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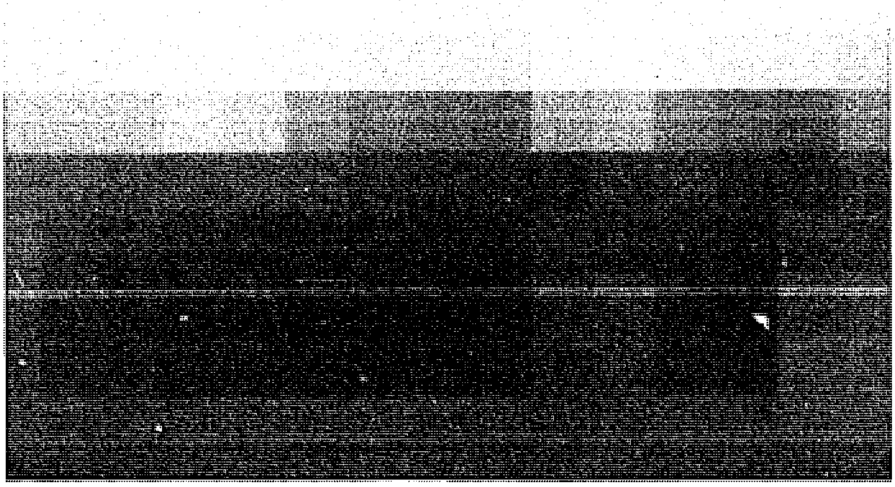
Guide
ST 1.2

Application of Maximum Radiation Exposure Values and Monitoring of Radiation Exposure



Säteilyturvakeskus
Strålsäkerhetscentralen
Finnish Centre for Radiation
and Nuclear Safety

Application of Maximum Radiation Exposure Values and Monitoring of Radiation Exposure

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Appendix A The Quantities and Units for Assessing Radiation Exposure
Appendix B Table of the Quantities Used for Assessing the Radiation Exposure

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Authorization

Under section 70, paragraph 2, of the Radiation Act (592/91), the Finnish Centre for Radiation and Nuclear Safety issues general instructions, known as Radiation Safety Guides (ST Guides), concerning the use of radiation and operations involving radiation.

The Radiation Act stipulates that the party running a radiation practice is responsible for the safety of the operations. The responsible party is obliged to ensure that the level of safety specified in the ST Guides is attained and maintained.

Translation. Original text in Finnish.

1 General

The maximum values for radiation exposure given in the 2nd chapter of the Radiation Decree (1512/91) apply to the utilization of ionizing radiation, to any practice involving the exposure of humans to ionizing radiation, and to the use of nuclear energy. According to section 32 of the Radiation Act (592/91) the Finnish Centre for Radiation and Nuclear Safety (STUK, the Finnish-language abbreviation) shall issue instructions on the monitoring of radiation exposure and on the application of the dose limits.

This guide presents the principles to be applied in calculating the equivalent dose and the effective dose, instructions on application of the maximum values for radiation exposure, and instructions on monitoring of radiation exposure. In addition, the measurable quantities to be used in monitoring the radiation exposure are presented; these quantities are needed for estimating the equivalent dose and the effective dose.

2 Equivalent Dose and Effective Dose

In the practice of radiation protection the computational quantities equivalent dose and effective dose are used for estimating the probability of harmful late effects resulting from exposure to radiation. These late effects include cancer and such detriment to germ cells that is inheritable to the offspring (genetic harm).

Equivalent dose is used for estimating the harmful effects of irradiation on the organ or tissue under consideration. The equivalent dose in an organ or tissue is obtained by multiplying the absorbed dose in the organ or tissue by a weighting factor whose value depends on the type and energy of the radiation. If the radiation is composed of more types and energies of radiation than just one, the equivalent dose is given by the sum of the equivalent doses from the contributing radiations. The radiation weighting factors to be used for calculating the equivalent dose are given in Table *A1* of Appendix A.

The unit of equivalent dose is sievert (1 Sv = 1 J/kg).

Effective dose is used for estimating the harmful effects of irradiation on humans. The effective dose is the weighted sum of equivalent doses in all the organs and tissues of the body, with weighting factors (tissue weighting factors) depending on the organ or tissue. The tissue weighting factors to be used for calculating the effective dose are given in Table *A2* of Appendix A.

