Effective Dose: A Radiation Protection Quantity

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THE FIRST ICRP RECOMMENDATIONS, 1928

"The effects to be guarded against are injuries to superficial tissues, derangements of internal organs and changes in the blood"

As a remedy, a <u>prolonged vacation</u> and <u>limitation of working hours</u> were recommended.

The main emphasis was on <u>shielding requirements</u> and included no dose limits, but did advise the worker

"should on no account expose himself unnecessarily to a direct beam" and

"should place himself as remote as practicable from the X-ray tube" .

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ICRP Publication 9, 1966

The threshold for stochastic effects was dismissed:

"… the Commission sees no practical alternative, for the purposes of radiological protection, to assuming a linear relationship between dose and effect, and that doses act cumulatively.

The Commission is aware that the assumptions of no threshold and of complete additivity of all doses may be incorrect, but is satisfied that they are unlikely to lead to the underestimation of risks."

Modern radiological protection is based on the principles (ICRP Publication 26) :

- **Principle of justification:**

  No practice shall be adopted unless it produces a **net benefit**

- **Principle of optimisation**

  All exposures shall be **As Low As Reasonably Achievable**, economic and social factors taken into account

- **Principle of limitation**

  Doses to individuals shall not exceed **limits**

Assessment of radiation risks for individuals or groups of individuals is not a objective of radiological protection.

Practical Radiation Protection

The practical implementation of the principles of limitation and optimisation requires the definition of appropriate

radiation protection quantities

including their specific units,

and the availability of methods to assess these quantities in real exposure situations.

New Dose Quantity for Setting Exposure Limits after Publication 26

'Critical organs' abandoned – enough scientific knowledge available to calculate a weighted whole-body dose.

Publication *26* describes the weighting procedure but did not present the new quantity.

In a statement from the 1978 Stockholm Meeting of the ICRP the

effective dose equivalent, H_E

was introduced following a proposal by

Wolfgang Jacobi

Effective Dose (Equivalent):

1978

Effective Dose Equivalent, H_E , was introduced by ICRP to be used for setting and controlling dose limits in the regulatory context.

Why was it introduced?

The intention was to solve conceptual and practical problems (in particular for internal irradiations) with the until then used limitation concept based on "critical organ" and "maximum permissible dose".

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Effective Dose (Equivalent):

The concept is restricted to the control of stochastic effects and was (and still is) based on the assumption that

- at low doses - the total radiation detriment to the exposed person is given by the sum of radiation detriments to the single organs
- organ dose equivalent is linearly correlated with detriment.

The applicability of this quantity and its underlying concept requires the use of a linear dose –risk relationship without a threshold (LNT model).

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Effective Dose, E

has been introduced by ICRP as the primary

radiological protection quantity

to be used for

- **setting and controlling dose limits in the regulatory context**
- and for enabling the practical implementation of the **optimization principle**.

EffectiveDose

Organ absorbed dose

$$E = \sum_T w_T H_T = \sum_T w_T \sum_R w_R D_{T,R} [Sv]$$

radiation (quality)weighting

effective dose

tissue weighting

The quantity enables the necessary summation of doses from internal emitters and external radiation fields to provide a <u>single</u> numerical value for limitation and optimization.

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Weighting factors

- **Radiation weighting factors, w_R**

  Take account of differences in biological effectiveness of different types of ionizing radiation

- **Tissue weighting factors, w_T**

  Sex-and age averaged, relative contribution of individual tissues to total detriment of stochastic effectsfor low-LET irradiations:

  ⇒ **all $w_T < 1$ and $\sum w_T = 1$**

Selection of values for weighting factors by ICRP is based on scientific knowledge available.

