

Memorandum from the British Committee on Radiation Units and Measurements

Advice on the implications of the conversion coefficients for external radiations published in ICRP Publication 74 and in ICRU Report 57

Introduction

The International Commission on Radiological Protection (ICRP) has now published [1] the report of a Joint Task Group of the ICRP and the International Commission on Radiation Units and Measurements (ICRU) which provides a compilation of conversion coefficients to link the physical, operational and limiting quantities as defined by the two Commissions. The ICRU will publish the same data shortly [2]. These publications are particularly relevant since the Council of the European Union has now adopted a Revised Basic Safety Standards Directive [3] which reflects the recommendations in *ICRP Publication 60* [4] (ICRP 60) and member states should incorporate the requirements of this Directive into national legislation by 13 May 2000. The British Committee on Radiation Units and Measurements (BCRU) gave advice [5] in 1993 following the publication of ICRP 60 and that advice is updated in this memorandum.

The BCRU had the opportunity to contribute to the ICRP/ICRU document during its preparation and many of the detailed comments made by BCRU are incorporated in the final version of the report. In making its comments on the draft report, BCRU raised concerns (outlined in the earlier BCRU memorandum [5]) about the impact of the ICRP 60 dose limiting quantities in terms of radiation weighting factors rather than quality factors. However, the Joint Task Group was unable to address this issue as it was outside its terms of reference. In this memorandum, we outline the contents of the Joint Task Group report and give advice on the implications for the use of the conversion factors in the UK. A critique of the ICRP 60 concepts for the measurement of external radiations will be published separately.

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Address correspondence to V E Lewis (Secretary, BCRU), National Physical Laboratory, Teddington, Middlesex TW11 0LW, UK.

Content of the Report

The Joint Task Group report [1, 2] is divided into five chapters, the first of which is the Introduction which outlines the development of the recommendations and describes the terms of reference for the report. The quantities used in radiological protection are defined in chapter 2, which includes a discussion of the relationship between the physical, operational and limiting quantities and their theoretical basis:

Physical quantities are those which are suitable for standardization by bodies such as the National Physical Laboratory (NPL), namely absorbed dose, D and kerma, K .

Operational quantities are those which are used for operational measurements in radiation protection, namely ambient dose equivalent, $H^*(d)$, directional dose equivalent, $H'(d, \Omega)$ and personal dose equivalent, $H_p(d)$.

Limiting quantities are now called *Protection quantities* in the Joint Task Group report, namely effective dose, E and effective dose equivalent, H_E , and are used to indicate the risk associated with exposure to ionizing radiation.

The definitions of the quantities are given in ICRP 60 [4] and the methods used to calculate the quantities needed are outlined briefly in chapter 3 [1]. This chapter provides a helpful introduction to the data and techniques used to produce the sets of conversion coefficients but it is not meant to be an exhaustive critique of Monte Carlo codes.

The main part of the report is in chapter 4 where the tabulated conversion coefficients are provided to relate air kerma free-in-air or particle fluence to the protection and operational quantities. Conversion coefficients are given for organ-absorbed dose, effective dose, ambient dose equivalent, directional dose equivalent and personal dose equivalent for mono-energetic photons, neutrons and electrons over a range of energies and irradiation geometries. The calculations for photons do not go below an energy of 10 keV but a paper by Duane and Nahum [6] provides appropriate information for lower energies.

Finally, in chapter 5, the relationship between protection and operational quantities is analysed

to examine the influence of the various changes implicit in the new recommendations of the ICRP. The performance of the operational quantities in monitoring exposure to external radiations in terms of the protection quantities is discussed because, as they are presently defined, the operational quantities were designed to monitor the quantities recommended in ICRP 26 [7] and it is necessary to examine their performance in the new regime of ICRP 60 [4].

The data given in the reports will be valuable in any situation in which the interrelationships of radiation protection quantities are considered. For example, they can be used to convert the physical quantity measured with a secondary standard instrument into the operational quantity for the calibration of measuring instruments and personal dosimeters. Also, they will be used to convert measured or calculated field quantities into operational or protection quantities.

Within the constraints imposed by the Commissions, the report is well written and contains valuable data for radiological protection purposes. The authors are to be congratulated on its thoroughness and scope. There is a useful glossary at the beginning of the report but an index would have been very helpful.

Implications of the new Conversion Factors

A consequence of the publication of the Joint Task Group report [1, 2] is that BCRU is now able to update its previous advice on ICRP 60.

Review of previous BCRU recommendations

In 1993, BCRU published a memorandum [5] with the following recommendations for the use of the ionizing radiation quantities:

- (i) The three operational quantities defined by the ICRU, namely ambient dose equivalent, directional dose equivalent and personal dose equivalent, should be used in radiation protection.
- (ii) The values of these quantities should, for the present, be based upon the values of Q recommended in *ICRP Publication 26* [7].
- (iii) The organ weighting factors, w_T , recommended in *ICRP Publication 26* [7] should, for the present, be retained.
- (iv) The operational quantities should not be modified to incorporate the values of Q recommended in *ICRP Publication 60* until it has been demonstrated that they are satisfactory indicators of the limiting quantities defined in ICRP 60 [4].
- (v) Any changeover to the new values of the operational quantities should take place on a defined date.