The unit of effective dose is sievert (Sv).

Hereafter, when discussing radiation dose or dose, the equivalent dose in a specified organ or tissue, or the effective dose is to be ment according to the pertinent subject.

The rigorous definitions of equivalent dose and effective dose are presented in Appendix A. This Appendix discusses also the quantities used for monitoring radiation exposure.

3 Maximum Values of Radiation Exposure and their Application

One of the main criteria to the acceptability of radiation utilization is to keep the resulting radiation exposure as low as is reasonably achievable. The responsible party is required to take all measures to improve radiation safety that can be considered justified while taking into account the nature and costs of these measures and the effects on radiation safety. Complying with this principle is required even if the exposure does not exceed the maximum values presented below.

The Radiation Decree gives dose limits for two person categories. The dose limits of section 3 of the Radiation Decree apply to occupationally exposed persons (radiation workers) and the other dose limits given in section 5 apply to other than occupationally exposed persons. In addition, the dose limits that are given in section 4 of the Radiation Decree apply to pregnant women and are intended to protect the fetus.

If a person is exposed to both external and internal irradiation, the dose resulting from the external sources and the committed dose resulting from intaken radionuclides shall be summed. In this case particular care must be taken to ensure that the total exposure does not result to exceeding any of the dose limits.

The radiation exposure caused by medical procedures to a person being examinated or treated shall not be taken into account in applying the dose limits.

The dose limits that are given in section 8 of the Radiation Decree shall be applied to measures taken in an accidental situation in order to restrict the radiation hazard and bring the radiation source under control.

3.1 Dose Limits in Radiation Work

Work is classified as radiation work if the effective dose at work including the possibility of, and occurrence leading to exceptional radiation exposure in the course of work, is or may be higher than 5 mSv in a year.

The annual dose of a radiation worker must not exceed the dose limits issued by the Radiation Decree. The dose limits are presented in Table *I*.

The dose in a year shall be calculated to correspond to a calendar year. The five year period referred to in the table means five calendar years: the first period consists of the years 1992 - 1996, the second period consists of the years 1993 - 1997 etc.

Table I. Dose limits in radiation work.

Application	Dose limit mSv in a year
Effective dose	20*
Equivalent dose in	
· the lens of the eye	150
· the skin	500
· the hands and feet	500

* 20 mSv per year as an average over five years; the effective dose shall not exceed 50 mSv in any single year.

The equivalent dose at any point on the skin of a radiation worker shall not exceed 500 mSv. This dose in the skin shall be calculated as an average over an area of at most one quadrat centimetre, and the depth under consideration is set to be 0.07 mm. If there is no accurate dose estimate available for a point-like beta radiation source in contact with the skin, for example a hot particle, one may assume that the equivalent dose of 500 mSv is not exceeded when the total beta emission does not exceed 10^9 beta particles.

For the monitoring of the equivalent dose in the lens of the eye the depth under consideration is set to be 3 mm.

Once pregnancy has been declared the equivalent dose from external radiation on the surface of the lower trunk of the pregnant woman shall not exceed the value 2 mSv, and the effective dose caused by radionuclides entering the body that are liable to be hazardous to the fetus shall not exceed 1 mSv. The objective is that the dose in the fetus stays below 1 mSv during the pregnancy. This is generally achieved if, after the declaration of the pregnancy, the depth dose of the lower trunk (see item A.2.2 of Appendix A) does not exceed 2 mSv and if the intakes of radionuclides hazardous to the fetus stay below 1/20 of the annual limit on intake (see item 3.2). Radon intaken with inhaled air in the lungs of a woman is considered not to be a radionuclide hazardous to the fetus since it does not significantly expose the fetus.

According to section 37 of the Radiation Act the lower age limit for a person employed in radiation work is eighteen. A younger person can take part in radiation work only if it is necessary for training purposes. STUK will give individual instructions for the dose limits for 16 - 18 year old persons in professional training. The maximum values given in section 5 of the Radiation Decree shall be applied to persons younger than 16 years (see item 3.3).

3.2 Derived Limits in Radiation Work

Annual limits on intake and limits on radionuclide concentrations in air have been derived for various radionuclides and for their chemical compounds for the purpose of monitoring internal radiation dose.

