15 Annex - Energy

86. RULEBOOK ON THE IONISING RADIATION EXPOSURE LIMITS

RULEBOOK

ON THE IONISING RADIATION EXPOSURE LIMITS

(Official Gazette of the Socialist Federal Republic of Yugoslavia 32/98)

I BASIC PROVISIONS

Article 1

This Rulebook shall prescribe the exposure limits for persons occupationally exposed to ionising radiation and for the local population.

Article 2

For the purpose of this Rulebook, the expressions used herein shall have the following meaning:

1) Ionising radiation refers to electromagnetic or corpuscular radiation that is able to ionise matter and whose energy is greater than 12.4 eV, i.e. its wavelength is less than 100 nm or its frequency is greater than 3x1015 Hz;

2) Ionising radiation exposure (hereinafter referred to as the “exposure”) represents actions or conditions that cause the irradiation of a human body through ionising radiation;

3) External exposure refers to exposure that occurs as a result of the effects of an ionising radiation source external to the body;

4) Internal exposure refers to exposure that occurs as a result of the effects of a source of ionising radiation internal to the human body;

5) Total exposure refers to the sum of internal and external exposures;

6) Normal exposure refers to exposure that arises in determined conditions involving the application of ionising radiation sources;

7) Potential exposure refers to exposure which can arise from causes of a stochastic nature in certain irregular situations involving the application of ionising radiation sources, and the probability of it arising can be estimated in advance;

8) Occupational exposure refers to the exposure of persons who work with ionising radiation sources or who in their work are located in fields of ionising radiation (occupationally exposed persons);

9) Medical exposure refers to the exposure of patients and persons who help patients during the medical application of ionising radiation sources but who are not occupationally exposed persons, as well as of those persons who participate voluntarily in medical research programmes that involve the application of ionising radiation sources;

10) Public exposure refers to exposure in the event of an emergency and exposure resulting from the approved application of radiation sources, other than medical or occupational exposure and exposure from natural basic level radiation (phon);

11) Acute exposure refers to exposure during an emergency and the post-emergency clean-up;

12) Chronic exposure refers to exposure over a prolonged period of time that is a consequence of previous events or raised levels of ionising radiation in nature;

13) Practice refers to each application of the sources of ionising radiation that contributes to increasing the levels of exposure or the probability of potential exposure;

14) Intervention refers to each human activity undertaken in order to decrease exposure and/or to decrease the probability of potential exposure;

15) The ionising radiation dose refers to the physical quantity that serves as a quantitative measure of the level of exposure to ionising radiation in the manner determined in Annex 1, which accompanies this Rulebook and forms an integral part of this document;

16) The critical group for a given source of ionising radiation refers to a group of individuals from the local population whose irradiation is homogenous and representative for those individuals who receive the highest dose of radiation from the given source;

17) An individual from the local population refers to an individual from the critical group whose exposure (not including medical and occupational) is representative in terms of the verification of compliance with dose limits for the local population;

18) Intake refers to the process of the intake of radionuclides into the body through inhalation, ingestion or through the skin, as well as to the activity of those radionuclides absorbed;

19) The Annual Limit on Intake (ALI) for a given individual refers to the activity of radionuclides whose intake into the body would lead to the expected dose equalling the prescribed dose limits;

20) Radiation detriment refers to the total detriment that can arise in a certain population group and its descendents as a consequence of the population group being exposed to ionising radiation;

21) Risk refers to the probability that an individual will experience a certain detrimental stochastic effect as a result of exposure to ionising radiation;

22) Specially authorised exposure refers to exposure that exceeds the prescribed dose limits and is authorised only in special cases, during normal operations, when alternative procedures that do not cause such exposure cannot be used, i.e. when the technical or organizational possibilities for maintaining exposure within the dose limits do not exist, or when applying such possibilities is not justifiable or optimal;

23) A controlled area refers to a radiation area in which the employment of specific measures of protection and the following of safety procedures is required for the purpose of enabling the control of normal exposure to ionising radiation and preventing the spread of contamination in normal operating conditions, as well as preventing and limiting potential exposure;

24) A supervised area refers to a radiation area that is not designated a controlled area and in which the employment of specific measures of protection and the following of special safety procedures is not required, although the conditions of occupational exposure to ionising radiation are controlled;

25) The basic level of natural radiation (phon) for a given location refers to the total sum of ionising radiation originating from natural sources in the soil and cosmic radiation, up to a level that is not significantly increased by human activities;

26) Limits (limiting values) refer to the values for a radiation quantity that may not be exceeded;

27) Primary limits refer to the limiting values for the equivalent dose, the effective dose and the expected effective dose for the individual exposed;

28) Secondary limits refer to limiting values used instead of primary limits when the latter are not directly applicable;

29) Derived limits refer to the limiting values for radiation quantities that are derived from primary or secondary limits on the basis of standardised models and the use of which ensures that the primary limits are not exceeded;

30) Authorised limits refer to the limiting values for a radiation quantity determined for each source or practice and are lower than the primary, secondary or derived limits;

31) Operative limits refer to the limiting values for a radiation quantity determined by an authorised person for a given task or source that are equal to or lower than the authorised limits;

32) Dose limits refer to the limiting values for the effective dose or the equivalent dose which are absorbed by an individual from controlled practices or the sources of ionising radiation;

33) The reference level refers to the value of a radiation quantity used to determine a special course of action in a given situation;

34) The registration level refers to the value of the equivalent dose, the effective dose or an intake above which the information regarding the level of exposure must be registered and retained;

35) The inspection level refers to the value of the equivalent dose, the effective dose or an intake above which additional analysis is conducted;

36) The intervention level refers to the value of a radiation quantity above which measures must be undertaken aimed at cleaning-up following an emergency and decreasing the level of exposure;

37) Partial dosage limitation refers to the possible limit of the dose of exposure experienced by individuals from a specific source of ionising radiation or an approved practice, which, in the process of optimising protection from radiation arising from sources of ionising radiation, should ensure that the total exposure of individuals within the critical groups from all the controlled sources of ionising radiation and/or approved practices remains within the dose limits;

38) Partial dosage limitation for exposed personnel refers to the dose of individual exposure from each specific source of ionising radiation and/or approved practice and is used for limiting the possible choices when conducting the process of optimisation;

39) Partial dosage limitation for the local population refers to the upper limit of the annual dose for individuals from the local population to which they could be exposed through the planned application of each individual controlled source of ionising radiation.