Tissue weighting factors

• *ICRP 60*	0.01	bone surface, skin
(1991)	0.05	bladder, breast, liver, oesophagus, thyroid, remainder
	0.12	bone marrow, colon, lung, stomach
	0.2	gonads
• *ICRP 103*	0.01	bone surface, skin, brain, salivary glands
(2007)	0.04	bladder, liver, oesophagus, thyroid
	0.08	gonads
	0.12	bone marrow, colon, lung, stomach, breast, remainder

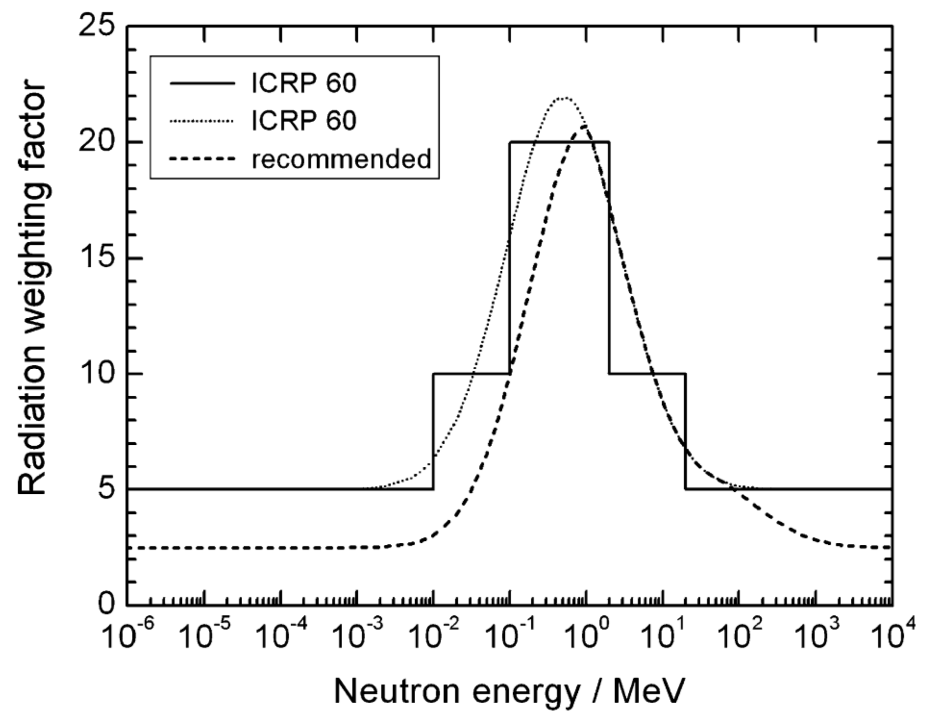
ICRP 103
Radiation Weighting Factors

Table 2. Recommended radiation weighting factors.

Radiation type	Radiation weighting factor, w_R
Photons	1
Electrons[a] and muons	1
Protons and charged pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	A continuous function of neutron energy (see Fig. 1 and Eq. 4.3)

All values relate to the radiation incident on the body or, for internal radiation sources, emitted from the incorporated radionuclide(s).

[a] Note the special issue of Auger electrons discussed in paragraph 116 and in Section B.3.3 of Annex B.



Reference Anatomical Models for Adults ("Reference phantom")

