PROPOSAL FOR A SIMPLIFICATION OF THE OPERATIONAL QUANTITIES FOR ROUTINE MONITORING

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Introduction

The basic concept of the operational quantities for use in radiation protection of external exposure has been described in the ICRU Reports 39 and 43 [1, 2]. The present definitions are given in ICRU Report 51 [3]. The various operational quantities recommended for area and individual monitoring are shown in the following scheme:

<table>
<thead>
<tr>
<th>Radiation type</th>
<th>Quantities for area monitoring</th>
<th>Quantities for individual monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly penetrating</td>
<td>ambient dose equivalent, $H^*(10)$</td>
<td>personal dose equivalent, $H_p(10)$</td>
</tr>
<tr>
<td>radiation</td>
<td></td>
<td></td>
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<tr>
<td>Weakly penetrating</td>
<td>directional dose equivalent, $H'(0.07, \Omega)$ and $H'(3, \Omega)$</td>
<td>personal dose equivalent, $H_p(0.07)$ and $H_p(3)$</td>
</tr>
<tr>
<td>radiation</td>
<td></td>
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$H'(0.07, \Omega)$ and $H_p(0.07)$ are used when the dose to the skin is to be assessed, in the cases, where a limitation of the dose of the lens of the eye becomes significant, $H'(3, \Omega)$ for area monitoring and $H_p(3)$ for individual monitoring have been recommended.

While in principle these operational quantities have been successfully applied in many situations and are broadly introduced into practice today, also in legal applications, there remains some concern about details in the definition of the quantities which results in some unnecessary confusion when the quantities are applied in practice or their concepts need to be explained to the public and to persons involved in radiation protection work. It is our opinion that it might be possible to introduce some simplifications in the definitions of the quantities without changing their general use in practice. In the following some ideas in this respect are outlined.
Strongly and Weakly Penetrating Radiation

The operational quantities for radiation protection are dose equivalent quantities presently defined either for "strongly penetrating" or for "weakly penetrating" radiation [1]. In ICRU Report 57 also the expressions penetrating and low-penetrating radiation are used [4].

The radiation incident on a human body has been characterized as strongly penetrating or weakly penetrating, depending on which dose equivalent is closer to the respective limiting value. The former definition in ICRU Report 39 [1] states explicitly that a radiation is said to be weakly penetrating when for a given orientation of the body in a uniform and unidirectional radiation field the dose equivalent received by any small area of the sensitive layer of the skin (nominally the dose at a depth of 0.07 mm) is more than ten times larger than the effective dose equivalent - otherwise it is considered to be strongly penetrating. The factor of ten introduced here was in relation to the fact that the skin dose and effective dose equivalent limit also differed by a factor of 10 (500 mSv per year as compared to 50 mSv per year).

The most recent definition [3] does not give such a factor but characterizes radiations “as either weakly or strongly penetrating, depending on which dose equivalent is closer to its limiting value. For weakly penetrating radiation, either the dose equivalent in the lens of the eye or that in the skin is relevant. For strongly penetrating radiation, the effective dose equivalent is appropriate.”

In practice, weakly-penetrating radiations are α-particles, β-particles with energies below 2 MeV and photons with energies below about 12 keV (such photon fields are usually of no interest). Neutrons are always considered to be penetrating radiation.

For the purpose of distinguishing these two characteristics of radiation for a workplace field with a broad energy distribution or composed of several radiation types, the values of protection quantities (effective dose and skin equivalent dose or a local skin equivalent dose) must be known. Furthermore, it has not been taken into consideration that the effective dose depends on the direction of radiation incidence on the human body [4]. For the skin dose it needs a further specification of the skin surface area applied in averaging (“any 1 cm²”). Especially in mixed radiation fields it is difficult to estimate the effective doses. The different limits for the dose to the skin and that to the lens of the eye does also not simplify the situation.
As has been proposed by Böhm and Burgkhardt [5], this complex specification of radiation types may be totally avoided in the definition of the operational quantities by relating the operational quantities to the tasks in radiation protection monitoring. For example, $H^*(10)$ and $H_p(10)$ are applied if the relevant protection quantity is the effective dose and $H(0.07, \Omega)$ and $H_p(0.07)$ will be used if the skin dose needs to be controlled.