The **annual limit on intake** (ALI) is the activity of a radionuclide whose intake will result to a committed effective dose equal to the dose limit.

The **Derived Air Concentration** (DAC) of a given radionuclide is the mean activity concentration of the radionuclide in air which allows a person to work 2 000 hours in a year without exceeding the dose limits. The derived air concentration has been calculated by dividing the annual limit on intake (ALI) of the considered radionuclide by the quantity of air inhaled during the workhours (2 400 m^3 in a year).

ST Guide 1.5 gives the annual limits on intake for radionuclides and the derived air concentrations for certain gases.

3.3 Other Maximum Values

The use of radiation shall be planned and organized so that the doses to persons other than those engaged in radiation work do not exceed the dose limits in section 5 of the Radiation Decree. These dose limits apply only to the utilization of radiation and to the use of nuclear energy. They shall not be applied to the exposure to natural radiation. The dose limits are presented in Table *II*.

Table II. Other dose limits.

Application	Dose limit mSv in a year
Effective dose	1
Equivalent dose in	
· the lense of the eye	15
· the skin	50

The equivalent dose in the lense of the eye and in the skin are determined as stated in 3.1.

No specific limits are provided for the equivalent dose in the hands and feet, but the limit for the equivalent dose in the skin applies also to the skin of the hands and feet.

4 Application of the Maximum Values to Natural Radiation

4.1 Natural Radiation

Natural radiation means ionizing radiation that originates in space, or refers to radioactive materials that occur in nature and are not used as radiation sources.

When necessary, the responsible party is required to investigate the radiation exposure originating from natural radiation as required in section 45 of the Radiation Act. Operations involving such radiation exposure may include:

- working in mines, excavation sites or underground spaces where there is a notable amount of radon in the air,
- working in other places where there is a notable amount of radon in the air,
- handling or storing materials that contain notable amounts of natural radionuclides and
- regular working in aeroplanes on flight routes where the radiation exposure caused by cosmic radiation may be high.

If the investigation shows that, even after the measures to reduce the exposure, the effective dose at work can exceed 5 mSv in a year, the work shall be classified as radiation work. In this case the responsible party shall provide for the monitoring of the radiation exposure and health surveillance of the employees as prescribed in the Radiation Act and in the Radiation Decree.

The dose limits given in section 3 of the Radiation Decree shall be applied to natural radiation when the work has been classified as radiation work. The dose limits given in section 5 of the Radiation Decree shall not be applied to natural radiation.

If a pregnant worker is exposed to natural radiation from other sources than radon, special measures shall be taken, if necessary, to ensure that the dose limits given in section 4 of the Radiation Decree to protect the fetus are not exceeded.

4.2 Radon at Workplaces

Natural radionuclides, mainly radon (^{222}Rn), may spread in the inhaled air of workplaces from the crust of the earth, either directly or with disposable water.

The safety requirement set for radon in the inhaled air at workplaces is that the annual mean of the radon concentration*, averaged over the total number of annual working hours, does not exceed 400 Bq m^{-3} when the annual total number of annual working hours is 1 600 hours or more**. If the total number of annual working hours is less than 1 600 hours or if the work is not regular the upper limits for radon concentration presented in Table *III* are applied.

The upper limits have been calculated so that if the workhours presented to the Table are followed the effective dose of the employee does not exceed 2.5 mSv in a year***. Here, it is assumed that the equilibrium factor is equal to 0.5. In adverse circumstances, when the ventilation is poor, the value of the equilibrium factor may be close to one and the upper limits for radon concentration shown in Table *III* result to an annual effective dose of 5 mSv.

***Table III.** The upper limit for radon concentration of the inhaled air of workplaces. The values represent the annual mean of radon concentration during the workhours.*

Annual workhours	Radon concentration* (Bq/m^3)
Regular workhours	400
Less than 600 hours	1 000
Less than 300 hours	2 000
Less than 100 hours	6 000

These limits are also applied to public buildings and to other places comparable to them. ST Guides discussing the limitation of the radiation exposure in mines and excavation workplaces have been issued separately.

* More rightfully, the quantity is the activity concentration.

** According to the decision of the Ministry of Social Affairs and Health (944/92) the radon concentration in a dwelling should not exceed 400 Mq m^{-3}.

