

SUMMARY OF RECOMMENDATIONS

This summary contains the principal recommendations and new concepts in the 1990 Recommendations of the Commission. Explanatory material is omitted. The order of the summary follows that of the Main Text of the recommendations.

Introduction

(S1) The Recommendations are intended to be of help to regulatory and advisory agencies and to management bodies and their professional staff. They deal only with ionising radiation and with the protection of man. The Commission emphasises that ionising radiation needs to be treated with care rather than fear and that its risks should be kept in perspective with other risks. Radiological protection cannot be conducted on the basis of scientific considerations alone. All those concerned have to make value judgements about the relative importance of different kinds of risk and about the balancing of risks and benefits.

Quantities Used in Radiological Protection

(S2) The Commission uses macroscopic dosimetric quantities while recognising that microdosimetric quantities based on the statistical distribution of events in a small volume of material may eventually be more appropriate. The principal dosimetric quantities in radiological protection are the mean absorbed dose in a tissue or organ, D_T , the energy absorbed per unit mass; the equivalent dose in a tissue or organ, H_T , formed by weighting the absorbed dose by the radiation weighting factor, w_R ; and the effective dose, E , formed by weighting the equivalent dose by the tissue weighting factor, w_T , and summing over the tissues. The time integral of the effective-dose rate following an intake of a radionuclide is called the committed effective dose, $E(\tau)$, where τ is the integration time (in years) following the intake. The unit of absorbed dose is the gray (Gy), and the unit of both equivalent and effective dose is the sievert (Sv). The values of the radiation and tissue weighting factors are given in Tables S-1 and S-2.

(S3) Another useful quantity is the collective effective dose, which is the product of the mean effective dose in a group and the number of individuals in that group. With some reservations, it can be thought of as representing the total consequences of the exposure of a population or group.

(S4) The Commission uses "dose" as a generic term that can apply to any of the relevant dosimetric quantities. The Commission also uses the term "exposure" in a generic sense to mean the process of being exposed to radiation or radioactive material. The significance of an exposure in this sense is determined by the resulting doses.

Biological Aspects of Radiological Protection

(S5) Ionising radiation causes both deterministic and stochastic effects in irradiated tissue. Radiological protection aims at avoiding deterministic effects by setting dose limits below their thresholds. Stochastic effects are believed to occur, albeit with low frequency, even at the lowest doses and therefore have been taken into account at all doses.

Table S-1. Radiation weighting factors¹

Type and energy range ²	Radiation weighting factor, w_R
Photons, all energies	1
Electrons and muons, all energies ³	1
Neutrons, energy < 10 keV	5
10 keV to 100 keV	10
> 100 keV to 2 MeV	20
> 2 MeV to 20 MeV	10
> 20 MeV	5
(See also Figure 1)	
Protons, other than recoil protons, energy > 2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

¹ All values relate to the radiation incident on the body or, for internal sources, emitted from the source.

² The choice of values for other radiations is discussed in Annex A.

³ Excluding Auger electrons emitted from nuclei bound to DNA (see paragraph 26).

Table S-2. Tissue weighting factors¹

Tissue or organ	Tissue weighting factor, 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 ^{2,3}

¹ The values have been developed from a reference population of equal numbers of both sexes and a wide range of ages. In the definition of effective dose they apply to workers, to the whole population, and to either sex.

² For purposes of calculation, the remainder is composed of the following additional tissues and organs: adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus. The list includes organs which are likely to be selectively irradiated. Some organs in the list are known to be susceptible to cancer induction. If other tissues and organs subsequently become identified as having a significant risk of induced cancer they will then be included either with a specific w_T or in this additional list constituting the remainder. The latter may also include other tissues or organs selectively irradiated.

³ In those exceptional cases in which a single one of the remainder tissues or organs receives an equivalent dose in excess of the highest dose in any of the twelve organs for which a weighting factor is specified, a weighting factor of 0.025 should be applied to that tissue or organ and a weighting factor of 0.025 to the average dose in the rest of the remainder as defined above.