adult male

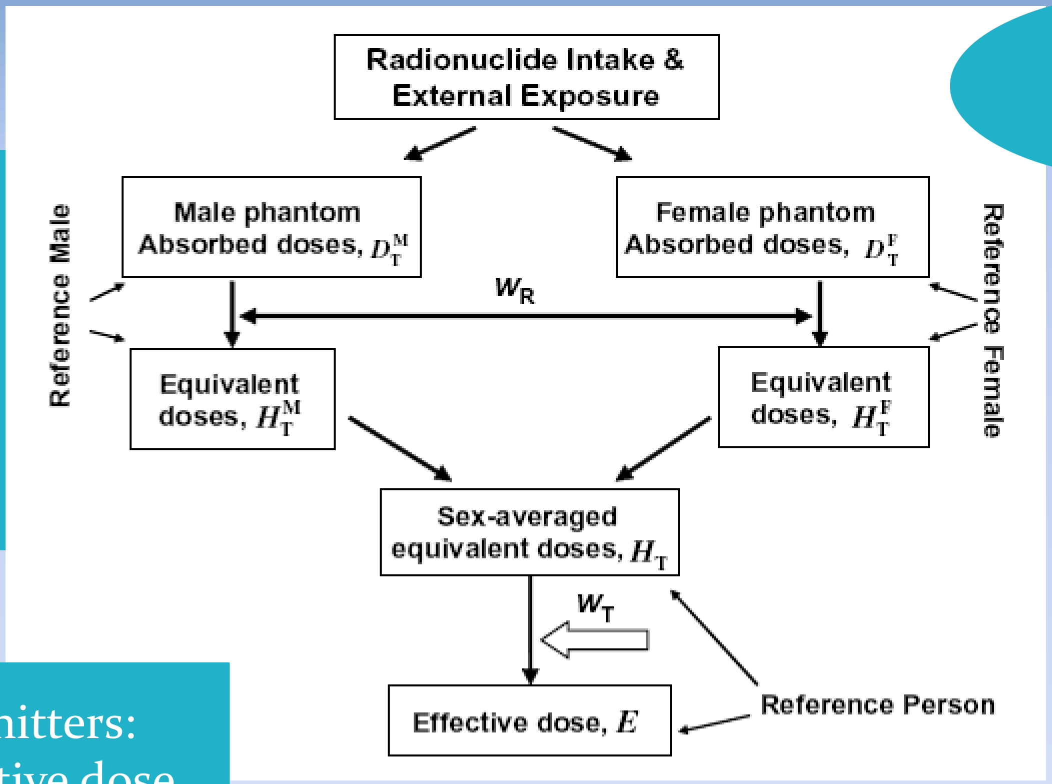
adult female

"Voxel phantoms"

ICRP Publication 110

Determination of Effective Dose: Reference Values

Transport Calculations and Biokinetic and Dosimetric Models



Individual specific

For internal emitters: committed effective dose

Assumptions, simplifications, approximations included in the definition of effective dose

- `The variability of radiation sensitivities of tissues is represented by **selected** tissue weighting factors which assume **only 4 different, nominal values** ranging from 0.01 to 0.12 The values were obtained by **averaging over both sexes, all ages across populations**.
- The radiation weighting factors are **selected** from published RBE-values and assume **only 3 different values 1, 2, 20** for all radiations and energies (except for neutrons).

Assumptions, simplifications, approximations included in the definition of effective dose

- Use of a Linear No Threshold (LNT) model for stochastic effects in the low-dose range.

- Validity of temporal additivity of dose (committed dose), in the low-dose range.

- Dose conversion coefficients are evaluated applying sex averaging.

Application of Effective Dose

- **E** is used **prospectively** for planning and optimization of occupational and public exposure to external sources and internal emitters.

- E is used **retrospectively** for regulatory purposes, for demonstrating compliance with dose limits and constraints.

Effective dose has proven to be an extremely useful quantity / tool for the intended purpose:

as a single, risk related quantity

for the practical implementation of the principles of limitation and optimization in operational radiological protection.

Effective dose is an indicator for stochastic risk but
it is not intended for the assessment of risks of individuals.
(because of the uncertainties in the low-dose range, underlying approximations, simplifications, sex and age - averaging)

However: in practice, it is often used as a first estimate for risk, e.g. in radiological diagnostics.

Individual Risk Assessment

Best assessments of individual risks need to take account of all available specific exposure data, relevant information on the individuals concerned and all available relevant scientific information:

- best estimates of absorbed dose to organs / tissues
- best scientific information on RBE for the radiation concerned and for the specific cancer types.
- age and sex specific cancer incidence data for the different organs instead of nominal risk coefficients and tissue weighting factors used in the definition of E.

Final Remarks

- **Individual risk assessments must also take account of uncertainties of the data used. In the radiation protection regime, i.e. in the low dose region these uncertainties are very large.**
- **Organ/tissue absorbed dose is the fundamental quantity, both in radiological protection and in risk assessments.**
- **Organ absorbed doses should therefore also be used in epidemiological studies and recorded in health follow-up projects.**

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