

NEW DESCRIPTORS OF RADIATION QUALITY BASED ON NANODOSIMETRY, A FIRST APPROACH

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After a short overview on the latest developments in nanodosimetry, measured frequency distributions of ionisation cluster size caused by 4.6 MeV α -particles or low-energy electrons in ‘nanometric’ volumes of nitrogen are compared with cluster-size distributions for liquid water cylinders that are equal in size to segments of DNA of 10 base-pairs length. Such frequency distributions are, to a greater part, governed by the same basic physical interaction data as those to be expected, if charged particles interact with DNA segments. Quantities derived from ionisation cluster-size distributions should, therefore, behave as a function of radiation quality similarly to the yields of single or double strand breaks in the DNA. To test this assumption, extensive Monte Carlo simulations were performed for electrons in the energy range between 12.5 eV and 100 keV for protons at energies between 0.7 MeV and 250 MeV and for α -particles in the energy range between 2 MeV and 100 MeV. The results are then compared with the yields of single- or double-strand breaks in the DNA, taken from the literature.

INTRODUCTION

It is generally accepted today that the initiation of radiation damage to genes or cells is the result of the spatial distribution of inelastic interactions of single ionising particles within the DNA or in its neighbourhood and is, in consequence, determined by the stochastics of particle interactions in volumes—a few nanometre in size. On account of the complexity of radiation-induced damage and to the almost insuperable difficulties for its detailed experimental investigation, our present knowledge on this topic almost exclusively stems from Monte Carlo simulations based on more or less highly sophisticated models of DNA as well as on cross section sets for water vapour or liquid water. For an overview of the computational modelling of DNA damage, see, for instance, the publications by Nikjoo *et al.*⁽¹⁾ and Friedland *et al.*⁽²⁾. Essential results of such simulations are the yields of single- or double-strand breaks in the DNA and also, in part, the distribution of DNA fragments. It is typical for all of these data that radiation damage strongly depends on radiation quality and cannot be described satisfactorily by macroscopic quantities, which, like absorbed dose, take into account neither the track structure of ionising particles nor the structure of radio-sensitive sub-cellular targets. It is, therefore, one of the challenges of current radiation physics to define more appropriate physical quantities, which (1) are easily measurable and, (2) are based on

particle interactions in nanometric sites and thus, behave as a function of radiation quality, similarly to the induction of radiobiological effects due to particle interactions in sub-cellular structures. The price, which possibly has to be paid for this, might be the loss of a correlation to quantities like the energy imparted or like absorbed dose, as was pointed out by Amols *et al.*⁽³⁾.

From the experimental point of view, the method that can be applied, for measuring quantities valid also in sub-cellular structures, is the determination of the radiation induced frequency distribution of ionisation cluster size (number of ionisations per primary particle) in liquid water, as a substitute for sub-cellular material, in volumes that are comparable in size with those of the most probable radio-sensitive volumes of biological systems (segments of the DNA, chromatin fibre, nucleosomes). Such frequency distributions are, to a greater part, governed by the same basic physical interaction data as those that can be expected, if charged particles interact, for instance, with DNA segments. In consequence, frequency distributions of ionisation cluster size in nanometric volumes of liquid water (nanodosimetry) can also be used for the definition of new descriptors of radiation quality.

It is the aim of the present paper to give a short overview on the latest developments in that branch of nanodosimetry that is based on the formation of ionisation clusters due to charged particles in “nanometric” gaseous volumes of nitrogen (or propane). Here, it is assumed that frequency distributions of ionisation cluster size measured at appropriate gas pressure and volume size are equivalent to those induced by charged particles in nanometric volumes of liquid water with sizes equal, for instance, to those of the short segments of DNA. Based on

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