**Directional dose equivalent, $H'(3, \Omega)$, and personal dose equivalent, $H_p(3)$**

A further remark deals with the quantities $H'(3, \Omega)$ and $H_p(3)$ which are proposed for the rare cases when the equivalent dose to the lens of the eye needs to be controlled separately. Despite the fact that a separate limit has been defined for its equivalent dose, it is questioned whether a separate operational quantity is really needed. In area monitoring, it appears that $H^*(10)$ and $H(0.07, \Omega)$ are usually sufficient for specifying and monitoring the radiation fields in practice – and this even in the rare cases where such monitoring is needed to estimate or control the external exposure to the lens of the eye. Whereas conversion coefficients for $H'(3, 0^\circ)$ are not listed in ICRU Report 57 [4], Fig. 34 shows that $H'(3, 0^\circ)$ is underestimated by $H(0.07, 0^\circ)$ above an electron energy of 1 MeV and that $H'(10, 0^\circ)$ is conservative with respect to $H'(3, 0^\circ)$ above 2.8 MeV, the underestimation being always less than about 30%. For $\beta$ radiation with a maximum energy of less than 3.5 MeV the dose to the skin is always higher by more than a factor of 3.3 than the dose to the lens of the eye and hence the skin dose limit is more relevant. This holds also for the case of individual monitoring.

In order to reduce the number of operational quantities to what is really needed in practice we would suggest omitting the quantities $H'(3, \Omega)$ and $H_p(3)$. These quantities have not yet been used for routine monitoring.

**Direction $\Omega$ in the definition of $H'(d, \Omega)$**

In the definition of the directional dose equivalent a direction $\Omega$ is specified because the dose-equivalent value in an arbitrary multidirectional expanded radiation field will depend on this direction within the field. The introduction of an angle $\alpha$ between the direction $\Omega$ and the direction of a parallel radiation field (and even more the definition of $H'(0.07)$ for $\alpha = 0^\circ$) has strongly overemphasized the calibration situation as opposed to the measurement situation in workplace fields. In practical measurements of radiation monitoring, only the maximum value of $H'(0.07, \Omega)$ at a given point is of interest. This value is usually determined by rotating the instrument—e.g. a contamination monitor or
area monitor for beta radiation - and thus varying its orientation and the direction of radiation incidence with respect to the detector surface if this is not isotropic. For simplification it is proposed to add to the definitions that the maximum value of $H'(0.07, \Omega)$ at a point of interest may be referred to as $H'(0.07)$, thus replacing the former convention $H'(0.07, 0^\circ) = H'(0.07)$. This agreement has already been included in the DIN 6814-3 standard [6] where the dose quantities and units used in Germany are defined.

**Extremity dosimetry**

Strongly penetrating radiation, of course, contributes to the equivalent dose to the skin, the lens of the eye and the tissues of the hands and feet. Under most circumstances, effective dose will be the limiting quantity. Only in exceptional cases of very inhomogeneous irradiations (e. g. in a strongly collimated radiation beam or handling a radionuclide source) will the contribution of penetrating radiations such as neutrons or photons to the equivalent dose to these organs and tissues need to be taken into account. In absence of a clear definition of sensitive tissues in the extremities other than the skin, and considering that the same annual limit applies for both skin and “the extremity”, the limitation of the dose to the skin is usually considered to be sufficient for the extremities.

These considerations would also support the change from the link between the definition of the depth in the phantom and the degree of penetration of the radiation to a link to the purpose of dose equivalent measurement, i. e. the surveillance of the protection quantity under consideration.

**Conclusion**

The foregoing comments lead to a proposal for a slightly modified scheme of operational quantities which simplifies their definition and are more directed to their specific applications. Their correlation with the most important limits in cases of external exposure becomes much more evident and the number of operational quantities is reduced to a minimum which can be simply described and explained. The following scheme may also help to demonstrate the concept of operational quantities in lectures and training courses.
<table>
<thead>
<tr>
<th>Objective</th>
<th>Quantities for area monitoring</th>
<th>Quantities for individual monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveillance of effective dose</td>
<td>ambient dose equivalent, $H^*(10)$</td>
<td>personal dose equivalent, $H_p(10)$</td>
</tr>
<tr>
<td>Surveillance of equivalent dose of the skin or lens of the eye</td>
<td>directional dose equivalent, $H'(0.07,\Omega)$ (or $H'(0.07)$ for recording)</td>
<td>personal dose equivalent, $H_p(0.07)$</td>
</tr>
</tbody>
</table>

Obviously, these changes will not have a strong impact on the present practical use of the operational quantities and most of these changes are only a consequence of their regular use. No changes of conversion coefficients are necessary.

References


