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SHORT COMMUNICATION

Relative Effectiveness of Mixed Radiation Fields

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Abstract

For all one-hit detectors the relative effectiveness of a mixed radiation field may be found as the dose-weighted average of the relative effectiveness of its components, segregated according to the atomic number ***Z*** and the energy ***T***. We emphasize that this procedure is incorrect for mammalian cells, whatever the nature of the segregation.

Let us consider the relative effectiveness R_j of a one-hit detector in track-segment irradiation with a monoenergetic beam of ions of atomic number Z_j, kinetic energy T_j, stopping power L_j, with action cross section σ_j, onto a detector for which the D_{37} dose for γ rays is E_0. Since the response to both radiations is exponential, equal effects are obtained with γ rays at dose D_γ and with ions at fluence F_j and dose $D_j = F_j L$, when

$$\sigma_j F_j = D_\gamma / E_0 \tag{1}$$

Thus

$$\mathrm{R}_j = D_\gamma / D_j = \sigma_j E_0 / L_j \tag{2}$$

Now consider the effectiveness of a mixed field of ions, as, for example, from neutrons or a spread Bragg peak, with secondary fragments.

We imagine that the irradiation with different fractions of the mixed field is sequential. Since the effect from each fraction is exponential we find the γ-ray dose producing the same effect as the mixed field from the equations

$$D_i = \sum F_j L_j \tag{3}$$

$$D_\gamma / E_0 = \sum \sigma_j F_j . \tag{4}$$

Thus the relative effectiveness R of the mixed field is

$$\mathrm{R} = D_\gamma / D_i \tag{5}$$

$$D_\gamma = \sum E_0 \sigma_j F_j (L_j / L_j) . \tag{6}$$

Finally,

$$R = (\sum R_j D_j) / D_i, \tag{7}$$

that is, the effectiveness of a mixed radiation field in its action on a one-hit detector is the dose-weighted average of the effectiveness of its components.

An expression equivalent to Equation (7) has been used by Gerstenberg *et al.* (1) for the calculation of the relative effectiveness of neutrons on alanine. Here we derive the general result for all one-hit detectors. If this procedure is repeated using the (four-parameter) track theory model of the response of biological cells to ionizing radiations (2), one cannot reproduce Equation (7). *Thus for biological cells it is not true that the relative effectiveness of a mixed radiation field is equal to the dose-weighted average of the relative effectiveness of its components.* This is the case regardless of the nature of the field decomposition, whether by atomic number and energy or by LET.

We note that the ICRP (3) recipe for the quality factor of a mixed radiation field takes it to be the dose-weighted average of the quality factors of its components, grouped by LET, for heavy ions, or for neutrons grouped by neutron energy. Neither of these arrangements is consistent with these calculations.

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References

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