Recommendations (i), (ii), (iii) and (v) remain essentially unchanged. However, the Joint Task Group report and other publications now allow further consideration of recommendation (iv) which has implications for recommendation (ii). See, for example, the proceedings of meetings held in 1994 [8] and 1995 [9].

Are operational quantities satisfactory indicators of the protection quantities?

Area monitoring

The data given in the Joint Task Group report indicate that, for mono-energetic photons and electrons, measurements of the operational quantities will provide a reasonable overestimate of the protection quantities in all irradiation geometries.

In the case of neutrons, the operational quantity can significantly underestimate or overestimate the protection quantity ([1] Figure 56). For anterior to posterior (AP) geometry, the ratio of the effective dose to the ambient dose equivalent at a depth of 10 mm, $E/H^*(10)$, can be as large as 2 for neutrons in the energy range 1–10 keV and above 100 MeV. In other irradiation geometries, $E/H^*(10)$ can be as small as 0.2 at thermal energies and between 10 keV and several MeV. However, the Joint Task Group report concludes that, in practice, irradiation by mono-energetic neutrons rarely occurs and that the ambient dose equivalent is usually a conservative estimate of the effective dose. It has been shown that, in a wide range of working environments, the energy and angular distribution of neutrons is such that $E/H^*(10)$ extends from 0.2 to 1.1 [10–13] but typically lies between 0.88 and 1.05. In environments where high energy neutrons (> 10 MeV) predominate, principally around high energy accelerators and in high altitude flight, calculations and measurements indicate that the values of $E/H^*(10)$ lie in the range 0.45–1.1 [14, 15].

Individual monitoring

For photons and electrons, measurements of the operational quantity for individual monitoring (personal dose equivalent) should provide a good estimate of the effective dose in AP and rotational (ROT) geometries which are of most interest for radiological protection. However, care is required in other irradiation geometries (particularly posterior to anterior (PA)) if underestimation is to be avoided ([1] Figures 68 and 69). This potential for underestimation has always been present and is not a function of the new quantities. Underestimation can be avoided by appropriate positioning of personal monitors, e.g. on the back of the person for PA irradiation.

For neutrons, the ratio of the effective dose to

the personal dose equivalent at a depth of 10 mm, $E/H_p(10)$, can significantly exceed unity at some energies, even in the rotational geometry. For AP geometry, the situation is very similar to that described above for $H^*(10)$, but in other geometries a measurement of $H_p(10)$ could seriously underestimate E ([1] Figure 57). However, under typical working conditions, where there is a broad range of neutron energies and directions of incidence, $E/H_p(10)$ typically lies between 0.6 and 1.8 for AP and ROT geometries [10–13]. The value of 1.8 corresponds to a scandium-filtered neutron beam but, although an underestimate of as much as 1.8 is undesirable, it is rarely as large as this value and stems from the artificially high value of E at intermediate neutron energies because of the over-weighting of photons generated by neutrons in body tissues. Thus the protection implications may not be serious in these situations of underestimation but it should be specifically noted, with the dose record, when narrow-band, intermediate-energy neutrons and neutrons of energies greater than 50 MeV have been monitored. In these situations, special estimates of E may be advisable.

BCRU Recommendations

It should be recognized that Approved Dosimetry Services should continue to operate under the Ionising Radiation Regulations 1985 [16] which is the legislation currently in force. Proposals are being developed to bring these regulations into line with the European Directive [3]: the revised regulations are expected to come into effect on 1 January 2000. BCRU commends the use of the new conversion factors (to relate the new values of the operational quantities to the basic physical quantities) in the reports of the ICRP and ICRU [1, 2] from the date when the revised Ionising Radiations Regulations come into force.

BCRU recommends that:

- (i) The three operational quantities defined by the ICRU, namely ambient dose equivalent, directional dose equivalent and personal dose equivalent should continue to be used in radiation protection.
- (ii) The values of these quantities should, for the present, be based upon the values of Q recommended in *ICRP Publication 26* [7], but when new UK legislation becomes operational, the values of Q in *ICRP Publication 60* [4] should be used.
- (iii) The values of the organ weighting factors, w_T , recommended in *ICRP 26* [7] should, for the present be retained, but when new UK legislation becomes operational, the new values of w_T in *ICRP 60* [4] should be used.

- (iv) Both now and in the future, it should be specifically noted, with the dose record, when narrow-band, intermediate-energy neutrons and neutrons of energies greater than 50 MeV have been monitored and in these situations, special estimates of E may be advisable.
- (v) The adoption of the new quantities and the new conversion coefficients, in the above recommendations, should take place when the revised UK legislation comes into force, and this is scheduled for 1 January 2000.

BCRU memorandum

Membership of BCRU during the preparation of this memorandum was: R J Berry (Chairman), S C Lillicrap (Vice chairman), V E Lewis (Secretary), P J Allisy-Roberts, R Bennett, P J D K Dawes, J A B Gibson, D T Goodhead, J R Harvey, J B Hunt, T O Marshall, A E Nahum, D I Thwaites and M K Williams.

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