GmbH and Khlopin Radium Institute, St.Petersburg, Russia). Maximal α-particle energy at the source surface is 5.5 MeV. The system is flushed with He gas, which reduces loss of particle energy. The source can be moved up and down to change energy/LET of α-particles at the exit window. The exit window is made of 2 µm thick mylar (density 0.278 mg/cm²) with a diameter of 30 mm. This arrangement allows a high energy of α-particles (up to 4.63 MeV) to be obtained with the source at the highest position close to the exit window. A thin precise photo shutter above the source regulates irradiation times. We have developed and implemented the measurement setup using a home-made p-i-n detector (Tisnek et al 2000) housed in a low pressure chamber. We estimated α-particle activity, measured α-particle energy distribution across the exit window of the irradiator and determined α-particle energy vs. distance from the source to the exit window. Another task was to measure of α-particle fluence vs. shutter time. The final stage of the work was Monte Carlo modelling of particle irradiation in a monolayer cell culture with the NASA Radiation Track Image software (NRTI, copyright by USRA). Absorbed, nuclear and cellular doses were estimated for cell monolayer using different fluence and energies of α-particles. Doses per hit cell, hit nucleus, and absorbed dose were estimated for three different energies and three fluences. For example, the absorbed dose for a virtual cell monolayer exposed to 4.5 MeV α-particles, with a fluence of 0.0182 particles per µm² was estimated to be 0.277 Gy. Results of modelling were in good agreement with the measured data. The SIS irradiator is housed in a specially adopted biological grade safety flowhood, which is located in a separate room classified as a radiation-controlled area. The facility can be used for irradiations of cell cultures and 3D tissue samples with α-particles of different energy/LET.

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