II EXPOSURE LIMITS FOR OCCUPATIONALLY EXPOSED PERSONS AND THE LOCAL POPULATION

a) Exposure limits for occupationally exposed persons

Article 3

The limit of the effective dose for occupationally exposed persons is 20 mSv per annum, expressed as the average value over a period of five consecutive years, with the additional limitation that in none of the years the effective dose should exceed 50 mSv.

The effective dose limit referred to in paragraph 1 of this Article relates to the sum of the external exposure dose over the defined period of time and the expected effective dose of internal exposure during the same period.

Article 4

The equivalent dose limits for limiting the exposure of individual organs of occupationally exposed persons are as follows:

1) for the lens of the eye 150 mSv per annum;

2) for skin 500 mSv per annum (relating to the equivalent dose averaged over any 1 cm^2 area of the skin, regardless of the size of the area exposed);

3) for extremities (hands, forearms, feet and ankles) 500 mSv per annum.

Article 5

Dose limits for persons over 18 years of age who during their schooling use sources of or work in fields of ionising radiation are equal to the dose limits for occupationally exposed persons.

Article 6

The effective dose limit for persons between the ages of 16 and 18 who use sources of or work in fields of ionising radiation during their schooling is 6 mSv per annum.

The equivalent dose limits for individual organs of persons from paragraph 1 of this Article are as follows:

1) for the lens of the eye 45 mSv per annum;

2) for skin 150 mSv per annum (relating to the equivalent dose averaged over any 1 cm^2 area of the skin, regardless of the size of the area exposed);

3) for extremities (hands, forearms, feet and ankles) 150 mSv per annum.

b) Exposure limits for the local population

Article 7

Dose limits for the local population are verified by dose limits for any one representative individual from the relevant critical group from the local population.

Article 8

The effective dose limit for individuals from the local population is 1 mSv per annum.

The limit referred to in paragraph 1 of this Article relates to the sum of the appropriate doses originating from external exposure over a certain period of time and the expected effective dose from internal exposure during the same period.

However, exception allows that, in the case of an emergency, exceeding the limit stated in paragraph 1 of this Article can be permitted for a single year, whilst ensuring that the average annual level over a period of five consecutive years does not exceed 1 mSv.

Article 9

The equivalent dose limits for limiting the exposure of individual organs of individuals from the local population are as follows:

1) for the lens of the eye 15 mSv per annum;

2) for skin 50 mSv per annum (relating to the equivalent dose averaged over any 1 cm^2 area of the skin, regardless of the size of the area exposed);

3) for extremities (hands, forearm, feet and ankles) 50 mSv per annum.

III EXPOSURE LIMITATION MEASURES

Article 10

No practice can be approved unless its benefit to exposed individuals or society as a whole is greater than the radiation detriment it can cause, i.e. unless it has a positive net benefit with respect to social, economic and other relevant factors.

Article 11

Every practical application of ionising radiation, doses of exposure of individuals, the number of individuals exposed and the probability of the occurrence of potential exposure shall be planned and maintained at as low a level as it is possible to achieve, taking into consideration economic and social factors.

Article 12

Each practice shall ensure that the exposure of individuals is liable to the limiting of the dose and the limiting of potential exposure in normal working conditions, except in cases of specially authorised exposure.

The exposure limits referred to in paragraph 1 of this Article do not apply in the following cases:

1) the exposure of patients during the medical application of radiation sources;

2) the medical exposure of persons helping patients during the medical application of radiation sources;

3) the medical exposure of persons who are involved in medical research programmes on a voluntary basis;

4) exposure during intervention in the event of an emergency;

5) exposure to sources of ionising radiation originating from natural sources other than those cases in which such exposure is considered to be occupational.

Article 13

All interventions must be justified so that the benefit gained by lowering the level of radiation detriment, and/or dose, is greater than the cost of intervention and the detriment it can cause, including any social effects.

Article 14

The type, scope and length of intervention must be optimized in such a way that the maximum net benefit gained through it is achieved.

Article 15

Intervention levels for acute and chronic exposures above which intervention is justified and mandatory are stated in Tables 1 and 2 of Annex 2, which accompanies this Rulebook and forms an integral part of this document.

Article 16

Intervention levels for chronic exposure to radon in apartments are equal to an annual average concentration of 200 Bqm-3 222Rn in the air in newly-built apartments, and 400 Bqm-3 222Rn in the air in existing residential properties.

Intervention levels for chronic exposure to radon in the workplace are equal to an average annual concentration of 1000 Bqm-3 222Rn in the air.

Article 17

Neither the addition of radioactive materials to foodstuffs, toys, personal jewellery, cosmetics and other items of general use nor the activation of such products is permitted.

Article 18

Occupational exposure for persons under the age of 16 is prohibited.

Persons under the age of 18 are prohibited from working in a controlled area, except during training and regular schooling when supervision is mandatory.

a) Measures for limiting the exposure of occupationally exposed persons

Article 19

For the purpose of limiting the exposure of occupationally exposed persons the following measures should be undertaken:

1) an initial assessment of the degree of exposure and radiation risk;

2) the classification of workplaces according to radiation areas (controlled or supervised), on the basis of the estimated annual doses and the predicted frequency and probability of increased exposure;

3) the classification of persons into occupational exposure categories;

4) the application of suitable control measures and of dosimetric measurements of persons and fields in the working environment;

5) the implementation of medical surveillance.