(S6) Deterministic effects result from the killing of cells which, if the dose is large enough, causes sufficient cell loss to impair the function of the tissue. The probability of causing such harm will be zero at small doses, but above some level of dose (the threshold for clinical effect) the probability will increase steeply to unity (100%). Above the threshold, the severity of the harm will increase with dose. Thresholds for these effects are often at doses of a few Gy or dose rates of a fraction of a Gy per year.

(S7) An important observation in children exposed in utero during a critical 8–15 week period, at Hiroshima and Nagasaki, is a downward shift in the distribution of IQ with increasing dose which can result, after higher doses, in an increase in the probability of severe mental retardation. The effect is presumed to be deterministic with a threshold related to the minimum shift in IQ that can be recognised.

(S8) Stochastic effects may result when an irradiated cell is modified rather than killed. Modified somatic cells may subsequently, after a prolonged delay, develop into a cancer. There are repair and defence mechanisms that make this a very improbable outcome. Nevertheless, the probability of a cancer resulting from radiation increases with increments of dose, probably with no threshold. The severity of the cancer is not affected by the dose. If the damage occurs in a cell whose function is to transmit genetic information to later generations, any resulting effects, which may be of many different kinds and severity, are expressed in the progeny of the exposed person. This type of stochastic effect is called “hereditary”.

(S9) The Commission has estimated the probability of a fatal cancer by relying mainly on studies of the Japanese survivors of the atomic bombs and their assessment by bodies such as UNSCEAR and BEIR. These committees have estimated the lifetime cancer risk by considering the accumulated data to 1985, the new dosimetry (DS86) and projection to lifetime by a multiplicative or modified multiplicative model, for high dose, high dose rate exposure. The Commission has concluded, after reviewing the available experimental information on dose–response relationships and the influence of dose and dose rate, that the most probable response is linear quadratic in form for low LET radiation. The linear coefficient at low doses or low dose rates is obtained from the high dose, high dose rate estimates of risk by dividing by a DDREF (dose and dose rate effectiveness factor) of 2. The nominal fatal cancer probabilities for a working population and for a general population, which differ somewhat because of the greater sensitivity of young people, are given in Table S-3. The Commission has made its own estimates of how this fatal cancer risk is distributed among organs and the length of life lost for cancer in each of these organs, by further analysis of the data on the atomic bomb survivors.

(S10) The estimates of severe hereditary effects are also based on the assessments of UNSCEAR and BEIR of experimental data on genetic effects in animals. Evidence suggests that these estimates are not less than the corresponding effects in man. For low dose and dose rates, the probability coefficient for severe hereditary effects in all generations (resulting about equally from dominant and X-linked mutations on the one hand, and multifactorial diseases weighted for severity on the other) are given for both a working population and a general population in Table S-3.

(S11) The Commission uses the term detriment to represent the combination of the probability of occurrence of a harmful health effect and a judgement of the severity of that effect. The many aspects of detriment make it undesirable to select a single quantity to represent the detriment and the Commission has therefore adopted a multi-dimensional concept. The principal components of detriment are the following stochastic quantities: the probability of attributable fatal cancer, the weighted probability of

Table S-3. Nominal probability coefficients for stochastic effects

Exposed population	Detriment (10^{-2} Sv^{-1}) ¹			Total
	Fatal cancer ²	Non-fatal cancer	Severe hereditary effects	
Adult workers	4.0	0.8	0.8	5.6
Whole population	5.0	1.0	1.3	7.3

¹ Rounded values.

² For fatal cancer, the detriment is equal to the probability coefficient.

attributable non-fatal cancer, the weighted probability of severe hereditary effects and the length of life lost if the harm occurs. The values of this aggregated detriment at low dose for both a working population and a general population are also given in Table S-3.

(S12) The Commission has also assessed the distribution of the detriment in organs and tissues by considering first the fatal cancer probability in each of them, multiplying by an appropriate factor for non-fatal cancer (which is determined by the severity (lethality factor) for that cancer), adding in the probability of severe hereditary effects and adjusting for the relative length of life lost. This distribution of aggregate detriment among organs is represented, after appropriate rounding, by the tissue weighting factors, w_T , given in Table S-2.

