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PROGRESS REPORT

Project: Nanodosimetry and nanodosimetric-based models of radiation action for radon alpha particles (DE-FG02-90ER61022).

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Progress Report for the period July 1, 1991 through June 30, 1992

The objective of our research work is to provide - with the aid of biophysical models of radiation action - information on human risks following exposure to radon alpha particles. The approach proposed consists of a) developing appropriate models (parametric and non-parametric) for alpha radiation induction of relevant end points (survival, cellular transformation), b) providing an accurate physical characterization of the particle tracks in terms of nanodosimetric distributions, c) supporting the models by detailed, molecular studies of the direct and indirect effects of alpha particles on DNA. Activities in the second year of this project are detailed below along these lines:

A. Biophysical models for radon alpha particles (parametric models)

We have completed and submitted for publication several articles in which we treat the modeling of radiation effects. The first study, "Compound Radiation Action" (Radiation Research, in press) deals with the following problem: in the typical α-β dose response function (used almost universally to describe radiation effects) it has been noticed that the quadratic term, β, changes with LET, particularly at high LET - the domain of radon alpha particles. Our model offers an explanation to this phenomenon, and provides mathematical expressions for its treatment. The studies "Elements of dual radiation action: the treatment of matrix saturation with application to DNA single- and double-strand breaks" (Radiat. Res., submitted) and "The application of the principle of dual radiation action to biophysical modeling" (in press) deal with the question of high-LET saturation of effect. We have also developed "A mathematical model for cell cycle progression under continuous low dose irradiation" (Radiat. Res., submitted) which proposes a solution (based on Boltzman's equation) for the question of the effect of dose and dose rate on mitotic cycle parameters.

B. Biophysical models of radon alpha particles (non-parametric)

In a study of the Hit Size Effectiveness model entitled "A non-parametric, microdosimetric based approach to the evaluation of the biological effects of low doses of radiation" (in press) we derive a quality factor function, q(y), (y=lineal energy) for eight sets of experimental data on cellular inactivation, mutation, chromosome aberration and neoplastic transformation. Functions q(y) are of immediate relevance to the problem of estimating the risks of radon exposures.

C. Simulation of alpha particle tracks penetration of condensed media by Monte Carlo methods

The Monte Carlo transport code for condensed water is complete. Important modifications relative to the old, gas-phase code are: a) a treatment of single particle excitation (ionizations) based on ab initio calculations of the generalized oscillator strength distribution; this was obtained from the dielectric response function of the system, b) updated ranges for subexcitation electrons based on liquid water data, c) formation and decay of collective excitations in water (plasmon, exciton). Relevant publications are in the Reference section.

D. Nanodosimetric calculations

The new Monte Carlo generated tracks are currently used for obtaining nanodosimetric spectra for alpha particles. A problem of great interest to us is the relation between the exact nanodosimetric spectrum and the measured distribution which includes the effects of electron multiplication in the counter. This interest stems from the potential availability in our laboratory of a nanodosimeter (under development by Dr. Kliauga) and the possibility of measuring alpha-particle spectra.

E. Direct and indirect effects of radiation on DNA

Biophysical modeling notwithstanding, it is of crucial importance to establish, ab initio, the effects of ionizing radiations on DNA. Available data are sparse and mostly contradictory (for instance, there is still no agreement on whether the RBE for double-strand DNA breaks does or does not change with LET). Theoretical studies are then eminently necessary. We are developing a program to study direct effects on DNA with Monte Carlo transport. We have also completed work on a stochastic chemistry code to observe indirect effects in the presence of various sensitizers or protectors. Both studies will be reported this summer at the Microdosimetry Symposium and submitted for publication.

Publications

Zaider, M. Charged-particle transport in the condensed phase. In: Physical and Chemical Mechanisms in Molecular Radiation Biology. (submitted, 1991).

Fung, A. and Zaider, M., An improved approach to evaluate the dielectric response function of biopolymers. Phys. Med. Biol. (submitted, 1991).

Rossi, H.H. and Zaider, M., Elements of Microdosimetry. Med. Phys. 18, 1085-1092 (1991).

Zaider, M., On the microdosimetric treatment of one-hit detectors: reply to R. Katz. Radiat. Res. 126: 270 (1991).

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Zaider, M. and G.N. Minerbo, The response of cell populations to protracted doses of radiation: cell cycle progression. Radiat. Res. (submitted, 1991).

Zaider, M. The application of the principle of "dual radiation action" in biophysical modeling. In: Biophysical Modelling of Radiation Effects (IOP Publishing, Adam Hilger), 1992.

Varma, M.N. and M. Zaider, A non=parametric, micordosimetric-based approach to the evaluation of the biological effects of low doses of ionizing radiation. In: Biophysical Modelling of Radiation Effects (IOP Publishing, Adam Hilger), 1992.

Vracko, M.G. and M. Zaider, A calculation of the exciton energies in periodic systems with helical symmetry: Application to a hydrogen fluoride chain. Int. J. Quantum Chem. (in press, 1992).

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Zaider, M., Elements of Dual Radiation Action: The treatment of matrix saturation with application to DNA single- and double-strand breaks. Radiat. Res. (submitted, 1991).

Zaider, M. and C.S. Wuu, The biological effects of mixed-radiation fields on cellular systems of variable radiosensitivity (OER and cell-cycle stage). In: Proceedings of the International Workshop on Macro and Microdosimetry and Treatment Planning for Neutron Capture Therapy (1991, submitted).

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