*** The conversion coefficient from concentration to dose according to ICRP Publications 65 [4].

If the radon concentration in the air at the workplace, as measured or estimated from measurements and averaged over the work-hours in a year, exceeds the concentrations presented in the Table, the employer shall take measures to reduce the radon concentration. The higher a radon concentration is observed the more urgent the measures shall be.

If the measures taken to reduce the radon concentration do not, in spite of sufficient effort, reduce the radon concentration averaged over the total number of annual working hours is below the concentrations shown in the Table it has to be investigated whether the radiation exposure from radon is so high that the work must be classified as radiation work.

If the annual mean of the radon concentration during the workhours exceeds the upper limits presented in the Table by a factor greater the two, the work shall be classified as radiation work.

4.3 Natural Background Radiation

When determining the radiation dose to the employee, the part caused by natural background radiation is subtracted from the dose. Background radiation includes, among other things, the internal irradiation due to potassium-40 in the body and the external irradiation due to cosmic radiation at the ground level. Also the irradiation due to radionuclides of the earth's crust shall be considered as background radiation unless otherwise has been concluded on the basis of the investigation referred to in section 45 of the Radiation Act.

5 Monitoring of Radiation Exposure in Radiation Work

According to the Radiation Decree the working conditions affecting the radiation exposure shall be determined and monitored at the workplace in such a way that undue radiation exposure can be detected and prevented. Methods and equipment used for monitoring radiation exposure and for the relevant working conditions are subject to approval by STUK.

The radiation dose to a person shall be determined by measurement or by calculating methods. In addition, biological dosimetry is used to estimate a received or suspected dose of exceptional magnitude.

A verified or suspected exceeding of a dose limit, or of a constraint lower than the dose limit, as referred to in section 6 of the Radiation Decree and given specifically for the pertinent operation, shall be notified separately and immediately to STUK.

The data of the radiation exposure of radiation workers shall be reported to the Dose Register at STUK. The instructions for monitoring of personal radiation doses, for reporting dose data to the Dose Register and for proceeding in damage and accident situations are given in ST Guide 1.6.

5.1 External Irradiation

The personal radiation exposure due to external irradiation is monitored by using personal dosemeters. The definitions of the quantities to be measured, the depth dose and the surface dose, are presented in section A.2.2. of Appendix A.

The limit on the effective dose will not be exceeded if the measured value for the depth dose will not exceed 20 mSv in a year. The limit on the equivalent dose in the skin will not be exceeded if the measured value for the surface dose will nowhere exceed 500 mSv in a year. The annual equivalent dose in the lense of the eye or in the extremities is estimated from the depth dose and the surface dose, or from separate measurements, if necessary.

Exposure conditions can be monitored by measurements of the external irradiation at the workplace or in the environment.

5.2 Internal irradiation

Intakes of radionuclides are monitored by measurements of excretions, by whole body counting or by measurements specific to the organ under consideration.

The exposure conditions at the workplace can be monitored by measurements of surface contamination. The concentration of radionuclides in air is monitored by using meters intended for the measurement of the activity concentration, or with aid of samples obtained by using air samplers.

The radiation exposure of the employees from radon shall be monitored by radon concentration measurements and accounting of workhours at workplaces where the effective dose due to radon inhaled with air exceeds 5 mSv in a year.

The dose limits will not be exceeded, with respect to a single radionuclide, if the annual limits on intake and the concentration limits will not be exceeded. If a person is exposed to several radionuclides, intakes of radionuclides shall be lower than the annual limits on intake, and the concentration of the radionuclides in air shall be lower than the concentration limits, such that the dose limits given in Table *I* are not exceeded. A more thorough discussion of the monitoring of internal irradiation is presented in ST Guide 1.5.

6 Bibliography

1 ICRP Publication 35, General Principles of Monitoring for Radiation Protection of Workers. The International Commission on Radiological Protection, Pergamon Press, Oxford 1982.

2 ICRP Publication 60, 1990 Recommendations of the International Commission on Radiological Protection. The International Commission on Radiological Protection, Pergamon Press, Oxford 1991.

3 ICRP Publication 61, Annual Limits on Intake of Radionuclides by Workers Based on the 1990 Recommendations. The International Commission on Radiological Protection, Pergamon Press, Oxford 1991.