(S13) The effective dose is the sum of the weighted equivalent doses in all the tissues and organs of the body. It is given by the expression

$$E = \sum_T w_T \cdot H_T$$

where H_T is the equivalent dose in tissue or organ T and w_T is the weighting factor for tissue T. The effective dose can also be expressed as the sum of the doubly weighted absorbed dose in all the tissues and organs of the body.

The Conceptual Framework of Radiological Protection

(S14) A system of radiological protection should aim to do more good than harm, should call for protection arrangements that maximise the net benefit, and should aim to limit the inequity that may arise from a conflict of interest between individuals and society as a whole.

(S15) Some human activities increase the overall exposure to radiation. The Commission calls these human activities "practices". Other human activities can decrease the overall exposure by influencing the existing causes of exposure. The Commission describes these activities as "intervention".

(S16) The Commission uses a division into three types of exposure: occupational exposure, which is the exposure incurred at work, and principally as a result of work; medical exposure, which is principally the exposure of persons as part of their diagnosis or treatment; and public exposure, which comprises all other exposures.

(S17) In practices and in intervention, it will often be virtually certain that exposures will occur and their magnitude will be predictable, albeit with some degree of error. Sometimes, however, there will be a potential for exposure, but no certainty that it will occur. The Commission calls such exposures "potential exposures".

The system of protection in practices

(S18) The system of radiological protection recommended by the Commission for proposed and continuing practices is based on the following general principles.

- (a) No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. (The justification of a practice.)
- (b) In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account. This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgements. (The optimisation of protection.)
- (c) The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures. These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances. Not all sources are susceptible of control by action at the source and it is necessary to specify the sources to be included as relevant before selecting a dose limit. (Individual dose and risk limits.)

The system of protection in intervention

(S19) The system of radiological protection recommended by the Commission for intervention is based on the following general principles.

- (a) The proposed intervention should do more good than harm, i.e. the reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social costs, of the intervention.
- (b) The form, scale, and duration of the intervention should be optimised so that the net benefit of the reduction of dose, i.e. the benefit of the reduction in radiation detriment, less the detriment associated with the intervention, should be maximised.

Dose limits do not apply in the case of intervention. Principles (a) and (b) can lead to intervention levels which give guidance to the situations in which intervention is appropriate. There will be some level of projected dose above which, because of serious deterministic effects, intervention will almost always be justified.

(S20) Any system of protection should include an overall assessment of its effectiveness in practice. This should be based on the distribution of doses achieved and on an appraisal of the steps taken to limit the probability of potential exposures. It is important that the basic principles should be treated as a coherent system. No one part should be taken in isolation.

The Control of Occupational Exposure

Dose constraints

(S21) An important feature of optimisation is the choice of dose constraints, the source-related values of individual dose used to limit the range of options considered in

the procedure of optimisation. For many types of occupation, it is possible to reach conclusions about the level of individual doses likely to be incurred in well-managed operations. This information can then be used to establish a dose constraint for that type of occupation. The class of occupation should be specified in fairly broad terms, such as work in x-ray diagnostic departments, the routine operation of nuclear plant, or the inspection and maintenance of nuclear plant. Limits prescribed by regulatory agencies and restrictions applied by managements to specific operations as part of the day-to-day control of exposures are not constraints in the sense used here. In general, they should be established on the basis of the results of optimisation. It will usually be appropriate for dose constraints to be fixed at the national or local level.

Dose limits

(S22) The dose limits for application in occupational exposure are summarised in Table S-4.

(S23) Dose limits are needed as part of the control of occupational exposure, both to impose a limit on the choice of dose constraints and to provide a protection against errors of judgement in the application of optimisation.