The user of the sources of ionising radiation shall ensure the implementation of the measures referred to in paragraph 1 of this Article, in co-operation with a legal entity authorised to perform measurements for the purpose of assessing the degree of exposure and determining the state of health of occupationally exposed persons.

Article 20

Radiation areas in which ionising radiation sources are used must fulfil the following conditions:

1) they must be clearly and visibly marked by a standardised sign for radioactivity and the following text: DANGER RADIATION, and if there is the need: DANGER CONTAMINATION;

2) the type of ionising radiation source must be marked (name of source, classification, activity, or intensity of dose);

3) clear and visible written instructions about the regime of working with an ionising radiation source must exist;

4) dosimetric monitoring of the work environment must exist.

In addition to satisfying the requirements referred to in paragraph 1 of this Article, each entry into the controlled area shall be controlled and recorded in accordance with the internal written procedures.

Article 21

Occupationally exposed persons are classified into two categories according to working conditions and levels of exposure to ionising radiation, as follows:

1) category A: persons who are professionally employed in a controlled area and those who are liable to receive effective doses greater than 6 mSv per annum or equivalent doses greater than 3/10 of the prescribed dose limits for individual organs for occupationally exposed persons;

2) category B: persons who work professionally or periodically in the supervised area or work periodically in the controlled area.

b) Measures for limiting the exposure of exposed personnel in cases of specially authorised exposure

Article 22

Exceptional exposure above the prescribed limits for exposed personnel can be authorised in exceptional circumstances under normal working conditions when it is not possible to use alternative procedures in order to contain exposure within the prescribed dose limits for occupationally exposed persons.

Exposures referred to in paragraph 1 of this Article must be contained below the limits determined for each individual situation for which exceptional exposure has been authorised.

Article 23

Exposure referred to in Article 22 of this Rulebook may be authorised only for category A occupationally exposed persons, whilst taking into account their age and health.

Exceptional exposure for persons referred to in paragraph 1 of this Article may be authorised for a maximum five-year period.

Article 24

For each specially authorised exposure, the opinion of an authorized legal entity which performs measurements for the purpose of assessing the degree of exposure and which also performs medical surveillance of exposed personnel must be supplied.

The exposure referred to in paragraph 1 of this Article must be justified and the persons involved in such exposure must be informed about the risk such exposure poses and about the measures that are to be undertaken during specially authorised exposure.

Article 25

Specially authorised exposure may not be approved

1) for persons who have received effective or equivalent doses greater than the prescribed dose limits during the previous 12 months;

2) for persons who, because of exceptional events, have received a total dose five times greater than the annual dose limit for occupationally exposed persons;

3) for women of childbearing age

Article 26

The effective dose for an occupationally exposed person for whom exceptional exposure has been authorised cannot be higher than 20 mSv per annum, averaged over a period of 10 consecutive years, and cannot be higher than 50 mSv in any particular year during the same time period.

The conditions under which exceptional exposure has been authorised must be re-assessed if the cumulative dose reaches the level of 100 mSv from the start of the specially authorised exposure.

Article 27

Information on the doses received by occupationally exposed persons during the specially authorised exposure shall be recorded separately and shall be added to the doses for regular personal dosimetric monitoring.

Article 28

Persons for whom exceptional exposure is authorised need not be excluded from regular professional tasks if this is the opinion of the authorised legal entity that conducts medical surveillance of the person.

c) Professional exposure to natural sources of ionising radiation

Article 29

For the purpose of determining the exposure of persons exposed to natural sources of ionising radiation at work, measurements shall be taken in order to assess the level of exposure in working environments where there is a possibility of increased exposure to natural sources of ionising radiation (mines, spas, phosphate-processing plants, the production of construction materials, paints, aeroplane engines, etc.).

Persons referred to in paragraph 1 of this Article are deemed to be occupationally exposed persons if they are exposed to natural ionising radiation above the prescribed limits for the local population.

Article 30

Aircraft crew is deemed to be persons that are occupationally exposed to natural ionising radiation if it is determined in the preliminary assessment of the level of exposure that the exposure level of such persons is above the prescribed limits for the local population.

Exposure of persons referred to in paragraph 1 of this Article shall be limited through the principles and measures that apply to practices.

g) Exposure limitation in the case of an emergency

Article 31

In the case of an emergency, the person who participates in interventions may be exposed above the prescribed limits for exposed personnel only in the following cases:

1) for the purpose of saving people’s lives and preventing severe injuries;

2) for the purpose of preventing the over-exposure of a large number of people;

3) for the purpose of preventing accidents of great or catastrophic proportions.

Persons who participate in interventions referred to in paragraph 1 of this Article shall be in agreement with and professionally trained for such interventions and familiar with the health risks.

Article 32

In those cases referred to in Article 31 paragraph 1 items 2) and 3) of this Rulebook, all safety measures shall be applied so that the doses of exposure of persons participating in interventions are contained below a level that is double the annual limit for occupationally exposed persons.

Exposure doses for persons who participate in saving people's lives shall be contained below a level that is ten times the annual dose limit for occupationally exposed persons.

In exceptions, persons may undertake interventions referred to in paragraph 2 of this Article in which the dose can exceed a value that is ten times that of the dose for occupationally exposed persons only if the benefit gained through the intervention is greater than the personal risk to them.

Article 33

Upon completion of the intervention in an emergency, exposed persons shall be referred for a health check-up and are informed about the doses of total exposure that have been measured and an assessment of the corresponding risk.

IV ESTIMATION OF THE DEGREE OF EXPOSURE TO IONISING RADIATION

Article 34

An estimation of the degree of exposure of exposed personnel shall be made on the basis of the results of monitoring external and internal exposure, following the Methodology given in Annex 3 to this Rulebook, which forms an integral part of this document.

Article 35

The degree of external exposure of category A occupationally exposed persons shall be measured by personal thermoluminescent dosimeters with readings over a one month period.

Article 36

The degree of external exposure of category B occupationally exposed persons shall be assessed on the basis of the results of thermoluminescent dosimeters and corresponding dosimetric measurements in the working environment, operational data, and adopted models.