4 ICRP Publication 65, Protection Against Radon-222 at Home and at Work. The International Commission on Radiological Protection, Pergamon Press, Oxford 1993.

APPENDIX A

THE QUANTITIES AND UNITS FOR ASSESSING RADIATION EXPOSURE

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A.1 Computational quantities for radiation protection

Equivalent dose and effective dose are computational quantities that are used in radiation protection for estimating the detrimental late effects of radiation on man.

A.1.1 Equivalent dose and effective dose

Equivalent dose and effective dose are based on the average absorbed dose in an organ or tissue, D_T, that is also briefly referred to as the organ dose.

The tissue- or organ-average **absorbed dose,** D_T, is defined as below:

$$D_T = \frac{\varepsilon_T}{m_T} , \tag{A1}$$

where ε_T = the total energy imparted by ionizing radiation to the tissue or organ T and
m_T = the mass of the tissue T.

The unit of the tissue- or organ-average absorbed dose is gray (1 Gy = 1 J/kg).

Later, all tissues and organs are referred to as tissue.

Equivalent dose, H_T, in the tissue T is the sum of average absorbed doses multiplied by the radiation weighting factors:

$$H_T = \sum_R w_R D_{T,R} , \tag{A2}$$

where w_R = the weighting factor for radiation R and
$D_{T,R}$ = the average absorbed dose from radiation R in tissue T.

The unit of the equivalent dose is sievert (1 Sv = 1 J/kg).

The probability of the manifestation of detrimental late effects of radiation is affected not only by the dose, but also by the quality of the radiation (type and energy of radiation). The use of radiation weighting factors is an attempt to include this effect. The weighting factor of a specific type and energy of radiation has been set with the intention to be proportional to the relative biological effectiveness (RBE) of the radiation for the detrimental late effects at low doses.

For calculating the equivalent dose the radiation weighting factors specified by the International Commission on Radiological Protection (ICRP) are used. These weighting factors are presented in Table *A1*.

Table A1. Radiation weighting factors w_R [2].

Type and energy of radiation	w_R
Photons, all energies	1
Electrons* and muons, all energies	1
Neutrons, energy	
lower than 10 keV	5
higher than 10 keV but lower than (or equal to) 100 keV	10
higher than 100 keV but lower than (or equal to) 2 MeV	20
higher than 2 MeV but lower than (or equal to) 20 MeV	10
higher than 20 MeV	5
Protons**, energy higher than 2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

* Excluding Auger electrons emitted from nuclei bound to the DNA-molecule
** Other than recoil protons

If needed, STUK will give guidance for calculating the equivalent doses from radiation types and energy whose weighting factors are not given in the Table.

The detrimental late effects caused by irradiation depend, besides the dose and the type and energy of the radiation, also on the irradiated tissue. The risk of radiation induced harm varies with the tissue.

Effective dose enables one to estimate the detrimental late effects of irradiation on man irrespective of the uniformity of the dose distribution in the body. The **effective dose,** E, is the sum of equivalent doses in all the tissues and organs of the body weighted by the tissue weighting factors w_T:

$$E = \sum_T w_T H_T , \qquad \text{(A3)}$$

where w_T = the weighting factor for tissue T and
H_T = the equivalent dose in tissue T.

The unit of the effective dose is sievert (Sv).

For calculating the effective dose the tissue weighting factors specified by the ICRP are used. These weighting factors are presented in Table *A2*. When the dose limits are being applied, the weighting factors are to be used as such for calculating the effective dose in both males and females.

Table A2. Tissue weighting factors w_T [2].

Tissue or organ	w_T
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05

The weighting factor for the remainder is used for weighting the average equivalent dose in the tissues not mentioned in the Table. The average equivalent dose is the mass-average equivalent dose in these tissues. The recommendations of the ICRP [2] lists other tissues and organs that can be included when calculating the dose. If the equivalent dose in a tissue is in excess of the highest dose in any of the twelve tissues mentioned in the Table, the value of 0.025 is used for the weighting factor of that tissue. In this case the equivalent dose in the rest of the remainder tissues is weighted by the factor of 0.025.

The tissue weighting factors have been selected such that each factor represents the contribution of that organ or tissue to the total detriment when the whole body is uniformly exposed to radiation. This selection method of the weighting factors causes the sum of the tissue weighting factors to equal unity.

