SETTING THE SCENE/OUTLOOK

TECHNICAL AND REGULATORY IMPLICATIONS OF THE ICRU PUBLICATION 95 'OPERATIONAL QUANTITIES FOR EXTERNAL RADIATION EXPOSURE'

Information overview prepared by the Inter-Agency Committee on Radiation Safety (IACRS)

November 2022

Introduction

The International Commission on Radiation Units and Measurements (ICRU) published in December 2020 its Report 95 *[ICRU 2020]*. This report recommends alternative definitions of the operational quantities that are considered better estimators of the associated protection quantities.

The purpose of the ICRU operational quantities is to provide acceptable estimates of the protection quantities. The operational quantities for the monitoring of external radiation recommended by the ICRU in ICRU Reports 39 *[ICRU 1985]*, 43 *[ICRU 1988]*, and 51 *[ICRU 1993]* were introduced in two groups: for individual monitoring, and for area monitoring at workplaces and the environment. The dose equivalent at a specific depth in the human body or in a phantom of specified geometry and depth is chosen to describe the exposure situation. Dose equivalent is calculated as the product of absorbed dose and a quality factor, Q, that is a function of the linear energy transfer, L, of the radiation at the point of interaction. The quantity used as a measure of effective dose for individual monitoring is personal dose equivalent at a depth of 10 mm in the human body and, for workplaces and the environment, ambient dose equivalent in the ICRU sphere at a depth of 10 mm. The quantities used as estimates for organ equivalent doses to the lens of the eye and local skin are personal dose equivalents at the respective depths of 3 mm and 0.07 mm, and directional dose equivalents at these depths in the ICRU sphere.

The purpose of this paper is to briefly discuss the limitation of the current quantities and to introduce the basis for new definitions proposed. It is also expected that the present document would enhance awareness and capacity of IACRS member organizations, and their respective Member States, on technical and regulatory implications of the alternative definition of the current operational quantities proposed in the ICRU Report on 'Operational Quantities for External Radiation Exposure' jointly published with the International Commission on Radiological Protection (ICRP). Finally, this paper also aims at encouraging each relevant organization or association to consider and to document all potential implications of those new operational quantities for the current radiation protection system, in the framework of their mandate (including the calibration process, re-design of dosimeters and monitoring equipment, management of national dose registries, regulatory implications and training needs).

The main findings of this forthcoming review activities will form the basis for advice on how and whether to include the observations of this review in the next set of general recommendations that is expected to be published in a decade or so. The role of the IACRS would be essential in this endeavour.

Limitations of the ICRU Three-Report Series on Operational Quantities [1]

Inconsistencies arise between protection and operational quantities as a consequence of their respective definitions:

- The ambient dose equivalent, $H^*(10)$, was defined in the ICRU sphere that has no resemblance to the reference anthropomorphic phantoms used to define the protection quantity effective dose, E.

- Personal dose equivalent, $H_p(d)$, was defined in depth d in the human body, but the conversion coefficients are calculated in simple geometrical bodies of slabs, cylinders, and rods.

- The evaluation of personal and ambient dose equivalent at a single, defined depth d = 10 mm did not reflect the geometrical complexity of the human body with organs (tissues) at different locations in the body, explicitly accounted for in the definition and calculation of effective dose, E. For neutrons, this led to an overestimate of E below 1 MeV and a progressive underestimate of E at energies above 10 MeV *[ICRU 1985]*.

- At low photon energies (E_p < 70 keV), the choice of the depth d = 10 mm for ambient and personal dose equivalent led to a considerable overestimation of effective dose. At the same time, the construction of personal dosimeters and area monitoring instruments adapted to this energy range was difficult because of the high sensitivity required at low photon energies to represent the operational quantities.

- For electrons of energy lower than 1 MeV, the quantities $H'(3)$ and $H_p(3)$ underestimated equivalent dose to the lens of the eye, in particular when considering the radiation-sensitive part of the lens. The underestimation of dose increased for oblique radiation incidences and lower energies *[Behrens 2012]*.

- The quality factor, $Q(L)$, and the radiation weighting factor, w_R, have the purpose of giving a relative weight to different types of radiation, but they are based on different concepts of defining and measuring radiation effectiveness.

- It is recommended by the ICRU Reports 39 and 51 that the system of operational quantities be replaced with a simpler scheme in which the ICRP/ICRU reference phantoms of the human body are used as the basis for calculations of both the operational and protection quantities, ensuring that the operation quantities provide measures of the protection quantities across all energy ranges.

There are now more sources of high-energy radiations than 30 years ago, when the present operational quantities were developed. The energy fields listed below are examples of radiation fields considered in the new proposal:

- increasing use of medical accelerators with potentials of up to 20+ MV for radiotherapy with photons and electrons,

- use of high-energy proton and heavy-ion accelerators for radiotherapy,

- use of cyclotrons for production of radiopharmaceuticals,

- radiation fields near high-energy particle accelerators for research,

- natural sources of high-energy radiation (at aviation altitudes and in space).

[1] Referred as ICRU Report 39/51.

The consequence of these inconsistencies were poor/inaccurate estimations of the protection quantities for certain particles and energies, and generally differences between the conversion coefficients for protection and operational quantities.

Recommended Operational Quantities

To address the need for an extension of both the range of radiation types and energies over which operational quantities are defined while preserving a good approximation to the protection quantities over this extended range, a change of paradigm in the definition of operational quantities is needed. The ICRU Report 95 recommends a redefinition of the operational quantities as the products of radiometric or dosimetric quantities at a point in space or on the surface of the body and conversion coefficients related to values of protection quantities.

The practical application of such operational quantities can be made if conversion coefficients to an internationally agreed phantom exist. ICRP and ICRU have now defined ICRP/ICRU adult reference phantoms in ICRP Publication 110 [ICRP 2009]. These phantoms are used to define reference values of conversion coefficients to the protection quantities and can be used to define the operational quantities. The recommended operational quantities aim at leading to a better estimation and assist in the comprehension of radiological protection quantities by users.

The two purposes of the ICRU Report 95 are to introduce the general definitions of operational quantities for external radiation protection which overcome the limitations of the ICRU Report 39/51 operational quantities, and to publish specific sets of conversion coefficients that permit the calculation of the operational quantities from physical quantities characterizing the radiation.

Potential Technical and Regulatory Implications

A quotation from page 44 of the ICRU Report 95 reads: '*It seems reasonable to assume that the changes proposed in this Report will be introduced on a similar time-scale to changes in the protection quantities. The ICRP will only introduce changes to the protection quantities when the next general recommendations are issued, and the parallel introduction of updated operational quantities would appear appropriate. Anticipating the time required for incorporation of recommendations into safety standards and legislation, there may be a period of around 20 years during which preparations can be made.*'

International and national authorities and other professional bodies, such as the European Radiation Dosimetry Group (EURADOS) *[EURADOS 2022]*, continue to recognize the need for a gradual and prudent period of evaluation of the impact and adoption to balance the costs of implementation with the benefit of a more coherent system of operational quantities, representing the protection quantities in measurement.

References

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