The reading period of thermoluminescent dosimeters referred to in paragraph 1 of this Article may not be longer than three months.

Article 37

In controlled areas, when the estimated levels of exposure exceed 25 mSv per day, the use of personal electronic dosimeters with direct readings is mandatory.

The person responsible for applying safety measures against ionising radiation distributes dosimeters and records the results.

Article 38

For the purpose of estimating the degree of internal exposure of occupationally exposed persons, the following measurements shall be taken, from which the expected effective dose shall be calculated:

1) direct measurements of the total activity in the body as a whole or in critical organs (the thyroid gland, lungs);

2) measurements of the specific activity of radionuclides in biological samples (urine, blood, smear, saliva).

Article 39

The period of monitoring the level of internal exposure for exposed personnel who deal with open sources of ionising radiation shall be determined by taking into account the biological specificities of the radionuclides with which those persons work and the operational data, as follows:

1) for exposure to tritium **–** measuring the tritium content in 24-hour urine, once in seven days;

2) for exposure to 131I – measuring specific activity in 24-hour urine, once in seven days and measuring thyroid gland activity if the need arises;

3) for exposures to long-lasting gamma emitters **–** check-up once every six months.

As far as radionuclides not mentioned in paragraph 1 of this Article are concerned, the authorized legal person shall recommend a monitoring plan and its dynamics with the specificities of the radionuclide in mind.

Article 40

The degree of internal exposure of persons who work with open sources of ionising radiation shall be estimated by calculating expected effective doses on the basis of the results of measurements referred to in Articles 38 and 39 of this Rulebook.

Article 41

Radiation monitoring in the work and living environment comprises

1) measuring the intensity of the dose, with an indication of the nature and quality of radiation;

2) measuring the concentration of radionuclides in the air and the surface density of the contaminated radioactive matter, with an indication of its nature and its physical and chemical state.

The results of the measurements referred to in paragraphs 1 and 2 of this Article shall be recorded and used to estimate the degree of individual exposure.

Article 42

Compliance with the prescribed dose limits shall be demonstrated by means of comparing the total effective dose with the relevant dose limit, where the total effective dose Et is calculated thus:

$$Et = Hp(d) + \sum_{j} e(g)_{j,ing} I + \sum_{j} e(g)_{j,ing} I_{j,inh}$$

where

Hp(d) is the individual equivalent dose;

e(g)j,ing and *e(g)j,inh* are the expected effective doses per unit-intake for ingested or inhaled radionuclide *j* by an individual in age group *g* – these are given in Attachment 4 to this Rulebook, which forms an integral part of this document;

Ij,ing and *Ij,inh* respectively are the relevant intakes via ingestion or inhaling of the radionuclide.

V FINAL PROVISIONS

Article 43

The Rules governing the limits above which members of the public and persons working with ionising radiation sources shall not be exposed to radiation, and the Rules governing the measuring of the degree of exposure to ionising radiation of persons who work with sources of such radiation, and those governing the analysis of the contamination of the work environment (Official Gazette of the Socialist Federal Republic of Yugoslavia 31/89) shall be repealed on the day of entry into force of this Rulebook.

Article 44

This Rulebook shall enter into force on the eighth day following that of its publication in the Official Gazette of the Federal Republic of Yugoslavia.

Annex 1

DEFINITIONS OF DOSIMETRIC VALUES

1) Absorbed dose, D, of ionising radiation is the quotient of dividing the mean energy, de, imparted by ionising radiation to the matter in a volume element, by the mass, dm, of the matter in this volume element, and is expressed by the formula

$$D = \frac{de}{dm}$$

The SI unit for the absorbed dose is joules per kilogram ($J\ kg^{-1}$), termed the gray (Gy);

1) Unlimited linear energy transfer, L , is given by

$$L = \frac{dE}{dl}$$

where dE is the average loss of energy of an electrified energy particle E, whilst traversing the distance dl. In the text of this Rulebook, it is denoted by L.

8) The quality factor, Q, is a function of linear energy transfer L which expresses the different quality of individual types of ionising radiation with regard to the appearance of stochastic effects.

9) The effective quality factor, Q, is the mean value of the quality factor when the absorbed dose is imparted to particles with different linear transfer of energy L**,** and is calculated according to the formula

$$L_{\infty} = \frac{1}{D}\int_{0}^{\infty} Q(L) D_1 \, dL$$

10) The equivalent dose of ionising radiation, H t,r, is the product of the mean absorbed dose, *D* T, R, in tissue or an organ, *T*, which is delivered by type R radiation, and the corresponding radiation weighting factor, wR, for type R radiation, is expressed by the formula

$$H_{T,R} = D_{T,R}\, w_R$$

When the radiation field comprises several types of radiation with different radiation weighting factors, the equivalent dose is the sum of all the equivalent doses of the individual types of radiation, as follows:

Ht = :*wR*D*TR*
R

The SI unit for equivalent dose is joules per kilogram ($J\ kg^{-1}$) and is termed the sievert (*Sv*).

11) The radiation weighting factor, *WR*, is a dimensionless factor used to express the difference in the biological effects of different types of ionising radiation. The values of radiation weighting factors for various radiation types and energies are presented in the following table:

Values of radiation weighting factors

Radiation type and energy range	Radiation weighting factor, WR
Photons, of all energies	1
Electrons and muons, of all energies[1]	1
Neutrons, of energies < 10 keV	5

Neutrons, of energies from 10 to 100 keV	10
Neutrons 100 keV to 2 MeV	20
Neutrons 2 to 20 MeV	10
Neutrons, of energies > 20 MeV	5
Protons, other than recoil protons, of energy > 2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

[1]Excluding Auger electrons, emitted from nuclei bound to DNA, for which separate micro-dosimetric considerations are applied.

When the use of a continual function for the calculation of the radiation weighting factor of neutrons is required, the following approximation can be used:

$$W_R = 5 + 17e^{-(\ln(2E))^{2/6}}$$

in which E is the neutron energy in *MeV*.