(S24) In setting dose limits, the Commission's aim is to establish, for a defined set of practices, and for regular and continued exposure, a level of dose above which the consequences for the individual would be widely regarded as unacceptable. In the past, the Commission has used the attributable probability of death or severe hereditary disorders as the basis for judging the consequences of an exposure. This quantity is still a major factor, but is no longer regarded by the Commission as sufficient to describe the detriment.

(S25) The Commission recommends a limit on effective dose of 20 mSv per year, averaged over 5 years (100 mSv in 5 years), with the further provision that the effective

Table S-4. Recommended dose limits¹

Application	Dose limit	
	Occupational	Public
Effective dose	20 mSv per year, averaged over defined periods of 5 years ²	1 mSv in a year ³
Annual equivalent dose in the lens of the eye	150 mSv	15 mSv
the skin ⁴	500 mSv	50 mSv
the hands and feet	500 mSv	—

¹ The limits apply to the sum of the relevant doses from external exposure in the specified period and the 50-year committed dose (to age 70 years for children) from intakes in the same period (see paragraph 143).

² With the further provision that the effective dose should not exceed 50 mSv in any single year. Additional restrictions apply to the occupational exposure of pregnant women, which is discussed in Section 5.3.3 of the Main Text.

³ In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.

⁴ The limitation on the effective dose provides sufficient protection for the skin against stochastic effects. An additional limit is needed for localised exposures in order to prevent deterministic effects. (See paragraphs 173 and 194.)

dose should not exceed 50 mSv in any single year. The 5-year period would have to be defined by the regulatory agency, e.g. as discrete 5-year calendar periods. The Commission would not expect the period to be introduced and then applied retrospectively. It is implicit in these recommended dose limits that the dose constraint for optimisation should not exceed 20 mSv in a year.

(S26) Subject to medical advice in individual cases, there need be no special restrictions applied to the exposure of an individual following a control period in which the exposure of the individual has exceeded a dose limit. Such events should call for a thorough examination, usually by the regulatory agency, of the design and operational aspects of protection in the installation concerned, rather than for restrictions or penalties applied to the exposed individual. If the dose is unknown, or is thought to be high, referral to a physician should be considered.

(S27) The recommended limits should apply to all forms of occupational exposure, unless special provisions have been made by the regulatory agency. Because of the difficulties of responding rapidly to an increase in stringency in operations on plant and equipment already in existence, the Commission recognises that regulatory agencies may wish to make temporary use of higher dose limits. Such arrangements should be regarded as transient.

(S28) The dose limit forms only a part of the system of protection aimed at achieving levels of dose that are as low as reasonably achievable, economic and social factors being taken into account. It is not to be seen as a target. It represents, in the Commission's view, the point at which regular, extended, deliberate, occupational exposure can reasonably be regarded as only just tolerable.

(S29) The restrictions on effective dose are sufficient to ensure the avoidance of deterministic effects in all body tissues and organs except the lens of the eye, which makes a negligible contribution to the effective dose, and the skin, which may well be subject to localised exposures. Separate dose limits are needed for these tissues. The annual limits are 150 mSv for the lens and 500 mSv for the skin, averaged over any 1 cm², regardless of the area exposed.

(S30) For internal exposure, annual limits on intake will be based on a committed effective dose of 20 mSv. The estimated intakes may be averaged over a period of 5 years to provide some flexibility. The occupational limits for radon are under review. Meanwhile, the values given in *Publication 47* (1986) remain valid.

The occupational exposure of women

(S31) The basis for the control of the occupational exposure of women who are not pregnant is the same as that for men and the Commission recommends no special occupational dose limit for women in general.

(S32) Once pregnancy has been declared, the conceptus should be protected by applying a supplementary equivalent dose limit to the surface of the woman's abdomen (lower trunk) of 2 mSv for the remainder of the pregnancy and by limiting intakes of radionuclides to about 1/20 of the ALI. The Commission wishes to emphasise that the use of its system of protection, particularly the use of source-related dose constraints, will usually provide an adequate guarantee of compliance with this limit without the need for specific restrictions on the employment of pregnant women. The principal criterion will then be that the employment should be of a type that does not carry a significant probability of high accidental doses and intakes. High-dose and high-risk occupations from which pregnant women should be excluded should be defined by regulatory agencies.

