THE IMPLICATIONS OF ICRU RECOMMENDED QUANTITIES FOR INDIVIDUAL MONITORING

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THE NEW SITUATION

In Report 39/1/, ICRU has recommended new quantities to be used in radiation protection measurements for exposures from external sources (cf also ref. /2/). These are

- for environmental monitoring
  - of strongly penetrating radiation, the ambient dose equivalent, $H^*(10)$,
  - of weakly penetrating radiation, the directional dose equivalent, $H'(0.07)$,
- for individual monitoring of exposure of the trunk of the body
  - to strongly penetrating radiation, the individual dose equivalent, penetrating, $H_p(10)$,
  - to weakly penetrating radiation, the individual equivalent superficial, $H(0.07)$.

Whereas the application of the quantities for environmental monitoring in the 30 cm diameter ICRU sphere does not pose serious conceptual problems and their implementation will probably be only a matter of time, the quantities for individual monitoring are the subject of lively international discussion. The Problems arise because $H_p(10)$ and $H_s(0.07)$ are defined

- at a specified position <u>within</u> the exposed individual,
- in the ICRU standard soft tissue, and <u>not</u> in the tissue actually existing at the specified position in the individual.

$H_p(10)$ and $H_s(0.07)$ therefore neither actually exist, nor are they measurable in the strict sense. However, besides these rather formal objections, there are other reasons for questioning the expedience of their choice. In particular, there is no generally valid unique relation of $H_p(10)$ [1] or a dose equivalent actually existing at the specified position of the individual to the quantities used in calibration, i. e. air kerma free-in-air (formerly exposure) for photon radiation and particle fluence for neutron radiation. The reason for this is that this relation depends on the geometrical peculiarities of the individual under consideration, the more so when strongly penetrating secondary radiations originating in the exposed person contribute substantially to the dose equivalent at the point of interest. Moreover, there will be no primary standards for dose equivalent in the forseeable future, i. e. for dose equivalent, irrespective of radiation type and quality.

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1) The following considerations will be restricted to $H_p(10)$, as $H_s(0.07)$ is less affected by variations in individual geometry due to the short ranges of weakly penetrating radiation.

RETROSPECT

Individual monitoring has been successfully performed for many decades. For photon radiation the procedure is as follows. Materials for dosemeter probes are selected to meet the requirement that their response be proportional to the air kerma (or exposure) independent of incident photon energy, if possible over the whole range of energies of interest, at least within admitted uncertainties. Alternatively, the readings of several probes with different energy responses are skillfully combined in order to achieve an energy-independent performance (e.g. photographic film with different filters). The expediently designed monitor (or a selected representative specimen of a bunch) is then calibrated free-in-air in units of exposure (or air kerma), thereby obtaining the calibration factor N (the quotient of air kerma K_a or exposure X and reading M).

After exposure of the monitor on the individual's body, the observed reading M is multiplied by the calibration factor N_K (or N_X), thereby obtaining the air kerma (or exposure) at the monitor's position on the body where it was exposed:

$$K_a = N_K M \quad \text{or} \quad X = N_X M$$

In order to obtain the individual's dose equivalent, K_a or X are multiplied by the conversion factor 1.15 Sv/Gy (for air kerma) or 0.01 Sv/R (for exposure). This result is routinely recorded as "personal dose":

$$H_{ind} = 1.15\ K_a \text{ Sv/Gy} \quad \text{or} \quad H_{ind} = 0.01\ X \text{ Sv/R}$$

H_{ind} is a good approximation of the dose equivalent at or near the surface of the exposed person and thereby in general, a safe estimate of the whole body dose or the effective dose equivalent, if the monitor's position at the body surface is representative of the person's radiation exposure.

For neutron radiation the procedure is different as the individual monitor is usually calibrated on a phantom approximating the trunk of the body (cf. ref. /3/), this requirement being a necessary consequence of the energy dependence of the dose equivalent response of most monitors, the varying Q factor being the chief reason.