For types of radiation and energies not presented in Table 1, it can be assumed that the radiation weighting factor, *wR*, is equal to the effective quality factor, Q, at a depth of 10 mm in a tissue-equivalent (ICRU) sphere that is 30 cm in diameter, has a density of 1 g cm^{-3}, and a mass composition of 76.2 % oxygen, 11.1% carbon, 10.1% hydrogen and 2.6 % nitrogen, as follows:

$$\bar{Q} = \frac{1}{D}\int_0^\infty Q(L) D_L \, dL$$

where *D* is the absorbed dose at a depth of 10 mm in an *ICRU* sphere, *Q(L)* is a quality factor as a function of the unlimited linear energy transfer *L* in water at a depth of 10 mm, and *DL* is the distribution of the absorbed dose in *L*.

The relation *Q(L)* between the unlimited linear energy transfer *L* and the quality factor *Q,* is given by the equation

Q(L)=1 *L*10
Q(L)=0,32**L* - 2,2 10<*L*<100

300
Q(L) = ------------ *L* B 100
·/SPAN>L

where *L* is expressed in keV mm^{-1}.

12) The effective dose, *E*, is the sum of the product of the equivalent dose, *HT*, in tissue or an organ, *T*, and the appropriate tissue weighting factor, *wT*, over all the exposed tissue/organs of the body, and is given by the formula

E = :wHt= :wt " :wR " DTR
T T R

The SI unit for the effective dose is joules per kilogram (J"kg^{-1}), termed the sievert (*Sv*).

13) The tissue weighting factor, *wT*, is a dimensionless factor used in protection against ionising radiation in order to enable the consideration of the varying sensitivity of individual organs and tissues to the induction of the stochastic effects of ionising radiation effects.

Values of tissue weighting factors are given in the table below:

Values of tissue weighting factors

Tissue or organ	wT
Ovaries or testicles (gonads)	0.20
Red bone marrow	0.12
Colon	0.12
Lungs	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid gland	0.05
Skin	0.01
Bones	0.01
Remainder	0.05

a The tissue weighting factor for the colon is applied to the mean equivalent dose, according to mass, in the walls of the upper and the lower intestines.

b The category ‘Remainder’ encompasses the adrenal glands, the brain, the extrathoracic region, the small intestine, kidneys, muscle tissue, the pancreas, the spleen, the thymus and the uterus. In exceptional cases, when only one tissue or organ from the Remainder category is exposed to radiation to a much greater degree than other tissues and organs, the value of the tissue weighting factor for such tissues or organs is 0.025, while it is 0.025 for other tissues and organs belonging to this category.

14) The expected absorbed dose is the absorbed dose received by a particular tissue or organ during a certain time period after intake. When the time period is not explicitly stated, it is taken to be 50 years for adults, and to age 70 years for the intake of radioactive materials into children’s bodies. The amount of the expected absorbed dose is given by the formula

$$D(\tau) = \int_{t_0}^{t_0+\tau} D(t)\,dt$$

where *t0* is the time of the intake of radioactive material into the body and *D(t)* is the intensity of the absorbed dose in an individual tissue or organ at moment *t*.

The SI unit for the prospective absorbed dose is joules per kilogram ($J\ kg^{-1}$), termed the gray (Gy).

15) The expected equivalent dose, *HT(t),* in tissue or organ *T* is the equivalent dose received by a particular tissue or an organ during a certain time period following intake. When the time period is not explicitly stated, it is taken to be 50 years for adults, and to age 70 years for the intake of radioactive materials into children’s bodies. The value of the expected equivalent dose is expressed by the formula

$$Ht(\tau)= \int_{t_0}^{t_0+\tau} Ht(t)dt$$

where *t0* is the time of the intake of radioactive material into the body, and *HT(t)* is the intensity of the equivalent dose in tissue or organ *T* at moment *t*.

The SI unit for the expected equivalent dose is joules per kilogram (J"kg^{-1}), termed the sievert (*Sv*);

16) The expected effective dose, *E(t)*, is the sum in all the exposed tissues and organs of the products of the tissue weighting factors and the expected equivalent doses in each exposed tissue or organ,

$$E(t) = \sum_{T} Wt \cdot Ht(t)$$

where *HT(t)* is the expected equivalent dose in tissue or organ *T* at time *t*.

The *S*I unit for the expected effective dose is joules per kilogram (J"kg^{-1}), termed the sievert (*Sv*);

17) The collective effective dose, *S*, is the total effective dose for the local population or a certain population group and is defined by the equation

$$S = \sum_{i} Ei \cdot Ni$$

where *Ni* is the number of individuals in such a group and *Ei* is the average effective dose.

The collective effective dose can also be defined as an integral

$$S = \int_{0}^{x} E \cdot \frac{dN}{dE} \cdot dE$$

where $\frac{dN}{dE}\,dE$ is the number of individuals who received the effective dose between the interval *E* and *E* + *dE*.

The unit for the collective effective dose is man sievert (man Sv);

Annex 2

Table 1 Intervention levels for acute exposures of organs and tissues

Organ or tissue	Projected absorbed dose for an organ or tissue in less than two days (Gy)
Whole body (bone marrow)	1
Lungs	6
Skin	3
Thyroid	5
Eye lens	2
Gonads	3

Table 2 Intervention levels of the equivalent dose intensity for chronic exposures

Organ or tissue	Equivalent dose intensity (Gy per annum)
Gonads	0.2
Eye lens	0.1
Bone marrow	0.4

Annex 3

METHODOLOGY FOR ESTIMATING THE LEVEL OF EXPOSURE TO IONISING RADIATION

I ESTIMATION OF EXPOSURE LEVEL FOR OCCUPATIONALLY EXPOSED PERSONS

a) X-ray diagnostics

1. The degree of exposure to ionising radiation for persons who, as part of their occupation, handle diagnostic x-ray machines used in diagnostic procedures involving x-ray radiation shall be determined in the cases of imaging and illumination.