The Control of Medical Exposure

(S33) In the justification of a practice leading to medical exposures, the practice should be defined in broad terms. However, each procedure, either diagnostic or therapeutic, is subject to a separate decision, so that there is an opportunity to apply a further, case-by-case, justification for each procedure. This will not be necessary for simple diagnostic procedures based on common indications, but may be important for complex investigations and for therapy.

(S34) There is considerable scope for dose reductions in diagnostic radiology using the techniques of optimisation of protection. Consideration should be given to the use of dose constraints, or investigation levels, selected by the appropriate professional or regulatory agency, for application in some common diagnostic procedures. They should be applied with flexibility to allow higher doses where indicated by sound clinical judgement.

(S35) Constraints should also be considered in the optimisation of protection for medical exposures when the procedures are not intended to be of direct value to the exposed individual, as in scientific and clinical studies involving the exposure of volunteers.

(S36) Medical exposures are usually intended to provide a direct benefit to the exposed individual. If the practice is justified and the protection optimised, the dose in the patient will be as low as is compatible with the medical purposes. The Commission therefore recommends that dose limits should not be applied to medical exposures. Further, it is not appropriate to include the doses incurred by patients in the course of diagnostic examinations or therapy when considering compliance with dose limits applied to occupational or public exposures.

(S37) Diagnostic and therapeutic procedures causing exposures of the abdomen of women likely to be pregnant should be avoided unless there are strong clinical indications. Information on possible pregnancy should be obtained from the patient herself. If the most recent expected menstruation has been missed, and there is no other relevant information, the woman should be assumed to be pregnant.

The Control of Public Exposure

(S38) The control of public exposure in all normal situations is exercised by the application of controls at the source rather than in the environment. The controls are achieved almost entirely by the procedures of constrained optimisation and the use of prescriptive limits. It is often convenient to class together individuals who form a homogeneous group with respect to their exposures to a single source. When such a group is typical of those most highly exposed by that source, it is known as a critical group. The dose constraint should be applied to the mean dose in the critical group from the source for which the protection is being optimised.

Dose limits

(S39) The scope of dose limits for public exposure is confined to the doses incurred as the result of practices. Doses incurred in situations where the only available protective action takes the form of intervention are excluded from that scope. Separate attention has to be paid to potential exposures. Radon in dwellings and in the open air, radioactive materials, natural or artificial, already in the environment, and other natural sources are

examples of situations that can be influenced only by intervention. Doses from these sources are therefore outside the scope of the dose limits for public exposure. The conduct of intervention involves occupational exposure and should be treated accordingly.

(S40) The Commission now recommends that the limit for public exposure should be expressed as an effective dose of 1 mSv in a year. However, in special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.

(S41) In selecting the limit on effective dose, the Commission has sought a value that would be only just short of unacceptable for continued exposure as the result of deliberate practices the use of which is a matter of choice. This does not imply that higher doses from other sources, such as radon in dwellings, should be regarded as unacceptable. The existence of these sources may be undesirable but is not a matter of choice. The doses can be controlled only by intervention, which will also have undesirable features.

(S42) Limits are also needed for the lens of the eye and skin since these tissues will not necessarily be protected against deterministic effects by the limit on effective dose. The Commission recommends annual limits of 15 mSv for the lens and 50 mSv for the skin averaged over any 1 cm², regardless of the area exposed. The recommended limits are summarised in Table S-4.

Potential Exposures

(S43) The initial treatment of potential exposures should form part of the system of protection applied to practices, but it should be recognised that the exposures, if they occur, may lead to intervention. At this stage, there should be two objectives, prevention and mitigation. Prevention is the reduction of the probability of the sequences of events that may cause or increase radiation exposures. Mitigation is the limitation and reduction of the exposures if any of these sequences do occur. A great deal can be accomplished at the stages of design and operation to reduce the consequences of accident sequences so that intervention may not become necessary.