The effective dose can be computed also from the average absorbed doses as:

$$E = \sum_T w_T \sum_R w_R D_{T,R} \quad , \qquad \text{(A4)}$$

where w_R = the weighting factor for radiation R,
w_T = the weighting factor for tissue T and
$D_{T,R}$ = the average absorbed dose in tissue T delivered by radiation R.

A.1.2 Committed equivalent dose and committed effective dose

Intake of radionuclides may expose the person a long time after the intake. When assessing the dose from internal irradiation, the dose resulting during the long time span is regarded as being received wholly at the year of the intake.

The quantities committed equivalent dose and committed effective dose are defined for the purpose of computing the equivalent dose and the effective dose resulting from a single intake of radioactive material.

The **committed** tissue or organ **equivalent dose** (in tissue T), $H_T(50)$, is the equivalent dose in this tissue resulting from a single intake of radioactive material. For adults, the committed equivalent dose is computed for a period of 50 years (50 a) from the intake:

$$H_T(50) = \int_{t_0}^{t_0 + 50a} \dot{H}_T(t)\, dt \,, \tag{A5}$$

where $\dot{H}_T(t)$ = the equivalent-dose rate in tissue T at time t and
t_0 = the time of the intake.

For persons younger than eighteen years, the committed equivalent dose is calculated for a period of 70 years; this quantity is denoted as $H_T(70)$.

The **committed effective dose**, E(50), is the sum of the committed equivalent doses in all tissues multiplied by the tissue weighting factors:

$$E(50) \sum_T w_T\, H_T(50) \,, \tag{A6}$$

where w_T = the weighting factor for tissue T and
$H_T(50)$ = the committed dose equivalent in tissue T as computed for a time span of 50 years.

For persons younger than eighteen years, the committed effective dose is calculated for a period of 70 years. In this case the committed effective dose is denoted as $E(70)$.

The unit of committed equivalent dose and of committed effective dose is sievert (Sv). The committed effective dose is recorded in the Dose Register for the year of the intake.

If a person is exposed to more than one radionuclide the committed effective doses resulting from the various radionuclides shall be summed.

A.2 Measurable quantities for dose estimation

The equivalent dose and the effective dose are computational quantities that cannot be measured directly. Therefore, measurable quantities that provide sufficiently accurate approximations of the effective dose and of the equivalent doses in specific organs are needed for monitoring external irradiation. Respectively, activity and quantities derived from it are measured for monitoring internal irradiation.

A.2.1 Absorbed dose and dose equivalent

The basic quantity of radiation measurements, the **absorbed dose,** *D*, is defined as

$$D = \frac{d\bar{\varepsilon}}{dm} , \tag{A7}$$

where $d\bar{\varepsilon}$ = the mean energy imparted by ionizing radiation to the matter of a mass element and
dm = the mass of the mass element.

The unit of the absorbed dose is gray (Gy).

The **dose equivalent,** H, is the product of the absorbed dose and the quality factor of the radiation:

$$H = Q\,D , \tag{A8}$$

where Q = the quality factor of the radiation at the considered point and
D = the absorbed dose.

The unit of the dose equivalent is sievert (Sv).

The quality factor of the radiation, *Q*, is a physical quantity that is based on the linear energy transfer (LET) of the radiation. It has been assumed that this quantity describes, with a sufficient accuracy, the relative biological effectiveness (RBE) of radiation.

In order to avoid misinterpretation it is necessary to remember the difference between the definitions of the dose equivalent and the equivalent dose. The dose equivalent is the absorbed dose in a point-like mass element multiplied by the quality factor [1]. The equivalent dose is the average absorbed dose in a tissue or organ multiplied by the radiation weighting factor [2].

A.2.2 Depth dose and surface dose

For the purposes of personal dosimetry an auxiliary quantity has been derived from the dose equivalent for estimating the equivalent dose and the effective dose. This auxiliary quantity is the personal dose equivalent, $H_p(d)$, at the depth d in the soft tissue of the body*. The depth *d* is usually chosen as 10 mm or 0.07 mm, but a different depth may be chosen for special applications.

The personal dose equivalent, or the **depth dose,** $H_p(10)$, is the dose equivalent at a point 10 mm below the body surface in soft tissue.