2. Measurements shall be taken at least once a year and/or after each time the x-ray tube is replaced or work has been done on the high-voltage generator and other parts (photo-timer, automatic exposure control devices).

3. Measurements shall be taken by dosimeters whose response time is in accordance with the exposure time, and phantoms. The dimensions of phantoms and their composition should be as follows:

- for diagnostic procedures: a 20 x 20 x 15 cm water phantom,

- for breast x-rays: a 15 x 15 x 5 cm Plexiglas phantom;

- for dental x-rays: a cylindrical-shaped water phantom, with a volume of 5l and 15 cm in diameter;

- for computer tomography: a special phantom.

4. The measurement results, as well as other vital statistical data, shall be retained by authorized persons even after the dismantling of the x-ray machine.

The estimation of the exposure of exposed personnel shall be based on the measurements of the absorbed dose of x-ray radiation or the intensity of the absorbed dose in the air covering the distance between the focus radiation tube and the head (chest, gonads, hands) of persons whose work involves the application of the least favourable conditions in terms of the loading factor (filming the lumbar region of the spine, the filming of the neck region of the spine on the stand, etc.)

In circumstances involving illumination, a high voltage x-ray tube of 90 kV is required and an anode current of 3 mA.

Measurements must also be undertaken in circumstances involving targeted x-raying of the stomach with the application of the highest values of loading factor that are used on a given appliance. A 20x20x15 cm water phantom must be used.

The determination of the exposure of occupationally exposed workers and other persons who are in adjacent premises, patients in waiting rooms and cubicles, shall be undertaken under the same working conditions 1m away from the surface of the wall, door or windows.

On the basis of the dosimetric measurements performed and the number of diagnostic procedures undertaken by the exposed personnel during a one-month period, the value of the absorbed dose in the air where they are stationed shall be determined and the result shall be compared with the personal dosimetry data.

b) Nuclear medicine

6. An estimation of the level of exposure for occupationally exposed persons in nuclear medicine shall be made on the basis of the results of measurements of contamination and radiation levels in the work environment in all occupational processes in those places where persons are present for the most length of time, the results of personal dosimetric monitoring, and the results of internal contamination if the need arises. The total effective dose shall be estimated on the basis of the values gained.

c) Radiotherapy

7. An estimation of the level of exposure of occupationally exposed persons shall be made through the prescribed measuring of the level of radiation in those places where persons are present for the most length of time during each individual therapeutic process.

d) Radiography control

8. An estimation of the level of exposure to ionising radiation of occupationally exposed persons shall be made on the basis of

1) the measurement of the intensity of exposure in places where those persons can spend time during the conducting of radiography, where the conditions are those of average activity of the radiographic source, i.e. of nominal values of the anode voltage and the electricity of industrial x-ray apparatus;

2) data on the length of stay of those persons in such places;

3) a calculation using the appropriate model.

The results acquired are compared to the results of personal thermoluminescent dosimeter readings and the readings of electronic dosimeters with direct readings.

The estimation from Paragraph 1 of this Article is made prior to the issuance of a permit for the use of each new radiation source and at least once a year during its usage.

d) Other non-medical applications of radiation sources

9. The degree of exposure of professionally exposed persons who work with closed ionising radiation sources in industry, agriculture, mining, geology, research, education and other non-medical applications, is evaluated on the basis of the following:

1) a measurement of the dose intensity in those places where such persons can spend time during the operation of the appliance;

2) data on the amount of time such persons spend in such places;

3) a calculation using the appropriate model.

The measuring referred to in paragraph 1 of this Article shall be conducted under conditions of an open and closed useful radiation beam.

The results acquired shall be compared to the results of personal dosimetry.

The estimation referred to in paragraph 1 of this Article shall be made prior to the issuance of a permit for the use of each new radiation source, prior to each alteration in the usage regime and after each repair, and at least once a year during its usage.

II ESTIMATION OF THE LEVEL OF PATIENT EXPOSURE

a) X-ray diagnostics

10. For the estimation of the irradiation of patients, it is necessary to determine the value of mGy/mAs for the following values of the high-voltage x-ray tube: 60, 70, 80, 90, 100, and 110 kV. Measurements shall be performed in the presence of a patient of standard body mass and size. If the measurement is performed in the absence of a phantom or a patient, it is necessary to make a correction to the value of a return dissipation.

The results shall be used for determining the equivalent doses, i.e. the effective dose of radiation for a particular patient and a given diagnostic procedure.

The distance between the focus x-ray tube and the radiation detector must be 100 cm.

11. In circumstances involving illumination, it is necessary to perform the measurements of the absorbed dose of radiation, the intensity of the absorbed dose of radiation, or the product of the dose and the surface area, through the high-voltage X-ray tube of 90 kV and an anode current of 3 mA.

The measuring shall be performed across the distance between the focus x-ray tube and the back wall of the patient carrier (in the case that the x-ray tube is placed under the patient carrier), i.e. between the focus x-ray tube and the patient carrier at a distance of 115 cm.

12. Determining the degree of exposure of patients during dental x-raying shall be conducted through thermoluminescent dosimeters on a patient at the height of the sternum and gonads, or through a radiation detection device if a water phantom is used.

b) Nuclear medicine

An estimation of the level of patient exposure shall be made for every diagnostic and therapeutic procedure that involves radiopharmaceutics through the application of the standard MIRD technology.

c) Radiotherapy

An estimation of the level of patient exposure shall be made for every individual therapeutic procedure through the application of standard ICRU methodology.

III ESTIMATION OF THE LEVEL OF PUBLIC EXPOSURE

a) Radioactive lightning conductors and ionising smoke detectors

15. An estimation of the degree of exposure (of groups) of the local population from radioactive lightning conductors and ionising smoke detectors shall be made on the basis of the following:

1) measuring the intensity of exposure in the area surrounding these devices, in places where individuals and whole sections of population can reside;

2) data on the average time individuals from the local population spend in such places;

3) a calculation using the appropriate model.

