Monte Carlo Characterization of a Neutron Irradiation System for Radiobiological Experiments

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A neutron irradiation system for radiobiological cell experiments was characterized using Monte Carlo simulations to assess the mixed neutron–gamma radiation field and its suitability for biological applications. The irradiator consists of two $^{239}Pu(\alpha,n)^{9}Be$ neutron sources with a total ^{239}Pu activity of 444 GBq. The sources are housed in a graphite collimator and surrounded by lead and boron-doped polyethylene shielding to optimize beam characteristics and minimize radiation levels in the surrounding area. An irradiation channel enables the placement of biological samples at different distances from the sources, allowing irradiations under varying neutron fluence rate conditions.

The characterization study was performed using the MCNP6 code [1]. A detailed computational model of the neutron sources, collimator geometry, shielding configuration, irradiation channel, and cell culture plates was developed. Neutron and gamma fluence distributions, absorbed dose, and linear energy transfer (LET) spectra within the biological samples were calculated to evaluate the radiation field characteristics relevant to radiobiological investigations. Simulations enabled the assessment of dose contributions from neutron and gamma components, spatial dose distributions, and irradiation conditions suitable for low dose-rate biological exposures.

Although radionuclide neutron sources cannot achieve the high fluence rates available at research reactors or accelerator-based facilities, they provide a simple, reliable, and cost-effective approach for fast neutron irradiation under stable and reproducible low dose-rate conditions. The present characterization provides essential dosimetric parameters for the interpretation of future radiobiological studies investigating DNA damage responses and biological effects induced by mixed neutron–gamma radiation fields.

[1] T. Goorley et al., 2012, *Initial MCNP6 Release Overview*. *Nucl. Technol.* 180, 298–315.