The personal dose equivalent, or the **surface dose,** $H_p(0.07)$, is the dose equivalent at a point 0.07 mm below the body surface in soft tissue.

The dose equivalent in the lens of the eye, $H_p(3)$, is the dose equivalent at a point at 3 mm depth in soft tissue.

* The subsercript p refers to the work 'personal'.

The depth dose is, aside from a few exceptions, a good approximation to the effective dose. This is not valid if the radiation is moderately penetrating, the body is mainly shielded and the depth dose is measured on the protecting shield. In this case the effective dose is notably lower than the depth dose and the effective dose shall be estimated individually from the measured depth dose.

The surface dose is an approximation to the equivalent dose in the skin.

A.2.3 Activity and radon concentration

The **activity**, *A*, *of an amount of radioactive nuclide is the number of spontaneous* nuclear transformations, *dN*, in a time interval, *dt*, divided by this time interval:

$$A = \frac{dN}{dt} . \qquad \text{(A9)}$$

The unit of activity is becquerel (Bq). An amount of matter has the activity of one becquerel if in this matter there occurs, on the average, one nuclear transformation in one second (1 Bq = 1 s^{-1}).

The **radon concentration** in air is the activity of radon in air divided by the air volume. The unit of radon concentration is Bq/m^3.

A.3 References

1 ICRP Publication 51, Data for Use in Protection Against External Radiation. The International Commission on Radiological Protection, Pergamon Press, Oxford 1987.

2 ICRP Publication 60, 1990 Recommendations of the International Commission on Radiological Protection. The International Commission on Radiological Protection, Pergamon Press, Oxford 1991.

APPENDIX B

TABLE OF THE QUANTITIES USED FOR ASSESSING THE RADIATION EXPOSURE

The quantity and its symbol	The definition of the quantity	The quantities in the equation
Absorbed dose *D*	$D = \frac{d\bar{\varepsilon}}{dm}$	$d\bar{\varepsilon}$ = the mean energy imparted by the ionizing radiation to the matter of a mass element dm = the mass of the mass element
Dose equivalent *H*	$H = Q\,D$	Q = the quality factor of the radiation at the point under consideration D = the absorbed dose
Activity *A*	$A = \frac{dN}{dt}$	dN = the expected number of spontaneous nuclear transformations dt = the time interval under consideration
Organ- or tissue-average absorbed dose D_T	$D_T = \frac{1}{m_T}\int_{m_T} D\,dm = \frac{\varepsilon_T}{m_T}$	m_T = the mass of the organ or tissue T D = the absorbed dose ε_T = the total energy imparted by the ionizing radiation to the tissue or organ
Equivalent dose H_T	$H_T = \sum_R w_R\,D_{T,R}$	w_R = the radiation weighting factor for radiation R $D_{T,R}$ = the organ- or tissue-average absorbed dose in the organ or tissue T resulting from radiation R
Effective dose *E*	$E = \sum_T w_T\,H_T$	w_T = the tissue weighting factor for the tissue or organ T H_T = the equivalent dose in the tissue or organ T
Committed equivalent dose $H_T(50)$	$H_T(50) = \int_{t_0}^{t_0+50a} \dot{H}_T(t)\,dt$	$\dot{H}_T(t)$ = the equivalent-dose rate in the tissue or organ T at time t t_0 = the time of the intake
Committed effective dose $E(50)$	$E(50) = \sum_T w_T\,H_T(50)$	w_T = the tissue weighting factor for the tissue or organ T $H_T(50)$ = the committed equivalent dose in the tissue or organ T as calculated for a period of 50 years

The unit of absorbed dose and of average absorbed dose is gray (1 Gy = 1 J/kg).

The unit of dose equivalent, equivalent dose, effective dose, committed equivalent dose, and committed effective dose is sievert (1 Sv = 1 J/kg).

The unit of activity is becquerel (1 Bq = 1 s^{-1}).

