Damage formation and repair data for radiations commonly used in microbeam studies of low-dose radiation biology

During the last several years charged-particle microbeams proved themselves as powerful tools in radiobiological research (for review see [1]). Currently two microbeam facilities are routinely used for radiobiological experiments. These are the Radiological Research Accelerator Facility (RARAF) at Columbia University [2] and the Gray Cancer Institute (formerly Gray Laboratory) microbeam [3, 4]. The Special Microbeam Utilization Research Facility (SMURF) at Texas A&M University is based on microbeam equipment relocated from Pacific Northwest National Laboratory [5] and is also available for radiobiological studies.

We used a Monte Carlo excision repair (MCER) model [6, 7] to generate damage formation and repair data for particles that have been used in various microbeam studies. The DNA damage portion of the MCER model is based on the Monte Carlo damage simulation (MCDS) algorithm proposed by us [8, 9]. The MCDS algorithm is capable of generating data for protons and α particles of different energies and for 4.5 keV electrons considered representative of low-LET radiation. The MCDS model parameters for heavy-charged particles (protons and α particles) are identical with the exception of one parameter, n_{seg}, which is dependent upon the particle LET (refer to Fig. 5 in [8]). This property allows one to determine the algorithm parameters for other heavy-charged particles of the same LET. Using this approximation, damage formation and repair data for 4 MeV α particles, which have LET of approximately 100 keV/μm, can be used in place of data for $^{3}He^{2+}$ ions that have been extensively used in studies performed with the Gray Cancer Institute microbeam.

Columbia University

The Columbia University microbeam is designed to deliver helium or hydrogen ions with different energies that cover the range of LET from 30 to 220 keV/μm [2]. To date, all the studies that utilized this microbeam have been performed with 5.3 MeV α particles that have LET of approximately 90 keV/μm (for examples of studies with this microbeam system, see [10–21]).

- 5.3 MeV α particles (input file, output file)

Gray Cancer Institute

The Gray Cancer Institute microbeam was initially configured to irradiate cells with protons of energies <3.5 MeV [3]. Later a change has been made to also deliver $^{3}He^{2+}$ ions. The majority of studies performed using the Gray Cancer Institute microbeam used $^{3}He^{2+}$ ions with LET of ~100 keV/μm [22–26]. 1 and 3.2 MeV protons have also been utilized in some experiments [27, 28].

- 4 MeV α particles; equivalent to 100 keV/μm $^{3}He^{2+}$ ions (input file, output file)
- 1 MeV protons (input file, output file)
- 3.2 MeV protons (input file, output file)

PNNL/Texas A&M University

The Texas A&M University microbeam is capable of producing α particles and protons with energies up to 6 MeV and up to 4 MeV respectively. Also available is a 100 keV electron microbeam. The predecessor of TAMU's microbeam, the microbeam at Pacific Northwest National Laboratory, has been applied in one study that utilized 3.2 MeV α particles [29].

- 3.2 MeV α particles (input file, output file)

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