More about Equivalent Dose and Dose Equivalent

Dear Editors:

FROM the review of risk estimates which prompted a fuller discussion of radiation detriment, there followed a broader definition of risk as recommended in Publication 60 of the International Committee for Radiological Protection (ICRP 1991). In ICRP 60 Publication, a new set of dosimetric quantities was introduced, to replace the one outlined in the earlier ICRP Publication 26 (ICRP 1977). The modified set of dosimetric quantities, nevertheless, is still not internationally standardized (ISO 1992). Hence, it has not been incorporated into legislations of most European countries, and the old units are still in use (EU 1994; EC 1994). However, in the drafting concept of the International Atomic Energy Agency's (IAEA) *International Basic Safety Standards* for protection against ionizing radiation and for the safety of radiation sources, which is jointly sponsored by most of the relevant international organizations, it is forceable that new set of dosimetric quantities will be universally accepted.

The new set of dosimetric quantities is frequently interchanged with the old one or is even misunderstood, the most evident example being that of dose equivalent and equivalent dose.

In some European countries certain difficulties in distinguishing between dose equivalent and equivalent dose arise from a purely linguistic level. Namely, in the Russian language, *dose equivalent*, as defined in the ICRP Publication 26 was named *equivalent dose* (эквивалентная доза; transliteration: èkvivalentnaja doza) (IAEA 1986). Therefore, in those European countries that have strong cultural ties with Russia (e.g., Bulgaria, Serbia, Montenegro, Macedonia) *dose equivalent* was also (incorrectly) termed *equivalent dose*. Considering ICRP Publication 60 recommendations, this causes additional confusion, not only from the terminological, but from the conceptual point of view. However, in the Croatian and Slovenian languages for *dose equivalent* either the term *dose equivalent* itself or *equivalent of dose* was used (Franić 1994).

The dose equivalent, H, at a point in tissue, is given by (ICRP 1977):

$$H = DQN, \tag{3}$$

where

D = the absorbed dose;
Q = the quality factor; and
N = the product of all other modifying factors.

The quality factor, Q, is a dimensionless modifier used in converting the absorbed dose to dose equivalent, since different types of radiation may have different harmfulness for the same absorbed dose. Therefore Q represents this different degree of harmfulness.

The product of all other modifying factors, N, has been assigned the value of 1 (ICRP 1977). N has attempted to take into the account such effects as different absorbed dose rates and fractionation.

Rewritten in a more formal way, eqn (1) (product of D, Q, and N in point P) is

$$H = D(P)Q(P)N \tag{4}$$

The absorbed dose at point P of mass distribution due to a radiation event is the limiting value of the quotient $\Delta\bar{\epsilon}/\Delta M$, where ΔM is the mass enclosed by a spherical volume element ΔV with center at P, $\Delta\epsilon$ is the mean energy emitted by the event that is absorbed by ΔM, and the limit is taken as ΔV is shrunk to the point P:

$$D(P) = \lim_{\Delta V \to P} \left(\frac{\Delta\bar{\epsilon}}{\Delta M}\right). \tag{5}$$

However, from the assumption about the proportionality between dose and dose-response (ICRP 1977) it would follow that for stochastic effects it would be justifiable to consider the mean dose over all cells of uniform sensitivity in a particular tissue or organ. Therefore, when reviewing implications of assumed dose-response relations in the ICRP Publication 26 report (ICRP 1977), the term dose equivalent refers to the *mean* dose equivalent over the entire organ or tissue (unless specifically qualified). Thus, the mean dose equivalent has to satisfy an equation of the form (Killough 1983)

$$H = \frac{1}{M}\int_R H(P)\rho(P)dV(P), \tag{6}$$

where M is the mass of the organ and the integral is taken over all points P belonging to the region R of space occupied by the organ; $\rho(P)$ is the local mass density with volume element $dV(P)$.

From the point of view of the ICRP Publication 60, in radiological protection it is the absorbed dose, D_T, averaged over a tissue or organ T (rather than a point), and weighted for the radiation quality that is of interest. Therefore D_T is defined as

Table 1. Comparison of dose equivalent and equivalent dose definitions.

Dose equivalent	Equivalent dose
ICRP Publication No. 26	ICRP Publication No. 60
Symbol: H	Symbol: H_T
Unit: Sievert (Sv)	Unit: Sievert (Sv)
Not a dose but harmful potential of absorbed dose	Strictly dose
Defined in a point	Macroscopic dosimetric quantity
Defined as a product: $H = D(P)Q(P)N$	Defined as a product: $H_T = W_R D_{T,R}$
$D(P)$ (absorbed dose at point P)	$D_{T,R}$ (absorbed dose of radiation R averaged over tissue T)
$Q(P)$ (quality factor at point P)	W_R (radiation weighting factors)
N (modifying factors)	

$$D_T = \frac{\epsilon_T}{m_T} \quad (7)$$

where

ϵ_T = the total energy imparted in a tissue or organ; and
m_T = the mass of that tissue, ranging from less than 10 g for the ovaries to over 70 kg for the whole body.

The weighting factor for this purpose is now called the radiation weighting factor, W_R. It is selected for the type and energy of radiation incident on the body, or in the case of sources within the body, for the type and energy of radiation emitted by the source.

Using eqn (5) for the absorbed dose averaged over a tissue or organ, the *equivalent dose* is defined as (ICRP 1991)

$$H_T = \sum_R w_R D_{T,R} \quad (8)$$

where

$D_{T,R}$ = absorbed dose due to radiation R, averaged over the tissue or organ T; and
w_R = radiation weighting factor.

This weighted absorbed dose is *strictly* a dose and ICRP names it equivalent dose, using symbol H_T. The change of name also serves to indicate the change from the quality factor to the radiation weighting factor.

Conceptually, the equivalent dose [eqn (6)] as an indicator of the subsequent stochastic effects, defined by means of absorbed dose [eqn (5)], is far less complex than the mean dose equivalent over the entire organ or tissue [eqn (4)].

From the foregoing considerations, the concepts of dose equivalent and equivalent dose can be summarized as in Table 1.

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