The estimation referred to in paragraph 1 of this Article shall be made at least once a year during its usage.

Annex 4

EXPECTED EFFECTIVE DOSE PER UNIT-INTAKE e(g) THROUGH INHALATION AND INGESTION (Sv"Bq-1) FOR OCCUPATIONALLY EXPOSED PERSONS

Nuclide	Half-life	INHALATION				INGESTION	
		Type	f1	e(g)1mm	e(g)5mm	f1	e(g)
1	2	3	4	5	6	7	8
HYDROGEN							
Tritiated water	12.3 g					1.000	1.810-11
Organically bound tritium	12.3g					1.000	4.210-11
BERYLLIUM							
7Be	53.3 d	M	0.005	4.810-11	4.310-11	0.005	2.810-11
		S	0.005	5.210-11	4.610-11		
10Be	1.60106 g	M	0.005	9.110-9	6.710-9	0.005	1.110-9
		S	0.005	3.210-8	1.910-8		
CARBON							
11C	0.340 h					1.000	2.410-11
14C	5.73103 g					1.000	5.810-10
FLUORINE							
18F	1.83 h	F	1.000	3.010-11	5.410-11	1.000	4.910-11
		M	1.000	5.710-11	8.910-11		
		S	1.000	6.010-11	9.310-11		
SODIUM							
22Na	2.60 g	F	1.000	1.310-9	2.010-9	1.000	3.210-9
24Na	15.0 h	F	1.000	2.910-10	5.310-10	1.000	4.310-10
MAGNESIUM							
28Mg	20.9 h	F	0.500	6.410-10	1.110-9	0.500	2.210-9
		M	0.500	1.210-9	1.710-9		

ALUMINIUM							
26Al	7.16105 g	F	0.010	1.110-8	1.410-8	0.010	3.510-9
		M	0.010	1.810-8	1.210-8		
SILICON							
31Si	2.62 h	F	0.010	2.910-11	5.110-11	0.010	1.610-10
		M	0.010	7.510-11	1.110-10		
		S	0.010	8.010-11	1.110-10		
32Si	4.50102 g	F	0.010	3.210-9	3.710-9	0.010	5.610-10
		M	0.010	1.510-8	9.610-9		
		S	0.010	1.110-7	5.510-8		
PHOSPHORUS							
32P	14.3 d	F	0.800	8.010-10	1.110-9	0.800	2.410-9
		M	0.800	3.210-9	2.910-9		
33P	25.4 d	F	0.800	9.610-11	1.410-10	0.800	2.410-10
		M	0.800	1.410-9	1.310-9		
SULPHUR							
35S (non-organic)	87.4 d	F	0.800	5.310-11	8.010-11	0.800	1.410-10
		M	0.800	1.310-9	1.110-9	0.100	1.910-10
35S (organic)	87.4 d					1.000	7.710-10
CHLORINE							
36Cl	3.01105 g	F	1.000	3.410-10	4.910-10	1.000	9.310-10
		M	1.000	6.910-9	5.110-9		
38Cl	0.620 h	F	1.000	2.710-11	4.610-11	1.000	1.210-10
		M	1.000	4.710-11	7.310-11		
39Cl	0.927 h	F	1.000	2.710-11	4.810-11	1.000	8.510-11
		M	1.000	4.810-11	7.610-11		
POTASSIUM							
40K	1.28109 g	F	1.000	2.110-9	3.1010-9	1.000	6.210-9
42K	12.4 h	F	1.000	1.310-10	2.010-10	1.000	4.310-10
43K	22.6 h	F	1.000	1.510-10	2.610-10	1.000	2.510-10

44K	0.369 h	F	1.000	2.110-11	3.710-11	1.000	8.410-11
45K	0.333 h	F	1.000	1.610-11	2.810-11	1.000	5.410-11
CALCIUM							
41Ca	1.40105g	M	0.300	1.710-10	1.910-10	0.300	2.910-10
45Ca	163 d	M	0.300	2.710-9	2.310-9	0.300	7.610-10
47Ca	4.53 d	M	0.300	1.810-9	2.110-9	0.300	1.610-9
SCANDIUM							
43Sc	3.89 h	S	1.010-4	1.210-10	1.810-10	1.010-4	1.910-10
44Sc	3.93 h	S	1.010-4	1.910-10	3.010-10	1.010-4	3.510-10
44mSc	2.44 h	S	1.010-4	1.510-9	2.010-9	1.010-4	2.410-9
46Sc	83.8 d	S	1.010-4	6.410-9	4.810-9	1.010-4	1.510-9
47Sc	3.35 d	S	1.010-4	7.010-10	7.310-10	1.010-4	5.410-10
48Sc	1.82 d	S	1.010-4	1.110-9	1.610-9	1.010-4	1.710-9
49Sc	0.956 h	S	1.010-4	4.110-11	6.110-11	1.010-4	8.210-11
TITANIUM							
44Ti	47.3 g	F	0.010	6.110-8	7.210-8	0.010	5.810-9
		M	0.010	4.010-8	2.710-8		
		S	0.010	1.210-7	6.210-8		
45Ti	3.08 h	F	0.010	4.610-11	8.310-11	0.010	1.510-10
		M	0.010	9.110-11	1.410-10		
		S	0.010	9.610-11	1.510-10		
VANADIUM							
47V	0.543 h	F	0.010	1.910-11	3.210-11	0.010	6.310-11
		M	0.010	3.110-11	5.010-11		
48V	16.2 d	F	0.010	1.110-9	1.710-9	0.010	2.010-9
		M	0.010	2.310-9	2.710-9		
49V	330 d	F	0.010	2.110-11	2.610-11	0.010	1.810-11
		M	0.010	3.210-11	2.310-11		
CHROMIUM							
48Cr	23.0 h	F	0.100	1.010-10	1.710-10	0.100	2.010-10