THE NEW SITUATION

What then, is changed in practical procedures with the implementation of the new ICRU recommended quantity for individual monitoring, $H_p(10)$, for strongly penetrating radiation? Most important, there is now a uniform unique quantity for all kinds of strongly penetrating radiation by its definition in the ICRU sphere as an approximation of the human trunk. ICRU /1/ states,

> "The calibration of dosemeters is done under simplified conventional conditions at the depth d in an appropriate phantom. For dosemeters worn on the trunk a suitable phantom is the ICRU sphere."

From this statement, it can be conclusively inferred that the calibration is to be done in terms of the directional dose equivalent H'(10) defined at 10 mm depth in the ICRU sphere. This, then, is a prescription for the monitor's spectral and angular response. It should be made clear, however, that this requirement does not necessarily call for the calibration to be performed on the prescribed phantom. For photon radiation, the dose equivalent is numerically equal to the tissue-absorbed dose. A monitor's probe which is designed in such a way that its reading is proportional to tissue kerma at its location may therefore be calibrated by any procedure securing this. When the probe then, is embodied in an individual monitor simulating the geometric conditions of the H'(10) definition, it will sense the radiation field actually existing at its position and give the correct reading in terms of tissue kerma, which under the prevailing conditions is numerically equal to H'(10).

More frequently, however, the complete monitor (probe with casing) is calibrated, and especially in the case of neutron exposures, it is neither expedient nor even possible to design the probe's response to be proportional to the dose equivalent at its position, irrespective of the energy of the incident radiation. Instead, the probe's response is skillfully shaped to meet the required response over at least a limited range of energies when sensing the radiation field at the surface of the wearer's body, as for example with albedo monitors: then, of course, calibration on a phantom in terms of H'(10) is necessary. When using for the sake of convenience a phantom other than the ICRU sphere, any noticeable deviation from the required H'(10) response introduced thereby should be corrected.

Conversion factors relating H'(10) to the calibration quantities air kerma K_a or exposure X and neutron fluence as a function of incident energy and direction can be found in the literature /4,5,6/.

EXPERIENCE WITH EXISTING MONITORS

Tests with existing individual monitors for photon radiation demonstrate that the required spectral and angular responses can be met to a sufficient approximation. However, up to the present there has been no generally required and clearly defined quantity for individual monitoring, still less for its dependence on the direction of radiation incidence, except that resulting automatically and involuntarily when the monitor is exposed on the surface of the wearer's body.

As the accuracy requirements for individual monitoring are not very stringent (cf. /8/), there appears to be no serious obstacle to accepting the recommended H'(10) response for individual monitors, the required angular response to be verified for the front hemisphere at the most, or more realistically, to a cone with an angle of aperture of 60° (or less) around the direction of perpendicular frontal incidence onto the surface of the sphere.

EVALUATION OF MONITORS IN PRACTICE

As pointed out at the beginning, the ICRU recommended individual dose equivalent $H_p(10)$ neither actually exists nor is it directly measurable or limited by any regulation. Why then strive for its determination? It would be better to retain the well established and approved procedure of taking the product of the reading of a properly designed monitor and its calibration factor as the "individual dose equivalent for recording". The only material difference to the traditional procedure is the substitution of the multiplicity of reference quantities (air kerma or exposure for photons, tissue absorbed dose for beta radiation, maximum dose equivalent for neutrons) by a single one, namely the directional dose equivalent H'(10), (or H'(0.07) for weakly penetrating radiation). But we should not fail to acknowledge that this is important progress.

There is really no danger in following the procedure advocated here and omitting the explicit determination of $H_p(10)$, especially as doses in particular organs and tissues or the effective dose equivalent are the quantities to be determined or estimated in those cases where stated investigation levels of the "individual dose equivalent for recording" are exceeded. The proposed agreement would be a clarification and recognition of well-established procedures.

REFERENCE

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