ST (SS) Guides (1.3.1996)

General Guides

ST 1.2 Application of Maximum Radiation Exposure Values and Monitoring of Radiation Exposure, 10 October 1995 (in English and Finnish)

ST 1.3 Safety Signs Denoting Radiation Sources, 9 April 1992 (in Finnish and Swedish)

ST 1.4 Organization for the Use of Radiation, 24 October 1991 (in English, Finnish and Swedish)

ST 1.5 Maximum Values and Classifications of Radionuclides, 26 November 1991 (in English, Finnish and Swedish)

ST 1.6 Monitoring of Radiation Exposure and Registration of Doses, 10 October 1995 (in English and Finnish)

ST 1.7 Health Surveillance of Persons Engaged in Radiation Work, 19 December 1991 (in English, Finnish and Swedish)

Radiation Therapy

ST 2.1 Quality Assurance for Radiotherapy Equipment, 13 January 1993 (in English, Finnish and Swedish)

SS 2.8 Radiation Protection Requirements for Radiotherapy Equipment and Treatment Rooms. High-Energy Radiotherapy Equipment, 21 December 1989 (in English, Finnish and Swedish)

SS 2.9 Radiation Protection Requirements for Radiotherapy Equipment and Rooms. X-ray Therapy Equipment (25 kV...400 kV), 21 December 1989 (in Finnish and Swedish)

SS 2.10 Radiation Protection Requirements for Radiotherapy Equipment and Rooms. Afterloading Therapy Equipment, 21 December 1989 (in Finnish and Swedish)

Diagnostic Radiology

SS 3.1 Dental X-ray Equipment: Type Inspection and Technical Requirements, 25 February 1987 (in English, Finnish and Swedish)

SS 3.2 Radiation Safety Requirements for Mammographic Equipment, 17 February 1987 (in English, Finnish and Swedish)

ST 3.3 Diagnostic X-ray Equipment and Its Use, 27 August 1992 (in English, Finnish and Swedish)

ST 3.4 Quality Control of Image Intensifier - Television Chains, 24 October 1991 (in English, Finnish and Swedish)

ST 3.5 Quality Control of Diagnostic X-ray Equipment and Film Processing, 3 December 1991 (in English, Finnish and Swedish)

ST 3.6 Radiation Shielding of X-ray Examination Rooms, 20 December 1991 (in English, Finnish and Swedish)

Measurement of Radiation

ST 4.2 Radiation Meters for Civil Defence, 6 June 1991 (in English and Finnish)

Industry, Research, Education and Commerce

ST 5.1 Radiation Safety of Sealed Sources and Equipment Containing Them, 27 August 1992 (in English, Finnish and Swedish)

ST 5.3 Use of Ionizing Radiation in the Teaching of Physics and Chemistry, 14 December 1992 (in English, Finnish and Swedish)

ST 5.4 Trade and Transport of Radiation Sources, 9 June 1995 (in English, Finnish and Swedish)

SS 5.6 Radiation Safety in Industrial Radiography, 6 January 1989 (in English, Finnish and Swedish)

SS 5.8 Installation, Repair and Maintenance of Radiological Equipment Used for Medical Purposes, 28 March 1988 (in English, Finnish and Swedish)

Unsealed Sources and Radioactive Wastes

ST 6.1 Radiation Safety Requirements for Radionuclide Laboratories, 30 May 1991 (in English, Finnish and Swedish)

ST 6.2 Radioactive Wastes and Discharges, 20 December 1991 (in English, Finnish and Swedish)

Non-Ionizing Radiation

SS 9.1 Radiation Safety Requirements and Type Inspection of Solarium Equipment and Sun Lamps, 1 September 1989 (in Finnish and Swedish)

ST 9.2 Radiation Safety of Pulsed Radars, 11 December 1991 (in Finnish)

ST 9.3 Radiation Safety During Work on Masts at FM and TV Stations, 9 April 1992 (in Finnish)

ST 9.4 Radiation Safety of High Power Display Lasers, 8 October 1993 (in Finnish)

Natural Radiation

ST 12.1 Radiation Safety in Mining and Excavation Work, 27 August 1992 (in English, Finnish and Swedish)

ST 12.2 Radioactivity of Construction Materials, Fuel Peat and Peat Ash, 2 February 1993 (in English, Finnish and Swedish)

ST 12.3 Radioactivity of Household Water, 9 August 1993 (in English, Finnish and Swedish)

SS Guides will be replaced by ST Guides when necessary.

Finnish Centre for Radiation and Nuclear Safety
P.O. Box 14, FIN-00881 HELSINKI
FINLAND
Tel. +358 0 759 881