(S44) In order to maintain a strict coherence in the treatment of actual and potential exposures, it would be necessary to extend the concept of detriment to include the probability of occurrence of the situation giving rise to the detriment. Techniques for achieving this are still being developed. A comprehensive approach to this problem calls for the application of multi-attribute analysis.

(S45) A simpler approach is possible for both individual and collective exposures if the doses will be small even if the event occurs. If the doses, should they occur, will not be in excess of dose limits, it is adequate to use the product of the expected dose and its probability of occurrence as if this were a dose that was certain to occur. The conventional procedures of justification and optimisation can then be applied.

The System of Protection in Intervention

(S46) Before a programme of intervention is initiated, it should be demonstrated that the proposed intervention will be justified, i.e. do more good than harm, and that the form, scale, and duration of the intervention have been chosen so as to optimise the protection. The processes of justification and optimisation both apply to the protective

action, so it is necessary to consider them together when reaching a decision. Justification is the process of deciding that the disadvantages of each component of intervention, i.e. of each protective action, are more than offset by the reductions in the dose likely to be achieved. Optimisation is the process of deciding on the method, scale and duration of the action so as to obtain the maximum net benefit. In simple terms, the difference between the disadvantages and the benefits, expressed in the same terms, e.g. costs, including social costs with an allowance for anxiety, should be positive for each protective action adopted and should be maximised by settling the details of that action.

Radon in Dwellings

(S47) Radon in dwellings needs special attention because both the individual and the collective doses from radon are higher than those from almost any other source. If improvements are needed in existing dwellings, they have to be achieved by intervention involving modifications to the dwellings or to the behaviour of the occupants.

(S48) The Commission recommended the use of action levels to help in deciding when to require or advise remedial action in existing dwellings. The choice of an action level is complex, depending not only on the level of exposure, but also on the likely scale of action, which has economic implications for the community and for individuals. For new dwellings, guides or codes for their construction in selected areas can be established so that it is highly probable that exposures in these dwellings will be below some chosen reference level. The Commission has initiated a further review of current experience with a view to issuing revised recommendations in due course. Meanwhile the guidance in *Publication 39* (1984) should still be used.

Intervention After Accidents

(S49) The benefit of a particular protective action within a programme of intervention should be judged on the basis of the reduction in dose achieved or expected by that specific protective action, i.e. the dose averted. Thus each protective action has to be considered on its own merits. In addition, however, the doses that would be incurred via all the relevant pathways of exposure, some subject to protective actions and some not, should be assessed. If the total dose in some individuals is so high as to be unacceptable even in an emergency, the feasibility of additional protective actions influencing the major contributions to the total dose should be urgently reviewed. Doses causing serious deterministic effects or a high probability of stochastic effects would call for such a review.

(S50) Occupational exposures of emergency teams during emergency and remedial action can be limited by operational controls. Some relaxation of the controls for normal situations can be permitted in serious accidents without lowering the long-term level of protection. This relaxation should not permit the exposures in the control of the accident and in the immediate and urgent remedial work to give effective doses of more than about 0.5 Sv except for life-saving actions, which can rarely be limited by dosimetric assessments. The equivalent dose to skin should not be allowed to exceed about 5 Sv. Once the immediate emergency is under control, remedial work should be treated as part of the occupational exposure incurred in a practice.

Practical Implementation of the Commission's Recommendations

(S51) Chapter 7 of the recommendations emphasises the importance of the operational level of radiological protection and shows how this should be developed from the requirements of regulatory agencies and the recommendations of the Commission. The Commission now recommends that the designation of controlled and supervised areas should be decided either at the design stage or locally by the operating management on the basis of operational experience and judgement. The classification of working conditions based upon expected dose is no longer recommended. The Chapter gives advice on the measurement of doses (monitoring and record keeping) and on medical surveillance. It also discusses emergency planning and the bases for exemption from regulatory requirements. It deals with both practices and intervention.