		M	0.100	2.010-10	2.310-10	0.010	2.010-10
		S	0.100	2.210-10	2.510-10		
49Cr	16.2 d	F	0.100	2.010-11	3.510-11	0.100	6.110-11
		M	0.100	3.510-11	5.610-11	0.010	6.110-11
		S	0.100	3.710-11	5.910-11		
51Cr	330 d	F	0.100	2.110-11	3.010-11	0.100	3.810-11
		M	0.100	3.110-11	3.410-11	0.010	3.710-11
		S	0.100	3.610-11	3.610-11		
MANGANESE							
51Mn	0.770 h	F	0.100	2.410-11	4.210-11	0.100	9.310-11
		M	0.100	4.310-11	6.810-11		
52Mn	5.59 d	F	0.100	9.910-10	1.610-9	0.100	1.810-9
		M	0.100	1.410-9	1.810-9		
52mMn	0.352 h	F	0.100	2.010-11	3.510-11	0.100	6.910-11
		M	0.100	3.010-11	5.010-11		
53Mn	3.70106 g	F	0.100	2.910-11	3.610-11	0.100	3.010-11
		M	0.100	5.210-11	3.610-11		
54Mn	312 d	F	0.100	8.710-10	1.110-9	0.100	7.110-10
		M	0.100	1.510-9	1.210-9		
56Mn	2.58 h	F	0.100	6.910-11	1.210-10	0.100	2.510-10
		M	0.100	1.310-10	2.010-10		
IRON							
52Fe	8.28 h	F	0.100	4.110-10	6.910-10	0.100	1.410-9
		M	0.100	6.310-10	9.510-10		
55Fe	2.70 g	F	0.100	7.710-10	9.210-10	0.100	3.310-10
		M	0.100	3.710-10	3.310-10		
59Fe	44.5 d	F	0.100	2.210-9	3.010-9	0.100	1.810-9
		M	0.100	3.510-9	3.210-9		
60Fe	1.00105 g	F	0.100	2.810-7	3.310-7	0.100	1.110-7
		M	0.100	1.310-7	1.210-7		
COBALT							
55Co	17.5 h	M	0.100	5.110-10	7.810-10	0.100	1.010-9

		S	0.050	5.510-10	8.310-10	0.050	1.110-9
56Co	78.7 d	M	0.100	4.610-9	4.010-9	0.100	2.510-9
		S	0.050	6.310-9	4.910-9	0.050	2.310-9
57Co	271 d	M	0.100	5.210-10	3.910-10	0.100	2.110-10
		S	0.050	9.410-10	6.010-10	0.050	1.910-10
58Co	70.8 d	M	0.100	1.510-9	1.410-9	0.100	7.410-10
		S	0.050	2.010-9	1.710-9	0.050	7.010-10
58mCo	9.15 h	M	0.100	1.310-11	1.510-11	0.100	2.410-11
		S	0.050	1.610-11	1.710-11	0.050	2.410-11
60Co	5.27 g	M	0.100	9.610-9	7.110-9	0.100	3.410-9
		S	0.050	2.910-8	1.710-8	0.050	2.510-9
60mCo	0.174 h	M	0.100	1.110-12	1.210-12	0.100	1.710-12
		S	0.050	1.310-12	1.210-12	0.050	1.710-12
61Co	1.65 h	M	0.100	4.810-11	7.110-11	0.100	7.410-11
		S	0.050	5.110-11	7.510-11	0.050	7.410-11
62mCo	0.232 h	M	0.100	2.110-11	3.610-11	0.100	4.710-11
		S	0.050	2.210-11	3.710-11	0.050	4.710-11
NICKEL							
56Ni	6.10 d	F	0.050	5.110-10	7.910-10	0.050	8.610-10
		M	0.050	8.610-10	9.610-10		
57Ni	1.50 d	F	0.050	2.810-10	5.010-10	0.050	8.710-10
		M	0.050	5.110-10	7.610-10		
59Ni	7.50104 g	F	0.050	1.810-10	2.210-10	0.050	6.310-11
		M	0.050	1.310-10	9.410-10		
63Ni	96.0 g	F	0.050	4.410-10	5.210-10	0.050	1.510-10
		M	0.050	4.410-10	3.110-10		
65Ni	2.52 h	F	0.050	4.410-11	7.510-11	0.050	1.810-10
		M	0.050	8.710-11	1.310-10		
66Ni	2.27 d	F	0.050	4.510-10	7.610-10	0.050	3.010-9
		M	0.050	1.610-9	1.910-9		
COPPER							
60Cu	0.387 h	F	0.500	2.410-11	4.410-11	0.500	7.010-11
		M	0.500	3.510-11	6.010-11		
		S	0.500	3.610-11	6.210-11		

61Cu	3.41 h	F	0.500	4.010-11	7.310-11	0.500	1.210-10
		M	0.500	7.610-11	1.210-10		
		S	0.500	8.010-11	1.210-10		
64Cu	12.7 h	F	0.500	4.410-10	5.210-10	0.500	5.210-10
		M	0.500	4.410-10	3.110-10		
		S	0.500	4.410-11	7.510-11		
67Cu	2.58 d	F	0.500	8.710-11	1.310-10	0.500	1.310-10
		M	0.500	4.510-10	7.610-10		
		S	0.500	1.610-9	1.910-9		
ZINC							
62Zn	9.26 h	S	0.500	4.710-10	6.610-10	0.500	9.410-10
63Zn	0.635 h	S	0.500	3.810-11	6.110-11	0.500	7.910-11
65Zn	244 d	S	0.500	2.910-9	2.810-9	0.500	3.910-9
69Zn	0.950 h	S	0.500	2.810-11	4.310-11	0.500	3.110-11
69mZn	13.8 h	S	0.500	2.610-10	3.310-10	0.500	3.310-10
71Zn	3.92 h	S	0.500	1.610-10	2.410-10	0.500	2.410-10
72Zn	1.94 d	S	0.500	1.210-9	1.510-9	0.500	1.410-9

The estimation from Paragraph 1 of this Article is made prior to the issuance of a permit for the use of each new radiation source and at least once a year during its usage................. 17